THE MANAGEMENT OF BURNS AND FIRE DISASTERS: PERSPECTIVES 2000

Proceedings of the Second International Conference on Burns and Fire Disasters

THE MANAGEMENT OF BURNS AND FIRE DISASTERS: PERSPECTIVES 2000

Edited by

M. Masellis, M D

Professor and Head, Division of Plastic Surgery and Burn Centre, Palermo; Secretary-General, Mediterranean Burns Club

S.W.A. Gunn, M D

President, Mediterranean Burns Club; Formerly Head, Emergency Relief Operations, World Health Organization

KLUWER ACADEMIC PUBLISHERS

DORDRECHT / BOSTON / LONDON

Distributors

for the United States and Canada: Kluwer Academic Publishers, PO Box 358, Accord Station, Hingham, MA 02018–0358, USA
for all other countries: Kluwer Academic Publishers Group, Distribution Center, PO Box 322, 3300 AH Dordrecht, The Netherlands

A catalogue record for this book is available from the British Library

ISBN-13: 978-94-010-6647-1 e-ISBN-13: 978-94-009-0361-6
DOI: 10.1007/978-94-009-0361-6

Copyright

Published in the United Kingdom by Kluwer Academic Publishers, PO Box 55, Lancaster, UK.

Kluwer Academic Publishers BV incorporates the publishing programmes of D. Reidel, Martinus Nijhoff, Dr W. Junk and MTP Press.

Typeset by EXPO Holdings, Malaysia.

Contents

Section IV: Epidemiology, Geographic pathology

Section V: Intensive care

Section VI: Immunology in burns

Section IX: Burn surgery

Section X: Biomaterials

Section XI: Burn scar management

Section XII: Electrical burns

Section XIII: Hand burns

Section XIV: Rehabilitation

Section XV: Burn centres

Section XVI: Forest fires

Acknowledgements

The publication of this book has been made possible through the generous grant from the Presidency of the Sicilian Regional Government.

The G. Whitaker Foundation, Palermo, was again a gracious co-sponsor.

Special acknowledgement is due to Dr. N. D'Arpa, who very successfully acted as Scientific Coordinator.

This support is gratefully recorded. Thanks are also due to the participating experts and organizations for their valuable scientific contributions to this Second International Conference on Burns and Fire Disasters: Perspectives 2000.

Mediterranean Burns Club*
Department of Plastic Surgery
and Burn Centre
Ospedale Civico
Via C. Lazzaro
I-90127 Palermo
Italy

*Subsequently renamed *Mediterranean Club for Burns and Fire Disasters*

Foreword

This volume is published with a triple aim: to take a look back over the advances during the ten years of the Mediterranean Burns Club and mark its anniversary; to follow up and strengthen the successful twinning of burns as a clinical, individual illness problem and fires as a societal, disaster management problem; and to look ahead at the perspectives of burn care and fire prevention in the fast-approaching new century.

The occasion also marks the tenth annual presentation of the prestigious G. Whitaker International Burns Prize, to which the Mediterranean Burns Club acts as the scientific fulcrum. The award is now established as the most distinguished recognition in burns science worldwide, and it is gratifying that the contributions of many of the renowned recipients will be found in this book.

This is a sequel to *The Management of Mass Burn Casualties and Fire Disasters*, which contained the Proceedings of the First International Conference on Burns and Fire Disasters. The book and the conference have fully justified the authors' initial concept that burn specialists, constantly combatting burn disease and promoting rehabilitation of the victims, especially in mass casualty situations, had for too long remained separate from that other essential sector, the fire-fighting authorities and fire prevention systems, whose aim is also the protection of the individual and the promotion of safety. This long overdue synergism has now become reality, and the present volume strengthens this desirable trend.

The Second International Conference on Burns and Fire Disasters and the resulting papers that will be found in this book again reflect the commitment of the Mediterranean Burns Club and of its collaborators worldwide to the reduction of fire hazards and the progress of burn therapy.

M. Masellis, MD
S. W. A. Gunn, MD

Section I

The burn and fire problem

1
Management of fire disasters: Doctors in or patients out?

JOHN A. D. SETTLE
Regional Burns Centre, Wakefield, England

During the past 7 years several fire disasters have occurred in which there were substantial numbers of burn casualties. I have personal experience of the medical response in two of these disasters.

On 11 May 1985 a football match was taking place in Bradford, England. Just before half-time, smoke was seen emerging from beneath the wooden floor at one end of the stand which contained about 2000 people. The police began to clear the spectators but the fire took hold and began to spread more quickly than the spectators could escape. As the fire raged, the intense heat caused radiant burns both to the rescued and the rescuers. From the first puff of smoke to when the whole of the stand was engulfed in flame took just 4 minutes. In that time 53 people were asphyxiated and / or burned to death.

Within a few minutes of the fire, casualties began to arrive at the nearby general hospital. Sixty-three were admitted to the Plastic Surgery Department and 11 with major burns were taken to the Regional Burns Centre some 17 miles away in Wakefield.

In summary then, the Regional Burns Centre was able to deal with the major burns. Early surgery for the patients admitted in Bradford was made possible by specialist help from colleagues in Leeds, Manchester and Newcastle: supra-regional support was provided but a national response was not needed.

On 1 June 1989 a leak developed in a gas pipeline in the Soviet Republic of Bashkiria and enveloped the nearby trans-Siberian railway. The gas exploded as two trains were passing through the area, causing massive damage to the surrounding countryside and to both trains. The explosion and fire injured or killed most of the approximately 1300 passengers on the trains. Some 400 were killed in the accident and most of the survivors had thermal injuries. Triage and transport of casualties were performed by the military and medical disaster teams from the nearest hospitals. Patients were initially moved to local hospitals and then to hospitals in the cities of Ufa, Cheylabinsk and Sverdlovsk where a total of about 700 patients were admitted, some 160 of whom where subsequently transferred to Moscow. The medical personnel in all these centres were augmented by the arrival of colleagues from many parts of the then Soviet Union. Further international assistance was requested by the Soviet government on 8 June 1989. The major response was provided by the USA, which supplied several specialist teams deployed mainly in Ufa and Moscow. Teams from European countries were also deployed but my personal knowledge is restricted to the activities of a small British and Irish team that arrived in Chelyabinsk one week after the accident.

Some 200 burn patients were being well cared for under the overall direction of Professor Lifshits. Our team comprised seven surgeons, three anaesthetists, five burns nurses and a dialysis team of doctor, nurse and technician. During the week that we stayed in Chelyabinsk, our contribution was small in comparison with the magnitude of the problem and the extent of the medical expertise already present. However, we were able to give support in the form of:

- discussion of difficult cases
- the provision of haemodialysis
- the administration of anaesthetics
- some help with burns surgery.

Not the least of the benefits resulting from our visit has been the professional relationships and friendships that have continued ever since.

The burn disaster in Bashkiria was of a completely different magnitude from that in Bradford. The massive number of casualties required them to be distributed between a number of specialist centres. These centres would themselves have been unable to deal effectively with 200 or more burn patients each without the influx of medical personnel from many parts of the neighbouring republics. International support, in the form of materials, equipment and personnel, further enhanced the provision of burn care in these centres. Moreover, it demonstrated that medical support need not be constrained by national boundaries.

I believe that burn disaster planning should comprise a number of scenarios to take account of disasters of different sizes. The smaller ones can be managed at a regional or supra-regional level, as was possible with the Bradford fire, but a disaster in the UK with say 200 major burn casualties would require involvement of most of the specialist burn centres. In burn disaster planning, the aims of management should be:

1. Triage should be carried out at the hospital nearest to the scene.
2. Definitive treatment should be provided as near as possible to the disaster consistent with a good standard of care.
3. There should be full utilization of local specialist facilities and personnel. The definition of 'local' will vary according to the geographic location of the facilities and the size of the disaster.

4. Prior thought should be given to type and size of disaster that would require the importation of support from other regions or other nations. Clearly, the size of disaster that should trigger this response will vary from country to country.

In conclusion, there is no simple answer to the question that I posed in my title. In some disasters it will be necessary to move doctors in, in others it will be essential to move patients out and sometimes it will be advisable to do both.

REFERENCES

Fedorov, V. D. and Alekseev, A. A. (1992). Medical care of mass burn victims: the Vishnevsky principles and organizaiton in the Ufa disaster. In: *The Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers.

McCollum, S. T. (1992). Lessons from the Dublin 1981 fire catastrophe. In: *The Management of Mass Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers.

2
History and evolution of surgical treatment of burns

S. TEICH ALASIA
Piedmont Foundation for Burns Study and Research, Traumatological Centre, Turin, Italy

A description of the evolution of surgical treatment in burns necessarily involves a description of the entire history of burns treatment. In ancient times various local treatments were directed at modifying the skin surface in order to obtain scarring, usually without surgical intervention but sometimes with loss of blood.

In the oldest document of all, an Egyptian papyrus written in the 16th century BC (Bryan, 1930), there is no reference to surgical treatment. However, in the 4th century BC, Hippocrates (Lloyd, 1975) stated that if wounds could not be healed medically they should be treated with the knife, and, if that was not sufficient, with fire. Hippocrates recommended that the wound should be cleansed with clean water or wine and then covered with a pomade made of pig fat, pine resin and bitumen, heated over fire.

In the 1st century AD, Celsius in his work *De Medicina* (Scarborough, 1969) advised excision of retracting scars following burns. Nothing is known however of the sequelae.

In the 14th and 15th century gunpowder began to be used. Military surgeons treated the consequent burns with heat, generally boiling oil. Ambrose Paré (Paré, 1582), a 16th century military surgeon, was the first to say that heat was contraindicated in the treatment of burns. There was thus a return to the use of cold as an antidote, as already recommended by Arab physicians in the 10th century (Levey *et al.*, 1966). In the 18th and 19th century applications of cold and cold water baths became popular with many physicians, and a Viennese dermatologist, Van Hebra (Hebra, 1861), constructed a special bath in which the burn victim was immersed, in warm water however. Many surgeons of the period, including Earle (1799) Kentish (1817) and Dupuytren (1832) asserted that cold water and ice were excellent analgesics capable of preventing local oedema.

In the early 17th century, in his volume *De Combustionibus*, Fabricius Hildanus (Hildanus, 1607), the father of German surgery, distinguished three degrees of burn:

1. Reddening and skin blisters;
2. Whitening of the skin without carbonization;
3. Formation of eschars and carbonization.

In 1607 Hildanus recommended that phlyctenae should be opened in order to prevent infection and subsequent deepening of the lesion. He also discussed how to prevent contractions in the hand, suggesting that scars should be cut by cross incisions and that the fingers should be stabilized in the correct position in order to prevent recidivation of contraction.

Escharotomy was a technique already known to the ancient world – it was used in the 8th century BC by the Hindu surgeon Sushruta (Bhishagratna, 1963) but subsequently forgotten for many centuries. The true era of surgical treatment of burns can be said to have begun with the introduction of skin grafts by the Swiss surgeon Reverdin (1869) in the second half of the 19th century. In 1870 Pollock (1871), a London surgeon, presented to the Clinical Society a series of 16 cases of burn patients healed with Reverdin grafts.

Reverdin's method was modified in the following years by Ollier (1872) and Thiersch (1886), who used thicker grafts, and subsequently by Wolfe (1875) and Krause (1893), who used full-thickness skin for the repair of substance loss of limited extent, as for example in the case of eyelid lesions.

True escharectomy was not known until the end of the 19th century. In 1891 Lustgarten for the first time suggested excision of the burned tissue, and 10 years later Wilms (1901) discussed escharectomy and successive coverage of bloody areas by means of skin grafts. A few years later Wiedenfeld and Zumbush (1905) recommended the use of excision in the acute phase, i.e. in the first few days post-burn. This is thus one of the first references to early excision.

A notable qualitative improvement was achieved by the use of extensive grafts obtained by means of a manual dermatome, described in the late 1920s by Blair and Brown (1929). The dermatome has also evolved: Padgett (1929) and Hood introduced the drum dermatome, and during the second world war Brown (1948) perfected the electric dermatome, both of which permitted the removal of extensive dimensions.

In the 1960s Tanner and Vanderput (Tanner *et al.*, 1964) constructed a dermatome that made it possible to expand grafts of various extent in a kind of meshwork, with the advantage of saving considerable quantities of skin and facilitating take.

These mesh grafts have made it possible to expand the skin by as much as nine times, opening the way to the surgical treatment of more and more extensive burn areas and saving increasing numbers of patients.

In the 1980s the pharmaceutical industry made great strides in the preparation of increasingly reliable and better tolerated skin substitutes, and Green *et al.* (1979) perfected a technique of epithelial culture that increases the area removed by as much as 10 000 times. This is the most recent, the most spectacular and possibly the most complex of trends in the surgical treatment of burns: the scientific world is extremely interested in the reports of favourable results in the treatment of third-degree burns affecting > 70% BSA.

Keratinocyte cultures were introduced into Italy by Cancedda (De Luca *et al.*, 1989) in 1986 and experiments in their use immediately began at the Turin Burns Centre. This technique, in theory at least, enables the surgeon to excise and cover any extent of burned skin. Such a possibility was unimaginable just 15 years ago – now it is a clinical routine.

Problems still exist, however, as the fragility of this tissue permits only partial take of the abundant extent of the transplant. Research is currently in progress to produce cultivated epidermis on more resistant and more easily manageable dermoequivalent supports. Other clinical research is being carried out to create an optimal receiving bed using biomaterials or allogenic dermoepidermal transplants. Important results are expected in order to respond to the ever more pressing demands of modern surgery.

I would like however to pause to consider some points not directly related to surgical therapy but which are important in the planning of the surgical operation and may influence its results. I am referring in particular to research carried out at the Piedmont Foundation for Burns Study and Research into the physiopathology of the recovery of sensitivity and pathological scarring. Our findings point the way towards new therapeutic approaches – particularly with regard to the improvement of burns sequelae – which are likely in the near future to modify the concepts at the basis of current surgical procedures in acute burns.

In the last few years the surgical treatment of burns sequelae has seen the rapid introduction of many novel techniques such as skin expansion and microsurgery, and these procedures must be oriented towards the recovery of burn patients by all persons responsible for their care. Hence the interest in the physiopathology of pathological scarring (Stella *et al.*, 1989) and in the recovery of skin sensitivity (Teich Alasia *et al.*, 1988): the reconstructed tissues must possess morphofunctional characteristics and properties analogous to those of healthy skin.

It is my hope and firm conviction that with responsible and constructive research we will be able to perfect our results still further for the benefit of our patients.

REFERENCES

Bhishagratna, K. K. L. (1963). English translation of Sushruto Samhita from a Sanskrit text

Blair, V. P. and Brown, J. P. (1929). Use and uses of large split skin grafts of intermediate thickness. *Surg. Gynecol. Obstet.*, **49**: 82

Brown, J. B. (1948). A motor driven dermatome. *Industrial Med.*, **17**: 46
Bryan, C. P. (1930). *Ancient Egyptian medicine: the papyrus Ebers*. London: Ares
De Luca, M., Albanese E., Bonanza S., Stella M., Bormioli M., Magliacani G. and Cancedda R. (1989). Multicentre experience in the treatment of burn with autologous and allogenic cultured epithelium fresh or preserved in a frozen state. *Burns*, **15**: 303
Dupuytren, G. (1832). *Lecons orales de clinique chirurgicale*. **I**, 413; **II**, 80. Paris: Baillière
Earle, J. (1799). *An essay on the means of lessening the effects of fire on the human body*. London: Clarke
Fabricius, Hildanus (1607). *De combustionibus*. Basle
Green, H., Kenhinde, O. and Thomas, J. (1979). Growth of cultured epidermal cells into multiple epithelia suitable for grafting. *Proc. Natl Acad. Sci. USA*, **76**: 5665
Hebra, F. V. (1861). Ueber Continierliche Allgemeine Bader und deren Anwendung bei Behandlung von Verbrennungen. *Allg. Wiener Med. Zeitung*, **6**: 351
Kentish, E. (1817). *An essay on burns*. Bristol: Longman
Krause, F. (1893). Ueber die Transplantation grosser ungelstielter Hauptlappen. *Verhandl. Dtsch. Gesellsch. Chir.*, **22**: 46
Levey, M. (1966). *Al-Kindi: the medical formulary of Aqrabadhin of Al-Kindi*. Madison: University of Wisconsin Press
Lloyd, G. E. R. (1975). The Hippocratic question. *Classical Q.*, **25**: 171
Lustgarten, S. (1891). Theorie der Primaren Todesursache bei Verbrennungen. *Wien Klin. Wochenschr.*, **29**: 528
Ollier, L. X. E. L. (1872). Sur les greffes cutanées autoplastiques. *Bull. Acad. Med.*, **1**: 243
Padgett, E. C. (1939). Calibrated intermediate grafts. *Surg. Gynecol. Obstet.*, **69**: 779
Pollock, G. D. (1871). Cases of skin grafting and skin transplantation. *Trans. Clin. Soc. Lond.*, **4**: 37
Reverdin, J. L. (1869): Greffes épidermiques. *Bull. Imp. Soc. Chir*
Scarborough, J. (1969). *Roman medicine*. Ithaca, New York: Cornell University Press
Stella, M., Castagnoli, C., Richiardi, P. and Magliacani, G. (1989). Fisiopatologia della cicatrizzazione ipertrofica (Revisione bibliografica). *Riv. Ital. Chir. Plast.*, **1**: 199
Tanner, J. C., Vandeput, J. and Olley, J. F. (1964). The mesh skin graft. *Plast. Reconstr. Surg.*, **34**: 387
Teich Alasia, S., Stella, M., Ramieri, G., Calcagni, M., Panzica, G. C. and Viglietti Panzica, C. (1988). La rigenerazione sensitiva cutanea nel paziente ustionato. *Riv. Ital. Chir. Plast.*, **20**: 405
Thiersch, C. (1886). Ueber Hautverpflanzung. *Verhandl. Dtsch. Ges. Chir.*, **15**: 17
Weidenfeld, S. and Zumbush, L. V. (1905). Weitere Beitrage zur Pathologie and Therapie Schwerer Verbrennungen. *Arch. Dermatol. Syphilis*, 76: 163
Wilms, M. (1901). Studien zur Pathologie der Verbrennungen. *Mitt. Grenzg. Med. Chir.*, **8**: 393
Wolfe, J. R. (1875). A new method of performing plastic operations. *Br. Med. J.*, **1**: 360

3
The maturity of society and disaster preparedness/prevention

MUNEO OHTA
Osaka Prefectural Senri Critical Care Medical Center, Suita City, Osaka, Japan

---

Society at any scale, from the basic unit of a family to the maximum unit of nation, is evaluated by its level of maturity. The very existence of a society is also recognized by the level of maturity and its actual performance of this. Accordingly, any human group must act, and follow its own way in its aim to grow as a society. However, we can at present identify no fully matured society. The maturity of a society is usually evaluated synthetically; some are considered to be matured on their expected merit. However, we should understand these as exceptions which do not represent the general rule.

Many criteria are applied to measure the maturity of society. At such an international conference, I would like to devote my attention to methods of measuring maturity of society, and the relationship between maturity and disaster preparedness / prevention.

The scales of measurement can be divided into two groups: physical and metaphysical. The physical consists of population, property, natural resources, political condition, economic state, productive capacity, activity of trade, scientific level, urban structure, human exchange, territorial circumstance, educational system, medical care system, etc. These are popular and convenient scales for comparison, but are usually fluctuating, unstable and unreliable.

The metaphysical consists of culture, religion, history, national traits, intelligence, morality and other ideal factors. These take a long time to mature, but they are generally stable, conventional and reliable. Furthermore, I would add love of mankind to this, because any action at the scene of disaster has to be based on love and suggests a clear relationship with maturity and disaster preparedness / prevention.

Suitable disaster preparedness / prevention depends on many factors. Usually, in the planning stage, physical factors such as economic condition predominate: consequently, any plan often stops at the minimum requirements because the official authorities who take the final decision fail to see beyond finances. It is possible to apply this method in a small-scale society, like a family, but not in a large-scale society, like a nation: if metaphysical factors could be discussed, the plan would be more effective. This view may be understood and the concept may also be easily stressed by the fact that investment for reconstruction far exceeds that for preparedness / prevention.

The concept of disaster planning cannot be achieved unless metaphysical factors are considered, and the citizens' sense of the value of human lives and dignity are respected. Universally, the sense of value is rapidly changing from the materialistic; in Japan, medical personnel have long watched and emphasized metaphysical factors during their usual emergency medical activities as well as during disasters; a sudden economic crisis and an aged society, with the relative deterioration in labour power that will surely come about in the very near future, have accelerated this change in the past few years. This has also made citizens recognize that preparedness for emergencies / disasters is a far more reliable investment than money.

Emergency aid for managing disaster should be based upon this, which is also the basic idea of Japan Disaster Relief (JDR). Although we cannot neglect variations in the views on disaster preparedness / prevention among nations, the victims of disaster in our universe cannot be dramatically reduced if many large-scale societies – including my own country – continue to consider only the economic state. The attitude of valuing lives more than physical factors will be required in the next century all over the world. Medical personnel must therefore promote this idea more and more.

These views and facts suggest to us the usefulness of the level of disaster preparedness / prevention (including the level of the mental basis) – as the measure of the maturity of society.

This MBC meeting and APCDM (the Asia-Pacific Conference on Disaster Medicine) give further motivation to this movement for a humanistic disaster management.

REFERENCE

Sakurai, R., Takahashi, S. and Uaki, T. (1992). Fire prevention countermeasures for cultural properties in Nara City. In: *The Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers.

4
Forest fires and related accidents in the social context

VITTORIO LEONE
Faculty of Agriculture, University of Bari
Institute of Sylviculture and Forest Management
70100 Bari, Italy

To introduce my topic in a way consistent with the theme of the conference, I would like to quote a passage from the book *My Life, My Trees* by Richard St. Barbe Baker, standard-bearer of the American conservationists, founder of the Civil Conservation Corps, founder of *Men of the Trees*, and supervisor of the reforestation of more than 15 000 000 hectares.

Baker observes: '... if a man loses one-third of his skin he dies ... If a tree loses one-third of its bark it dies. This has been proved scientifically by botanists and dendrologists. Would it not be reasonable to suggest that if the earth loses more than a third of its green mantle and tree cover, it will assuredly die? The water table will sink beyond recall and life will become impossible.'

Without splitting hairs over the possibility of lethal consequences resulting from extensive burns as cited by the author, his assertion is linked to the concept of the earth as a whole, living organism (the hypothesis of Gaia) and to the misdeeds which it, as such, suffers at the hand of man.

Fires are among the most damaging misfortunes this planet can suffer, and they are nearly always the work of man. News reports in the past few years have often cited fires of colossal dimensions.

This is not the place for a detailed discussion of the phenomenon of fires, since I would like to focus my report on the aspects of the problem concerning accidents and job-related injuries. I will limit myself to the observation that authoritative experts at the international level (Velez, Trabaud, Susmel) agree that 95–98% of fires are caused by man. It is estimated that in 1973, in the entire Mediterranean basin, there were 25 000 fires covering a surface area of 200 000–250 000 ha. Between 1980 and

1990 fires in the Mediterranean area consumed each year an average of 500 000 ha of forest and pasture, 90% of which was in EEC countries (France, Greece, Italy, Portugal and Spain). In these same countries in 1990, 55 000 fires, covering nearly 632 000 ha, were registered.

In Italy, the most recent statistics indicate an average of 12 000 episodes per year involving a surface area of approximately 147 000 hectares, of which two-thirds is agricultural land and one-third forest.

The percentage of these fires considered to be voluntary in origin is today 68.4% compared with 36.39% in 1981 (Leone and Saracino, 1992).

The southern and insular regions, in particular, as well as Liguria, have suffered an increase in the proportion of fires which are accidental in origin. (More than 70% of the fires observed fall into this category.)

The gravity of the situation can be summarized as follows: each year fires burn 0.8% of the forested area in our country and 0.56% of agricultural and forest land, with notable differences between regions. On average, each day of the year 30 fires are registered, with peaks in the winter and summer.

The phenomenon is serious, recurring, and increasing at a frightening rate. It is dangerous because these incidents are caused in two cases out of three by the voluntary action of persons who choose the moment and the most favourable conditions to cause the maximum damage.

Statistics, however, may be deceptive with regard to the true gravity of the phenomenon; in particular, when they record the burning of more than 92 000 hectares of unforested land, one may have the impression that these are lands of little importance in environmental terms.

The reality is quite different: included in these statistics are agricultural lands, often carrying crops, as well as territories which constitute the rural–urban interface, often residential areas with notable concerns for public safety. It is the rural–urban interface which presents the most serious problems in the planning of prevention measures and in the phases of fighting the fires (Leone *et al.*, 1990).

The gravity of the problem must be dealt with using multiple methods, which in Italy means interventions by institutional structures, the first of which would be the foresters, who by law are invested with this specific duty, and are assisted by urban firefighters and other groups.

Such structures utilize occasional manpower on a massive scale. Workers are hired seasonally to form crews for emergency operations and to provide the necessary surveillance for the territory.

This system is not without its drawbacks. I will consider only the most serious of these, i.e. the evidence that fires are started intentionally in order to guarantee oneself work. The phenomenon known as the 'fire industry' is especially widespread in regions where there is a high incidence of organized crime (Puglia, Campania, Calabria, Sicily; Leone and Saracino, 1990). This is a serious form of voluntary damage to one's own environment, motivated by economic need linked to the generous salaries paid to firefighters in areas suffering from acute economic depression and having high levels of unemployment.

The critical aspect of the fire phenomenon, as far as we are concerned, is the activity of extinction, in which firefighters are often involved in the front lines without having had any type of training. In these cases the only common skill shared by the firefighters seems to be a good familiarity with the management of fire as an agricultural tool presenting only modest characteristics of danger.

In the case of forest fires the reality is quite different and the fire can assume characteristics of extreme violence: even with flames of only 1.10 m in height, manual firefighting is impossible, and with average conditions of climatic adversity flames can easily reach 4–5 m, moving with unsuspected velocity and releasing energy that can reach 10 000 kcal/m/s.

It has been calculated that 1000 hectares of adult forest affected by fire release, albeit gradually, 200×10^9 kcal; the bombing of Hiroshima in 1945 released, in an instant, 180×10^9 kcal (Moreira da Silva, 1990).

In general, public opinion holds that large-scale investment in equipment (aeroplanes, helicopters and vehicles), often triumphantly announced in the mass-media, is a decisive factor in the fight against fires. In reality this equipment has to operate with personnel on land who have often been seasonally recruited and have no special preparation or training. Besides guaranteeing only modest efficiency in the overall organization, such a situation constitutes a serious factor which increases the risk of accidents on the job.

Firefighting operations take place in an atmosphere of general agitation, where there is limited visibility, in areas which present difficulty

Figure 1. Firefighting is a dangerous job, mainly when crew members operate without proper protective equipment (hard hat, goggles, coverall, gloves, leather boots with wool socks ...)

due to sloping land or density of vegetation, and during the summer when the heat at the centre of the fire increases already elevated atmospheric temperatures. Fires frequently occur at night and the use of dangerous, heavy equipment increases the risk of crossing rough terrain at high speeds in off-road vehicles which are not always driven by experienced drivers.

The very nature of fire, which releases enormous quantities of heat, causes serious problems: profuse perspiration, dehydration, cramp, heat stroke and the obvious risks of more or less serious burns and other traumatic lesions.

One of the primary problems which makes firefighting difficult is linked to the release of toxic substances in smoke. There is evidence that 74% of fire-related accidents result not from burns but from damage incurred by inhaling poisonous substances and gas at elevated temperatures (DFCI, 1985).

Carbon monoxide can cause insidious but lethal forms of acute intoxication which initially manifest themselves in a reduction in attention span and psychomotor ability and, therefore, reduced capacity for reaction. In fires of great intensity carbon monoxide is released in quantities of 10–250 g/kg combustible material and its concentration at the front of the fire normally ranges from 100 to 200 p.p.m. (Chandler *et al.*, 1983).

Besides carbon monoxide many other irritants and toxicants can be found in the composition of smoke. When Mediterranean undergrowth (juniper, rosemary, thyme, etc.) burns, a massive presence of aerosol substances has been noted. These substances are capable of inducing

Figure 2. With flames over 1 m high and a fireline intensity of 400 to 425 kW/m this fire is at the limit for direct attack with hand tools

acute and even lethal intoxication, often with serious symptoms of cutaneous sensitization. The substances which are released (monocyclic terpenes, pinenes, sesquiterpenes, thymol, paracymene, bicyclic terpenes) can cause circulatory collapse, digestive and urinary irritation, headaches, uncontrollable vomiting and hypothermia (DFCI, 1985). Examples of chemical components found in smoke, some of which are carcinogenic, are listed in Table 1 (Ward, 1989).

It is not surprising that in the USA, the job of fighting forest fires is seen as one of the most dangerous of all occupations, with a death toll of 51 / 100 000 men per year of work. The accident toll is 6150 / 100 000 men per year of work – about six times higher than in firemen in urban areas.

A study of 125 fatal accidents in the USA showed that the majority of fatalities were the result of carelessness in evaluating the behaviour of the fire. In 33% of the cases individuals were overtaken by the fire

Table 1. Comparison of emissions of polynuclear aromatic hydrocarbons from four sources: (1) prescribed fires in logging slash in western Washington and western Oregon (Ward *et al.*, 1989), (2) pine needle litter fuel of Southeast (McMahon and Tsoukalas, 1978), (3) fireplace emissions tests with green southern pine wood (DeAngelis *et al.*, 1980), and (4) woodstove emissions tests with green southern pine wood (DeAngelis *et al.*, 1980). Carcinogenicity is from National Academy of Sciences (1972) and is coded as follows: "–" is not carcinogenic; "±" is uncertain or weakly carcinogenic; "+" is carcinogenic; "++,+++" is strongly carcinogenic

Compound	*Logging slash*		*Pine needles*		*Fire-places*	*Wood stoves*	*Carcino-genicity*
	Mean	*S.D.*	*Mean*	*S.D.*			
	(μg of compound per g of particulate matter						
Anthracene / phenanthrene[1]	42	±29	185	±72	575	6345	– / –
Methylanthracenes / methylphenanthrenes[2]	61	±38			692	3147	
Benz(a)anthracene / chrysene[3]			43	±25	117	2276	+ / +
1,2-benzanthracene	17	±8					+
Chrysene / triphenylene	29	±11					
Dibenzanthracenes / dibenzphenanthrenes					4	3	
Fluoranthene[4]	47	±23	51	±29	125	1153	–
Benzofluoranthene			11	±11	133	865	
Benzo(ghi)fluoranthene	11	± 5					–
Benzo(a)fluoranthene	7	± 4					
Benzo(b / j / k)fluoranthenes	26	± 9					++ / ++ / –
Pyrene	42	±24	73	±46	133	1153	–
Benzo(a)pyrene[5]	13	±7	3	± 2			+++
Benzo(e)pyrene[6]	13	± 5	6	± 3			–
Benzopyrenes / perylene					117	578	
Perylene	3	± 2	2	± 2			
Indenopyrene	13	±14					
Indeno(1,2,3-c,d)pyrene			N.D.		N.D.	N.D.	+
Anthanthrene / dibenzopyrene	6	± 8			8	1	–
Benzo[ghi]perylene[7]	15	±19	N.D.		117	288	–

Reprinted from Ward, 1989.

Figure 3 (a) Dust and smoke expose firefighters to high concentrations of poisonous carbon monoxide and other toxic gases

ascending a slope, where fire reaches a particularly high rate of spread (Chandler *et al.*, 1983).

The seasonal workers who constitute the mass of the available work force for firefighting in Italy, as in other Mediterranean countries, are not always selected on the basis of aptitudinal criteria or according to their physical capabilities; nor are they always young.

According to a study related to the period 1984–89 (Leone and Saracino, in press), among 6260 seasonal firefighters employed in the provinces of Puglia the percentage of workers born between 1936 and 1946 fluctuated between a minimum of 39% (province of Brindisi) and a maximum of 54.9% (province of Taranto). Those born between 1928 and 1935 amounted to 22.13%. One man out of five was therefore > 50. On average one employee in two was of an age hardly compatible with the rigorous physical fitness requirements necessary to fight fires and prevent accidents.

In comparison, in the USA the physical selection of firefighters is based on the measurement of aerobic capacity, using either the 'step test' (this involves stepping up and down from a 40 cm high step 22 times/min for 5 min) or a 2400 m race which must be run in less than 11 min 40 s (Davis, 1979).

The 'step test' is now becoming standard practice for recruitment of personnel in Spain, where older individuals are penalized by a point system in which points are subtracted according to age and weight.

The massive employment of individuals who are not physically selected nor adequately trained and whose ages range between 40 and

55 years can be found elsewhere, although no analogous studies are known to have been conducted in other parts of Italy.

A consequence of this situation is the high number of often fatal accidents which occur in the course of firefighting operations. The national statistics are summarized in Table 2. These statistics show that in the last 3 years there has been an average of one fatal accident for every 20 250 total hectares burned, for every 7500 hectares of forested territory burned and for every 2100 fires. Major or minor accidents are recorded every 2100 hectares burned. Compared with the previous period of observation (1978–81) the mortality rate has remained substantially unchanged, from one fatal accident for every 2100 fires to one every 2000 fires. It has however improved with respect to the surface area burned. The accident rate is decidedly worse, by an average of 30%, with respect to the number of accidents and the surface area burned.

In addition, the ever-increasing number of fires makes it necessary to have an ever more massive mobilization of heterogeneous forces, thus multiplying the chances for accidents to occur. Some data may serve to illustrate the complexity of firefighting activities.

For the extinction of forest fires in 1988, 170 000 operations by personnel were necessary, 62% of whom were paid seasonal firefighters and volunteers; in 1989 there were 127 000 operations (Sardinia excluded), in which 55% of the personnel were paid seasonal firefighters; and in 1990 there were 215 278 interventions (Sardinia excluded).

Included in the statistics on fatal accidents are accidents to pilots of aeroplanes which crash during firefighting missions. One must also bear

Figure 3 (b).

Table 2. Fatalities and accidents related to forest fires in Italy

Year	*Affected area*		*Number of fires (N)*	*Number of accidents*		*Index*					
						Fatalities			*Accidents*		
	Forested (ha)	*Total (ha)*		*Fatal (m)*	*non-fatal (i)*	*m/N*	*m/ha b.*	*m/ha tot.*	*i/N*	*i/ha b.*	*i/ha tot.*
1978	43,331	127,577	11,052	3	47	1/3500	1/14500	1/42500	1/235	1/925	1/2700
1979	39,788	113,234	10,325	10	32	1/1000	1/4000	1/11300	1/328	1/1245	1/3500
1981	74,287	155,563	14,503	9	40	1/1600	1/8250	1/17300	1/360	1/1850	1/3900
1989	45,933	95,161	9,699	32	80	1/805	1/3850	1/7930	1/120	1/575	1/1200
1990	9,841	195,319	14,477	10	119	1/4500	1/9850	1/19500	1/120	1/800	1/1650
1991	30,172	998	11,905	3	29	1/4000	1/10000	1/33300	1/400	1/1050	1/3450

Data source: C.F.S.

in mind the number of tourists who perished in the flames (20 in 1989) but who have not been included in the statistics.

The statistics from other countries are similar: in Spain the mortality rate is one death per 750 fires, per 10 500 hectares of forest burned and per 24 500 total hectares burned (1970–1986).

In the first 9 months of 1985, a deadly year at the international level, there were 47 fatal accidents in the Mediterranean countries in the EEC: 19 of the accidents occurred in France and 18 in Portugal. In both cases firefighters were killed during operations to extinguish forest fires.

The figure of one fatal accident per 15 000 total hectares and per 7000 hectares of forest burned, reported in EEC statistics, partially corroborates the national statistics. The mortality rate is particularly high, one death per 600 fires, which suggests an anomalous year.

The frequency of fatal accidents must not make us lose sight of less serious accidents, which are often linked to failure to use preventive measures against accidents, in particular failure to wear protective clothing (helmet, gloves, shoes, fireproof suit, mask) as prescribed by the law (Presidential Decree 24-04-1955 n. 547), which establishes standards for the prevention of accidents on the worksite. These standards are systematically sidestepped in the formation of firefighting squads at the time of the extinction of fires and as a result of the frenetic rate of turn-over connected to the methods used for hiring firefighters.

Forest fires clearly constitute a serious problem not only in terms of the safety of firefighters but also of those who find themselves unexpectedly amidst the flames. Many of this latter group are temporary or permanent residents, whether in forested areas or wherever there may be combustible vegetation, since fires break out even in sparsely populated rural areas.

It should be emphasized that a great number of fires are started intentionally. This often occurs when there are adverse weather conditions such as high winds and elevated temperatures rendering firefighting operations more difficult and exposing firefighters to a greater risk of disabling injuries.

It is therefore an absolute necessity that firefighters should be physically fit and selected by means of strict aptitudinal tests and that they begin work only after rigorous theoretical and practical training in order to improve the efficiency of their service. During the training phase it is important, considering the statistics relative to accidents at the workplace, that firefighters become familiar with basic personal security standards to be adopted in emergency situations. They must also be trained to work in crews in extreme conditions, e.g. limited visibility, the presence of smoke and elevated temperatures – all of which increase the risk of entrapment.

Initiatives to bring about these changes can be adopted only if they are directed at a stable work force and not a fluctuating group of temporary workers who are mainly interested in reaching the minimum 51 days required to receive adequate health benefits and compensation in Italy.

The present system for hiring firefighters and forming crews from employment lists does not guarantee the level of professionalism necessary to operate with efficiency and security. This unnecessarily exposes human lives to serious risks, not the least of which is the sudden stress in temporary firefighters who may have somewhat sedentary activities during the rest of the year.

In order to face a phenomenon whose connotations are increasingly more criminal in nature, it is essential to create an efficient professional organization based on training, operative experience, qualification and physical fitness and not solely on good will.

BIBLIOGRAPHY

Chandler, C. *et al.* (1983). Fireline safety. In: *Fire in Forestry,* vol. II, New York: Wiley-Interscience, p. 297

Davis, J. B. (1979). Building professionalism into forest fire suppression. *J. Forestry,* **7,** 423–426.

DFCI (1985). Les fumèes de feux de forêts. Sont-elles toxiques? *Information no. 4,* 1–5.

Icona, S. D. (1990). – *Aptitud fisica del personal de extincion.* IV Curso Superior de Defensa contro Incendios. (Unpublished handout)

Leone, V., Saracino, A. (1990). Arson and forest fire industry: the state of the art in Italy. Proceedings of the International Conference on Forest Fire Research, Coimbra, 19–23 Nov

Leone, V., Saracino, A. (1992). Osservazione sugli incendi boschivi nel 1991. *Cellulosa Carta,* **5.**

Leone, V., Saracino, A. (In press). *Attività antincendio e manodopera occasionale: analisi del periodo 1984–1989.*

Leone, V., Perrone, R., Saracino, A. (1990). Incendi boschivi nelle aree forestali periurbane. *Monti Boschi,* **2–4,** 11

Moreira, D. A., Silva, J. B. (1990). La gestion forestière et la sylviculture de prévention des espaces forestiers menacés par les incendies au Portugal. *Révu For. Franc., num. spec. 'Espaces Forestiers et incendies'.* 337–345.

St. Barbe Baker, R. *My Life, My Trees.* Scotland: Findhorn, Forres

Ward, D. E. (1989). Air toxics and fireline exposure. Proceedings of the 10th Conference on Fire and Forest Meteorology. April 17–21, Ottawa, Canada

5
Ethical problems in mass disasters

R. KÖNIGOVA
Burn Centre, University Hospital, Prague, Czechoslovakia

In 1977 Rudolf Frey conveyed his thoughts on the missions and roles of the medical profession, which include not only prevention, diagnosis and treatment of the health problems of individual patients, but also the management of disasters which strike communities or nations and result in mass casualties.

In 1988 Peter Baskett and Robin Weller asked 'What planning might help alleviate the effects of disasters? What can be done to help afterwards?' (Baskett and Weller, 1988). The most basic disaster response must include methods for determining which victims will receive treatment first and what type of treatment will be given during the various stages of the disaster.

At the International Symposium on Burns in Padua, Italy, organized by the late Professor Dogo in September 1980, one session was dedicated to psychology in association with mass burn disasters. One communication (Königová and Pondělíček, 1981), prepared by the Prague Burn Centre, discussed the psychological problems encountered in burn victims. Many of these are not because of their somatic injury but as a result of mental stress and breakdown. They are prone to so-called 'blind action' or to chaotic behaviour. Often they do not realize the seriousness of their injury or even the danger to their life. This condition has been defined as 'trauma agnosis'. It expresses a 'dead point' in the conscience of the victims in a state of general panic, which may be the cause of the death not only of the injured and burned but also of a great number of healthy individuals. We resolved to draw attention to the psychological aspects of the affected population. Bearing in mind the consideration that without a psychological approach the patients' selection triage for treatment and transport is inadequate, we address the first stage of the ethical problems.

WHO SHOULD RECEIVE HIGHER AND WHO LOWER PRIORITY IN TRIAGE?

Modern triage is based on the assessment of the patient which is completed at the accident site, in conjunction with the judgement of the actual and possible severity and prognosis of the burn victims. In 1988 Howard Champion pointed out the lower priority for patients who will live without treatment and for those who will die despite treatment (Champion, 1988).

Over-response to the disaster may deplete valuable resources, while under-response may increase mortality. Over-response may even result in increased mortality, by wasting scarce resources on hopeless cases. Some types of injury, and in particular burns, require continuous use of operating-room time over a period of days or weeks for dressings and grafting. Arrangements need to be made to provide not only sufficient operating-room time but also sufficient numbers of surgeons and anaesthetists skilled in the management of such cases.

The identification of savable patients – and again, in burns, there are numerous factors influencing individual outcome – is difficult under optimal conditions, let alone under the chaotic circumstances created by a disaster.

'To treat or not to treat' was the topic of Bent Sørensen's 'Rudy Hermans Memorial Lecture' at the 3rd EBA Congress in Prague in 1989 (Sørensen, 1989). The title did not express exactly the intention of the contents, which dealt with the more serious ethical question of 'how to treat'. More than 200 years ago Samuel Johnson had taught medical students: 'It is our duty to serve society ...' However, true service to society has changed over the centuries and especially during the last decades with advances in science, along with changes in the law and societal perceptions. Critical care has established its place in modern medicine, but in spite of all the accumulated knowledge and recent innovations the successful treatment of many critically ill patients seems to be an ever-receding goal. We are confronted with more complicated syndromes on the one hand and ethical, economic and social considerations on the other (Crippen, 1992).

Previously inconceivable possibilities have been developed, at a price which includes not only tremendous financial costs but also the additional cost of human suffering. We cannot cure all patients, and many patients are 'saved' but remain with severe disabilities that may cause so-called 'social death' (Königová and Pondělíček, 1987). Intensive therapy is very expensive and therefore its performance should be carefully examined even under normal conditions. Under disaster conditions, when not all can live, we have to decide who shall live, knowing very well that withdrawal of medical treatment is more difficult than withholding treatment before it has commenced (Sprung, 1990).

Various models for prognostic prediction provide rough estimates of patient outcome, but they cannot be applied prospectively to a single patient with any confidence. Several scoring systems seek to measure the severity of injury or illness and thus quantify the risk of death. Their primary use in disaster is to triage patients for treatment and to allocate resources.

There are statistical reasons why a predictive model may not work when tested in different populations. Another consideration regards the misclassification rate and the specificity of the rule. The model should not incorrectly predict death in patients whose recovery is feasible. The level of specificity chosen, and who sets it, is a difficult problem. The balance required to set a reasonable level of specificity is not based solely on mathematics. It also includes factors such as the wishes and options of relatives and society to continue to treat such patients despite the cost, both in human and financial terms (Crippen, 1992).

Prediction rules suffer from criticisms that are not based upon their design (Krob *et al.*, 1991):

1. They have not been shown to be better than clinical judgement (APACHE III modification is being developed).
2. There is disagreement on how much computer predictions should influence clinical judgement, when the use of such rules may lead to clinical nihilism. If treatment is withdrawn on the basis of a prediction rule, the prediction will almost certainly be fulfilled.

A computer-generated prediction of death is an objective statement concerning the patient's inability to overcome the initial insult despite therapy. Nevertheless, appropriately used prediction rules may represent an advanced form of audit. They will confirm early decisions about the relevance of continuing treatment.

The channelling of resources to the most appropriate patients is an important aspect of clinical management, particularly in mass disasters.

In 1991 Krob *et al.* enquired: 'Do trauma scores accurately predict outcomes for patients with burns?' (Krob *et al.*, 1991). The scoring systems of Baux, Edlich and Zawacki place significant emphasis on burn size and the patient's age, the two most important factors in determining survival. Other factors that are considered in the formulae (Baux *et al.*, 1989) are:

- partial pressure of arterial oxygen at the time of admission;
- presence of inhalation injury; and
- history of bronchorespiratory disease.

The short-term outcome is still the most commonly used measure for the efficacy of treatment, but in disaster triage the long-term outcome must not be disregarded, this being influenced not only by age but also by underlying diseases and primary services (medical and/or surgical).

In making triage decisions, apart from age factors, the mechanism of injury should be considered. There is a tendency to prolong resuscitation in children, leading to a higher survival rate but also an increased incidence of sequelae (Miranda, 1990).

Concern over management, cost and efficiency could reduce our concern for the patient as a person, but interest in the assessment of quality of life (following ICU treatment) provides a framework for maintaining the importance of the total patient. Quality of life measurement requires clinicians to make an effort to determine how the patient was functioning prior to his injury or illness – information vital for prognosis, but also potentially useful for tailoring treatment to an individual's ability to benefit.

In 1989 Reichel and Dyck published their contemplation on euthanasia – a contemporary moral quandary. They stressed that the highest goal of a community is to protect the lives of all its members. The affirmation of life is not just the concern of a particular religion or culture but is the basis for the whole human community. What Albert Schweitzer called a 'reverence for life' underlies all our moral principles and values of civilized society, and is the basis of a professional ethic that has served humanity well over the past 2000 years. Our role as physicians should be to maximize the potential for life, even though death is inevitable. On the other hand, with limited resources in mass disasters, the patients with end-stage injury or disease should not be given intensive care, even if the recognition of terminal condition, on emergency admission, can be very difficult. Permitting death without intervening (passive euthanasia) avoids unnecessary distress and expense.

When we no longer heal, our ethical duty is to palliate and comfort. We can best serve disaster victims by considerate management of fear and pain. This has been the time-honoured tradition of medicine (Knaus, 1989).

Outcome prediction, cost efficiency and quality of life assessment have not been taught in medical schools, nor are they emphasized in residency or postgraduate training. However, they may be among our most important tools for meeting the challenges of tomorrow.

REFERENCES

Baskett, P. and Weller, R. (eds). (1988). *Medicine for Disasters*. Oxford: Wright, p. 230.

Baux, S., Mimoun M., Saade H. *et al.* (1988) Burns in the elderly. *Burns*, **15**: 239.

Champion, H. (1988). In: Baskett P. and Weller R. (eds) *Medicine for Disasters*. Oxford: Wright.

Crippen, D. (1992). Dealing with families who demand inapproriate medical treatment for moribund patients. *Intens. Care World*, **9**: 78.

Knaus, W. A. (1989). The changing challenges of critical care. *Intens Care Med.*, **15**: 415.

Königová, R. and Pondělíček, I. (1981). Euthanasia: psychology associated with mass burn disasters. *Burns*, **8**: 64.

Königová, R. and Pondělíček, I. (1987). Psychological aspects of burns. *Scand. J. Plast. Reconstr. Surg.*, **21**: 311.

Korb, M. J., D'Amico, F. J. and Ross, D. L. (1991). Do trauma scores accurately predict outcomes for patients with burns? *J. Burn Care Rehab.*, **12**: 560.

Miranda, D. R. (1990). Quality of life after intensive care. *Crit. Care Digest*, **9**: 34.

Reichel, W. and Dyck, A. J. (1989). Euthanasia: a contemporary moral quandary. *Lancet*, **2**: 1321.

Sørensen, B. (1989). To treat or not to treat. Third EBA Congress, Prague.

Sprung, L. (1990). Changing attitudes and practices in forgoing life-sustaining treatments. *JAMA*, **263**: 2211.

6
Terminology of burns and fire disasters

S. W. A. GUNN
The Mediterranean Burns Club;
President, World Association for Disaster and Emergency Medicine

All techniques, professions and organized activities generate their own and specific terminology – and surgery, burn therapy and fire protection are no exception. Whether an accidental burn, a major thermal injury, a fire disaster or a natural catastrophe, the response calls for specialized health care, prolonged surgical intervention, mobilization of community fire-fighting services, pertinent government departments and even international assistance, depending on the gravity and magnitude of the emergency. The many agencies, professions, specialists and individuals, from different disciplines, different countries, different cultures, and using different professional languages, converge on the stricken area to help the victims, who themselves may be of a different language and background.

Communication among these different people and an understanding of the technical, operational, administrative and even colloquial terminology of the disciplines involved in the medical management, emergency direction and civil protection become paramount if the inherent difficulties of the situation are not to be compounded by an overlay of communications disaster. Even in such an apparently specific problem as burns and fires, the many actors do not understand one another. If for a burn surgeon or nurse the terms 'second degree', 'tbsa' or 'acidosis' may appear quotidian and self-evident, they may not be so clear to a psychiatrist, let alone the director of the city's firefighting services. For the latter 'fireproof', 'fire resistant' or 'Class B fire' are perfectly clear notions, but does his medical counterpart know the differences? Yet the surgeon may be dealing with a case of 'third-degree burns' caused by a 'Class C' fire reported by the fireman. In more widespread disasters the situation becomes a Tower of Babel, for here, in what is often a multidisciplinary operation, the physician has to understand the meteorologist's terms, the transport engineer the doctor's, the nurse the journalist's, the defence minister the interior minister's, and the stricken population the language of specialists.

If such understanding is essential at the site of the accident or on the disaster field, it is becoming equally necessary away from the place of action, in planning boardrooms, lecture halls, electronic language networks, statistical tables, press centres or medical schools, where disaster preparedness and response are increasingly receiving attention. Indeed it is heartening that the European Union embarked on the harmonization of terms in civil protection and the World Association for Disaster and Emergency Medicine (WADEM) is currently compiling a standardized vocabulary of terms used in emergency and disaster medicine.

Following on from my *Multilingual Dictionary of Disaster Medicine and International Relief*, adopted by the United Nations and the World Health Organization as the standard terminology on the matter, I was requested to prepare *The Civil Protection Multilingual Lexicon* for the EU, and the original *Dictionary* has been translated into Japanese and other languages. Concrete indications of the need for such instruments or understanding, and the Food and Agriculture Organization of the United Nations has issued a *Wildland Fire Management Terminology*. The Mediterranean Burns Club is currently compiling the standard terminology of burns and fire disasters, a needed endeavour.

This chapter gives a small selection of terms to show the scope and methodology used in the language of burns, fires and disasters.

CONCEPTS

Acceptable risk
The eventual loss and risk that a country or community is willing to accept rather than provide the necessary resources and finances to reduce such risk.

Catastrophe theory
A mathematical and philosophical theory to explain and define transitional continuity whereby a disaster represents a brutal dynamic change in the forces present in natural, physical or social phenomena. (– Thom)

Disaster
The result of a vast ecological breakdown in the relations between man and his environment, a serious and sudden event (or slow, as in drought) on such a scale that the stricken community needs extraordinary efforts to cope with it, often with outside help or international aid. (– Gunn)

Cf. natural disaster, man-made disaster, technological disaster, toxicological disaster, creeping disaster, fire disaster, environmental disaster, complex disaster, humanitarian disaster.

Hazard
The probability of the occurrence of a disaster caused by a natural phenomenon (earthquake, cyclone), by failure of man-made sources of energy (nuclear reactor, industrial explosion), or uncontrolled human activity (overgrazing, heavy traffic, conflicts). Some authors use the term in a broader sense, including vulnerability, elements at risk, and the consequences of risk.

Health
(1) The state of complete physical, mental, and social wellbeing, and not merely the absence of disease or infirmity. (– WHO)
(2) The state of an individual or a community free from debilitating conditions, demonstrating a reasonable resistance to diseases, and living in a salubrious environment.

Risk
The lives lost, persons injured, damage to property, and disruption of economic activity due to a particular hazard. Risk is the product of hazard and vulnerability. (– UNDHA)

Vulnerability
The degree of loss from a potentially damaging phenomenon, e.g. expressed in a scale from zero to 100 per cent. (– UNDRO)
Cf. elements at risk, hazard, natural hazard, risk, risk indicator, risk map.

SCOPE

Armed Conflict
State of hostilities in which two or more organized armies are at war against each other. In modern warfare, the attack may be with conventional, chemical, and / or biological, and / or nuclear weapons, incendiary weapons.

Burn
Tissue damage caused by heat produced from any thermal agent. Burns can be classified according to the depth of skin damage – first, second, third degree burn; according to the extent of body surface (tbsa) involved – 9%, 18%, 50%; or according to the cause – chemical, electric, flame, steam, sunlight, nuclear radiation burn.

Burn Disaster
The overall effect on living persons or animals, caused by massive burn action from a known thermal agent, characterized by a large number of immediate deaths and burnt patients and a high rate of secondary mortality and disability. (– Masellis)

Class of Fire
Fires can be classified according to size, according to the kind of fuel, whether natural or man-made, domestic or industrial, etc. Four classes are distinguished according to the kind of fuel and the resulting type of extinguishing, as follows:

Class A: Fires started from common combustibles, such as paper, wood, cloth, which require cooling, such as with water, retardants, etc.

Class B: Fires involving combustible or inflammable liquids or gases, which require air exclusion for extinction.

Class C: Fires caused by electricity.

Class D: Fires due to some combustible metals, such as sodium, potassium, which are extinguishable by heat absorption.

Combustiology
The science and art of burns management, from prevention, treatment, to rehabilitation. Term derived from *combustion*: catching fire; the development of heat and light through exothermic chemical reaction of a combustible material; oxidation of organic tissues.

Disaster Medicine
The study and collaborative application of various health specialties, e.g. paediatrics, epidemiology, communicable diseases, nutrition, public health, emergency surgery, military medicine, community care, social medicine, international health, to the prevention, immediate response, humanitarian care and rehabilitation of the health problems arising from disaster, in cooperation with other non-medical disciplines involved in disaster management. (– Gunn)

Natural Hazard
The probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon.

Technological Disaster
Man-made disaster due to a sudden or slow breakdown, technical fault, error, or involuntary or voluntary human act which causes destruction, death, pollution, and environmental damage.

Thermal Agent Disaster
Disaster causing severe losses in human lives and material goods as a result of massive heat production. It indicates the relationship between the cause of the event (massive heat production) and its consequences on man and the material environment, as a mathematical expression of the damage caused, i.e. the number of dead and injured and the extent of material damage. (– Masellis)

METHODS AND MANAGEMENT

Assessment
Survey of a real or potential disaster to estimate the actual or expected damages and to make recommendations for preparedness, mitigation and relief action.

Cf. damage assessment.

Backfire
In fire control, a fire intentionally set along the inner edge of a control line in order to consume the fuel in the path of a forest fire, or to change the direction of the fire's convection column.

In electricity, *back-fire* denotes the loss of the reverse blocking capacity of a valve, resulting in the flow of reverse current, and therefore a potential cause of accident.

Disaster Preparedness
The aggregate of measures to be taken in view of disasters, consisting of plans and action programmes designed to minimize the loss of life and damage, to organize and facilitate effective rescue and relief, and to rehabilitate after disaster. Preparedness requires the necessary legislation and means to cope with disaster or similar emergency situations. It also is concerned with forecasting and warning, the education and training of the public, organization, and management – including plans, training of personnel, the stockpiling of supplies, and ensuring the needed funds and other resources.

Firebug
Colloquial term for pyromaniac. A psychologically unstable and abnormal person with compulsive desire to cause a fire and taking pathological pleasure out of it.

Fireproof
The quality of a structure or object to resist fire either by its own nature or imparted to it by treatment with retardants so as to reduce the danger of fire starting or spreading.

Fire Resistant
The quality of a material or device to preserve its properties and function against exposure to fire under certain conditions.

Flameproof
The property of a material or device not to burst into flames during a lapse of time in a fire.

LAWS AND ORGANIZATIONS

Bilateral Co-operation
Technical co-operation or assistance by a donor country to a recipient country, through direct agreement between the two governments, without the UN or any other intermediary.

Disaster Act, Law
National legislation which provides the government or its appointed executive with special powers to mobilize the efforts and resources of the nation in face of a disaster, major fire or other catastrophes.

Geneva Conventions
The body of international agreements consisting of four Conventions (1949) and two Additional Protocols (1977) concerning the humanitarian treatment of victims of armed conflict, and put under the responsibility of the International Committee of the Red Cross. The first (Convention) regulates the care of the wounded and sick soldiers on the battlefield. The second is about the care of the wounded, sick, and shipwrecked in naval warfare. The third is on the treatment of prisoners of war. The fourth is on the protection of civilians in time of war. Additional Protocols I and II ensure more humane considerations not only in international conflicts but also in national strife, such as the treatment of guerrilla fighters.
See International Humanitarian Law, Red Cross.

Mediterranean Club for Burns and Fire Disasters
Organization that brings together all the medical, surgical, nursing and firefighting professions concerned with burn therapy and fire safety in all forms, particularly in the Mediterranean basin. It encourages the highest standard of burn care in all countries and collaborates internationally to strengthen prevention, care and rehabilitation in burns and fires. (Previously *Mediteranean Burns Club* – MBC.)

United Nations
The UN Department of Humanitarian Affairs (DHA) mobilizes, directs, and co-ordinates the emergency humanitarian activities of the various UN agencies and other organizations. It has established the International Disaster Management Information Network (UNIE NET), operates the UN warehouse in Pisa (Italy), and publishes studies on disaster relief and preparedness. In emergencies, UN-DHA dispatches field officers to the stricken site, while in normal times the UNDP resident-representative acts as its representative.

World Health Organization
The health arm of the United Nations aiming at 'the attainment by all peoples of the highest possible level of health'. The WHO co-ordinates efforts to raise health levels worldwide and promotes the development

of primary health. Besides multiple public health programmes and actions, it is engaged in disaster preparedness and relief both at headquarters and at six regional offices, and co-ordinates the health sector of the UN involvement in major emergencies. The organization has compiled the Emergency Health Kit. *Synonym*: WHO.

SUMMARY

These are a few of the many specialized terms which have been tested over the years in hospitals, training programmes and fires and are established as the standard terminology in disasters, burns and fire protection.

It is the author's conviction that in the difficult emergency situations of multilingual and multidisciplinary disaster action, the use of a commonly agreed vocabulary transforms a potential disaster of language into a commonly-understood language of disasters, and lessens the Babelian confusion which often risks to hamper the most well-meaning, humanitarian, disaster response.

REFERENCES

Food and Agriculture Organization, *Wildland Fire Management Terminology*. FAO, Rome, 1986.

Gunn, S. W. A., *Multilingual Dictionary of Disaster Medicine and International Relief*, Kluwer Academic Publishers, Dordrecht, London and Boston, 1990, in English, French, Spanish and Arabic.

Gunn, S. W. A., The Language of Disasters, *Prehospital and Disaster Medicine*, Vol. 5, 1990, pp. 373–76.

Gunn, S. W. A., Aono, M., Ukai, T. and Yamamoto, Y., *Japanese Dictionary of Disaster Management and International Relief*, Herusu Publishing Co., Tokyo, 1992, (Japanese-English).

Gunn, S. W. A., Murcia, C. and Parakatil, F., *Dictionnaire des Secours d'Urgence en cas de Catastrophe*, Conseil International de la Langue Française, Paris, 1984.

Masellis, M., Thermal Agent Disaster and Fire Disaster; Definition, Damage Assessment and Relief Operations. In: *The Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Kluwer Academic Publishers, Dordrecht, London, Boston, 1992.

World Association for Disaster and Emergency Medicine, *Glossary of International Disaster Assistance Terms*, an ongoing project. *Prehospital and Disaster Medicine*, 1995.

7
Basic principles and paths for perfecting the care of severely burned patients

V. D. FYODOROV and A. A. ALEXEEV
Burn Centre of the Vishnevsky Institute of Surgery, Moscow, Russia

The up-to-date treatment of burn patients involves early active prophylaxis and correction of haemodynamic disturbances, microcirculation and electrolyte exchange, improvement of resistance to infection, metabolism and immune status, prevention of endotoxalemia and infection, early reconstruction of lost skin, coverage, prophylaxis and correction of the pathological scars, effective pharmacological control of the patient, and full medical and social rehabilitation.

The basis of early burn disease treatment is immediate infusion–transfusion therapy. At the same time, a decisive influence upon the development, course and the outcome of the burn is exerted by the wound healing process. Exceptional importance is therefore attached to the use of treatment methods with the aim of early preparation for grafting.

Because of the political situation, the problems of health services in the CIS countries have become considerably more complicated owing to shortages of drugs and equipment necessary for successful treatment of burn patients in hospitals and medical institutions, and in particular in burn centres. There is, therefore, a threat to the success which had recently been achieved in the treatment of burn patients. This is reflected by the improvement in the survival rate, the reduction in treatment time and the decrease in the complication rate. This means that physicians who treat burn patients must observe a number of principles which are simple but require unconditional implementation.

The first of these is early initiation and adequate performance of anti-shock infusion therapy, with objective data control. A delay of only 1 hour in administration of anti-shock infusion therapy drastically worsens the prognosis. Consequently, an improvement in emergency preparedness, including medical aviation, and preparation of local and regional medical institutions for the initiation of competent infusion therapy on the spot or in the nearest hospital continue to be extremely important tasks and the object of further efforts to provide material capacities for these links in the medical network of the health service system. The solution to this problem would not encounter serious obstacles, since effective anti-shock therapy requires only a comparatively small quantity of necessary expensive drugs. Within the first hours and even on the day after trauma, infusion of widely available crystalloid solutions, such as Ringer's lactate, lactasol or glucose, is required. Only towards the end of the first day and sometimes on the second day is the infusion of albumen blood preparations necessary. Solutions of synthetic colloids are advisable only in the event of unstable haemodynamics. Checking the effectiveness of the therapy provided is easily done by measuring hourly diuresis and the blood haematocrit. More up-to-date and exact means of control, for example the measuring of lung artery pressure by insertion of a Swan-Janz catheter, need only be performed in the intensive care unit of a large hospital.

Secondly, at present the attitude of burn trauma specialists towards the transportation of burn patients in a state of shock is not uniform. There is no doubt that the most desirable course is admittance of severely burned patients to specialized burn centres on the first day. However, current conditions in our country make it impossible to carry out this in all regions, owing to the long distances, bad roads, and the lack or shortage of specialized transport. We therefore think that the transportation of severely burned patients within the first 72 hours after the trauma from one medical institution to another (which is what some physicians insist on in local hospitals which do not have special beds) is contraindicated and should be avoided in view of the threat of imminent burn shock and the problems of the administration of intensive care during transportation. However, with a 4–5 day delay in the transportation of a burn patient to a burn centre in the after-shock period there is a danger of missing the optimum time for local surgical treatment, and various infectious and non-infectious complications may develop. The considerable progress in burn management in recent years is undoubtedly related to the introduction of active methods of topical burn treatment. Early surgical and chemical debridement with further autodermoplasty has made it possible to drastically increase the survival rate of patients with critical burns. The data in the literature regarding surgical debridement in patients with large-scale burns, together with the positive examples of many patients, testify that early surgical debridement and the more conservative method of chemical debridement do not show any convincing advantage of the first method over the second. This is in fact quite natural because, though preventing infection, early surgical debridement does not avert primary disturbances of metabolism, immunity, microcirculation and other physiological functions, which can cause death in patients with burns to more than 60% of the total body surface area (TBSA). However, there is no doubt of the need for more active use of this method in patients with full-thickness burns of up to 40–50% TBSA; here the operation gives very good results. Use of this operation in patients with large burns requires special efforts for the maintenance of such patients, and here we come to the question of the burn centre facilities.

The majority of existing burn departments are situated in standard buildings, where they tend to be separate from the other departments and not particularly suited to burns treatment. We should insist on the design and construction of specialized regional burn centres which meet the needs of the given region and are provided with the most up-to-date equipment. The wide introduction of active surgical treatment in patients with large burns will not be possible without the introduction of aseptic methods of treatment, which can be achieved by specific construction features of the burn centre building and its equipment, planned in the design phase, with a sufficient quantity of fluidized beds, special baths and other necessary equipment, and with single-use instruments, linen and dressings. For staged surgical debridement in patients with full-thickness burns temporary biological covers and artificial skin substitutes are necessary. Very good results have been achieved using preserved network xenoskin. One of the problems of the surgical procedure of skin coverage in the short term is the availability of a sufficient quantity of autogenous material. For this reason it is necessary to solve the problem of growing skin *in vitro* with its wide possibilities of use in autoplasty.

Nutrition is an important aspect of the general treatment of burn patients. Recently, our industries have begun to produce equipment for enteral nutrition. However, the inadequate supply of systems makes the large-scale introduction of this method into clinical practice impossible.

With a view to increasing the effectiveness of treatment, great hopes are pinned on the further elaboration of methods combatting the depression of immunity, by perfecting the principles and means of antibiotic and antibacterial therapy in general.

The organization of day hospitals in burn centres is of great significance. This will make it possible first of all to treat patients with limited burns on an out-patient basis, providing the necessary medical care, with considerable reduction in the cost of treatment. Secondly, it will improve the conditions and organization of out-patient control; thirdly, it will make it possible to solve the problems of the patients' medical, social and professional rehabilitation.

Observance of the above basic principles will make it possible not only to preserve the present up-to-date level of burn patient treatment but also to predetermine its further perfection with regard to the ways described of intensifying treatment procedures.

8
Risk assessment of fire and explosion disasters: a systematic approach

HERBERT TIEDEMANN
Swiss Reinsurance Group, Zurich, Switzerland

INTRODUCTION

A systematic assessment of disasters (many casualties) by fires and explosions should be based on a quantitative analysis which starts with stock-taking and then investigates the particular exposure per peril. This means that the specific exposure to each peril and for each location must be ascertained and that the probability of occurrence of events leading to disasters (burns in the context of this chapter) must be available in the form of event-probability distributions which quantify the annual probability or return period of given events per risk category and per location. Moreover, the consequences of the events must be determined in similar distributions which correlate the magnitude of the given accident with the casualties to be expected. In both cases uncertainties must be stated clearly as any proper preparedness for disasters must allow for such uncertainties in the form of safety margins.

As regards consequences, it is necessary to define and quantify the most important parameters which determine the number of casualties and in the case of the injured the severity of the injury. Such parameters may vary very much from case to case.

This chapter will therefore discuss the prerequisites of a systematic assessment using examples from the fields of seismology, vulcanology and industrial risks. This approach can be extended to other perils which are beyond the scope of this chapter, like accidents in the field of aviation, or transport of dangerous goods by road, rail, or water. The discussion will include trends to some extent to show that past experience has to be used with care. The growing density of populations and the introduction of new categories or types of inflammable and/or explosive materials, as well as changes in technology related to the storage, handling, and processing of such materials, has led to an exponential growth of the exposure of modern technological societies.

Although a discussion of disaster preparedness is beyond the scope of this chapter, the information and data presented will assist in planning for emergencies for which no local experience is as yet available. As the impact of a disaster or the potential exposure is the product of its probability and the consequences, it is evident that any professional planning related to the handling of a disaster, i.e. disaster preparedness, but also disaster mitigation must allow for these parameters.

EARTHQUAKE-GENERATED FIRES

Although the risk of conflagrations in cities has in general decreased, for instance, since the fire in Chicago in 1871 or that due to the Tokyo earthquake of 1923 which killed approximately 130 000 persons by fire alone, chemical and petrochemical facilities have added in several ways to the exposure. We will discuss essential parameters to some extent because of their importance in any conflagration or explosion whether caused by earthquakes, volcanism, industrial accidents, or other disasters. It is, however, impossible to discuss probability aspects in this chapter. Details including seismic index maps permitting the calculation of earthquake return periods and those of volcanic eruptions are to be found in Tiedemann (1992).

Compared with ordinary (normal) fires the fire and explosion hazard related to earthquakes can constitute a substantial or heavy risk. The reason is the increased probability of ignition, of the escape and spread of inflammable material, and of the failure of fire-fighting facilities, together with the general catastrophe involving the burning site itself and the whole area including the families and relatives of those called upon to meet the situation logically, efficiently, and with a cool head.

Although in general the fire risk of buildings has decreased with the introduction of reinforced concrete to replace wood in frames, floors, and roofs, some other changes, such as the use of certain plastics, and gas mains or even pipe systems carrying liquid hydrocarbons criss-crossing cities, tend to add to the exposure.

The fire and explosion risk associated with earthquake is a very complex issue, considering the multitude of projects and the differences between them as well as the many factors which determine the probability and extent of the risk. One way of treating the subject economically is to discuss the factors that determine the occurrence of earthquake fires and explosions and the magnitude of the damage. We will not include parameters describing the exposure of persons in the risk area. This issue requires a specific assessment, based on the magnitude and time-history of a fire or explosion (cf. parameters below and Tiedemann, 1992), the number of persons exposed per zone, as well as on parameters which increase or decrease the risk.

The fire and explosion risk associated with earthquakes may be modelled with the following formula

$$X_{E(f,\,ex)} = f[I,\, H_G(m,\, p,\, t,\, t_{av},\, r_v,\, tech,\, cm,\, i,\, d,\, exo,\, sm,\, sp,\, H_R)]$$

This formula can also be used as a shorthand checklist when inspecting risks – the different parameters are defined as follows:

- $X_{E(f, ex)}$: Fire and/or explosion risk due to earthquake, whether as a direct or indirect consequence. This risk is a function (f) of the parameters within the brackets.
- I: Intensity of the event (without reference to any intensity scale) meaning the severity and duration of the event as related to the characteristics, sensitivity and vulnerability of the project which in turn determines the risk for people.
- H_G: The general human factor which influences the exposure of the project: the professionalism and care (risk aversion) involved in the planning and design, construction and erection, and also all characteristics of the plant which are affected by human reliability during operation and which do not come under H_R described below. The full meaning of this factor can be realized from the fact that it determines the extent of the exposure from all other parameters listed in this model.
- m: Material factors, e.g. the physical and chemical properties of all inflammable material in a project, whether installed or in the form of raw material, feedstock, semifinished product or final product. The physical properties include the phase, i.e. gaseous, liquid, or solid, the quantity, the concentration and the surface-to-volume ratio, which is particularly important for solids. The chemical properties include calorific value, ignition point, toxic properties, corrosiveness, stability and oxidising, reducing, basic and acidic properties.
- p: The pressure under which liquids and gases are stored and/or processed.
- t: The temperature at which materials are kept, sorted, and/or processed.
- t_{av}: The average residence time of material during storing and/or processing. Although the concept is mainly used in chemical engineering, it can just as well be applied to any other combustible material present in a plant which is not permanently installed there, like, for example polystyrene insulation, but which is used in manufacturing and packing of finished products.
- r_v: Reaction velocity. This again is generally associated with the operation of chemical plants. It is clearly a very important parameter, describing the behaviour of any combustible or explosive substance once the reaction starts.
- tech: Technical failure factors related to the design, manufacturing, erection or operation of plant components.
- cm: Construction material factor. If seen together with the foregoing parameter, it becomes evident that the properties of the material, its failure probability distribution depending on loads, load changes, temperature, fatigue, wear and tear, and influence of traces of the material on chemical reactions, are treated distinctly

under this heading, although the material is selected when the design is made.

- i: Ignition sources. Whereas welding and torch cutting are in general important sources of ignition, the situation is somewhat different in connection with earthquake fire and explosion. Here we have failure of apparatus, of machinery to retain hot substances, short circuits, static electricity, hammering, the hot surfaces of open fires which are normally not reached by combustible material, spontaneous decomposition of chemicals, etc.
- d: Distribution factor. This factor takes into account the horizontal and the vertical distribution of combustible material over the project. It is of particular importance with earthquake fires because modifications in the distribution may change the passive safety of the plant very noticeably by either providing or failing to provide adequate, safe spacing.
- exo: Exogenic hazards relate to events which originate outside the risk and cause or increase earthquake fire and explosion losses. Direct effects may be caused by tsunami, liquefaction, settlement or slides, and the failure of power or water supply. Independently arising events include water and power failure not caused by either earthquake, flood, inundation, or windstorm and electric storm. One should also include the probability of an outside fire and/or explosion, whether caused by earthquake or not, which may spread to the site under study.
- sm: Safety measures (passive). This includes all passive safety measures designed or built into the plant, or provided in the form of equipment installed to protect the project without requiring any action on the part of the personnel. Examples are spacing, fireproofing, self-actuating shutoff and safety valves, rupture plates, vent areas, explosion suppression systems, devices controlling or limiting relative movement, dump systems and dikes retaining released combustible material, ring mains and sprinklers, ponds or other receptacles holding water for fire-fighting, etc. and so on.
- sp: Safety procedures (active). This factor measures the safety standards as related to the actions of the personnel, such as general emergency or shut-down programmes, the availability and quality of the teams expected to act in case of an earthquake fire or explosion, such as plant or outside fire-fighting squads, first aid teams, or the assistance available from national guards, the military, etc.
- H_R: This is the residual probability of human error. Irrespective of the H_G standard discussed above, there is a residual human error probability which should not be underestimated since the situation will involve acute stress of a kind the people called upon to act will never before have experienced.

This list, which is not complete because not all parameters have been included and in particular not all sub-parameters, immediately shows that expert advice should be sought in case of exposure which appears to be complex. It is moreover evident that this chapter cannot discuss details and therefore only general issues will be presented in connection with each parameter.

Intensity of the event

The fire and explosion potential is generally not described by conventional earthquake intensity scales. Exposure would thus have to be considered on a case-by-case basis. For instance, flour mills and grain silos are notorious risks as regards dust explosion. Dust explosions generally happen in two stages, with a primary explosion resulting from dust suspended in the air disturbing more dust which had previously settled on sills, girders, machinery, etc. and which explodes in its turn in a secondary event. Violent earthquake shaking generates suspended dust, and the result may well be a larger than normal quantity of dust in the air and thus a more violent blast, if it is ignited.

A refinery or petrochemical plant with tall apparatus may be vulnerable to excitation by gentle rocking, leading to large relative displacement and thus a high probability of pipe failure with a resultant release of gases or liquids which can be ignited. Therefore, dangerous intensities could be reached with an event of moderate magnitude nearby in the case of a flour mill but, on the other hand, with a distant earthquake in the case of a petrochemical plant, in particular if the latter is sited on deep soft alluvium.

The intensities likely to cause fires and explosions have to be seen in relation to all components of a risk, whether in the form of buildings, machinery and apparatus, or material handled and processed.

The general human factor

The general human factor (H_G) is reflected in the quality of the earthquake building code of the country concerned and in the standards of material and workmanship. However, for power stations, factories, chemical plants and the like no codes are employed. The general human factor is a function not only of the professional competence of those involved in the general design and its details but also of risk consciousness and risk aversion.

Material factor

Here we have to consider physical and chemical properties and parameters. The exposure depends on the combination of the two. As regards physical properties of combustible materials, we first consider the phase – solid, liquid or gaseous – of the potential fuel. The degree of hazard depends to a certain extent on this and also on the stability of the phase. Solid materials are in general less risky than liquid or gaseous ones because the bonding forces which hold solids together are stronger than those in liquids. Furthermore, solids will tend not to disperse easily and thus not invade and ignite other areas in the plant. This is not the case with liquids, and even less with gases. Solid combustible material in powder form, however, is easily conveyed to other sections of the plant.

Some solids change their phase under the influence of heat or combustion. Wax and paraffin are familiar cases: under fairly mild heating they may liquefy and drip or flow, thereby dispersing combustible material. Plastics can also cause such problems.

A further important aspect is the conditions under which the combustible material is kept. In the case of solids, the most important is represented by the surface-to-volume ratio. The larger the volume in relation to the surface, the more difficult it generally is to ignite the material, and the more slowly the fire will develop. The ultimate in terms of particle size is dust, which introduces the risk of violent explosions as mentioned earlier.

A very important physical parameter is the quantity of potential fuel at any particular location. This determines the thermal energy which could be liberated during a fire and therefore the damage which could be done to objects in the vicinity. Further, the temperature developed and the heat radiated depend on the quantity of material burning, which therefore also controls the chance of ignition of other items. A further factor which is sometimes not recognized is that the larger the quantity of material involved in a fire, the more difficult it is to lower the temperature, e.g. by sprinklers or normal fire-fighting, in other words to extinguish the fire or to contain it. Considering that there may be an acute shortage of water after an earthquake, it is of paramount importance to look into fuel quantity aspects very carefully.

Turning to chemical properties, the first to consider is the calorific value which, together with the quantity of the material involved, determines the thermal energy liberated. Obviously, the higher the calorific value, the more pronounced the thermal exposure. The exposure may, however, also be influenced by the speed of combustion and the temperature reached. A large volume of combustible material with a high calorific value will release a large amount of thermal energy. If the speed of combustion is also high, a kind of a fireball will develop, i.e. a high thermal density will be produced. If the combustion temperature is high the energy density, which depends on the fourth power of the absolute temperature according to the Stefan-Boltzmann law, will be considerable, as will the chance of casualties, damage and of ignition at some distance from the flames.

As regards ignition temperature, the lower this temperature or the closer the item to a source of heat, the higher the risk that new 'fuel' will ignite. When they reach their so-called self-ignition temperature, solids will oxidize so strongly that the exothermic process leads to ignition, i.e. no additional source of heat is needed to start a fire. A further aspect is the stability of the potential fuel. Some chemicals are intrinsically unstable, i.e. they polymerize, decompose or inter-react even if there is no extraneous factor. An earthquake may trigger such reactions by supplying heat, catalysts and agitation, and even chemicals that are stable under normal conditions may then become unstable.

Explosions cause casualties and damage by the heat and by the pressure waves generated; as both interfere with fire-fighting, this aspect requires particular attention. Boiling liquids generate vapour clouds which may eventually produce devastating explosions. Such fireballs, similar in appearance to those produced by a nuclear explosion, may kill or injure people up to many hundred metres from the centre of the explosion. The menace of such disastrous explosions may render fire-fighting virtually impossible.

Dust explosions, which may be particularly violent, have already been mentioned. Obviously 'ordinary' explosive gases also present a considerable hazard within their explosive range, i.e. between the lower and upper gas–air mixture ratios where an explosive flame can develop. This range is also known as the flammable range. Liquids have to be vaporized to produce such air–gas mixtures, and it should be remembered that earthquakes can lead to vapour development not only because of fires, but also because pipe ruptures can lead to a sudden drop in pressure and violent vaporization.

Finally, corrosion, toxicity and the risk of contamination due to the chemical properties of material have to be considered. As heating or combustion in earthquake fires may alter the original properties of the chemicals present, the additional risk potentials most likely to arise in connection with synthetic hydrocarbon compounds will have to be investigated.

In plating facilities tanks holding cyanide and others holding hydrochloric acid not far from each other are to be found. If these liquids leave the tank due to splashing or overturning of the containment, hydrogen cyanide gas, which is extremely poisonous, will be produced. Many laboratories, in industries, schools and universities, have bottles with chemicals in their cabinets which will produce hydrogen cyanide if they can fall and mix their contents. This can compound the problems related to exposure from 'clean' fires and explosions. Hydrogen cyanide and hydrogen chloride are also generated when synthetic compounds in furniture and modern buildings burn.

Pressure and temperature

In general, pressure should be considered in conjunction with temperature when assessing variations in the hazard posed by inflammable liquids. Such liquids in tanks, pipes and reactors will vaporize as heat is added, and pressure will build up. This by itself, or in conjunction with physical earthquake forces, may lead to the failure of the containment, whereupon the resultant pressure drop will be followed by the rapid evaporation of the liquid. In this way large quantities of inflammable and explosive air–gas mixtures may be generated. If considerable pressure builds up within vessels before a failure and/or explosion occurs, the violence of the explosion will be substantial.

Average residence time

The average residence time of combustible and explosive materials should be understood in the broadest sense and not only in relation to chemical processes. The longer the time of residence, the greater the probability that the material may be involved in an earthquake fire and/or explosion. As exposure may change in the course of time, a detailed account of the time-history should be compiled.

The average time of residence is particularly important if a large quantity of dangerous material is treated in a hazardous process, or using hazardous equipment, i.e. where the chemical process as well as the machinery and apparatus used could produce problems if upset by an earthquake.

Reaction velocity

In general, the higher the reaction velocity, the higher the hazard, because of the energy involved per unit of time. Fire and explosion are exothermic processes, and if the fuel reacts strongly, a high and therefore destructive energy density is reached. Reactions are influenced by catalysts; these may be admixed accidentally during an earthquake and could alter the reaction. Failure of the cooling needed to control an exothermic process can cause problems because a 'run-away' reaction or explosion may occur.

Technical failure

Tanks collapsing during an earthquake, cracking or spilling their contents are examples of typical technical failure. The potential for dangerous pipe ruptures or the failure of fittings or anchoring, etc. due to indirect causes must also be considered. For instance, explosion suppression equipment generally works with electrical switches or detectors employing electricity. If the electricity supply is endangered, which can be expected during an earthquake, the system will not function.

One must look carefully at all elements in and around a project, for instance, sprinkler failures or a store with bottled gases or similar containers which contain explosive, toxic or corrosive gases. The release of such material would make fire-fighting impossible, and in addition some of these containers could be turned into missiles if their tops were knocked off.

Construction material

The failure probability of materials used in machinery, apparatus, pipe systems, etc. depends not only on the material itself but also on a number of parameters associated with operational conditions. The more 'exotic' (sophisticated) a given material is, and the more exacting the demands, the less pronounced will be the peak in the failure probability distribution and the greater the risk of high scatter in performance. Important are also the chances of additional adverse factors introduced by an earthquake, for instance, earthquake forces acting on elements working at full capacity.

Ignition sources

In addition to the 'standard ignition sources' which are present in most risks, there are earthquake-generated ignition sources. One such standard source is electricity, which accounts for about 25% of all fires and explosions in chemical plants under normal conditions. This problem if considerably aggravated by earthquakes. High and low tension equipment, e.g. insulators can be fractured, or the equipment can be overturned due to installation without regard to earthquake forces. Wiring may become a source of ignition due to sparking because of disrupted wires, loose connections or damage to the cables or wiring due to other objects touching or falling on to the conductors. Static electricity normally causes about 15% of fires and explosions in chemical plants. In plants where static charges are generated by the process, an earthquake is not likely to increase the generating capacity, but it may well interfere with the operation of the protective device used. Static electricity is, however, also generated by gaseous dielectric material, i.e. by dry gases which issue, for instance, from a crack in their containment at high velocity. A particularly dangerous situation arises where a cloud of gas is generated, due to failure of pipes or connections between pipes and tanks or apparatus, and is then ignited in bulk.

Although coal fires are not as numerous today as they were in San Francisco or Tokyo, there are still quite a number of open fires in households in several modern settlements, e.g. gas-fired water heaters or cooking ranges, open fireplaces or stoves made of Dutch tiles, etc. In industrial plants there is sometimes a considerable number of open fires in the form of furnaces, hearths, heating systems, boilers, reactors, etc. Under earthquake conditions liquids and even more so gases escaping from their containment can travel considerable distances before igniting. Cinders may transport a fire from one place to another as they are carried by air currents and may find fuel in the open or after entering through open or broken windows. The Tokyo earthquake of 1923 happened around midday when fires were being used for cooking. The severe shaking spread the burning fuel, and allegedly 277 fires broke out, 133 of which spread. The most important single factor, however, was the strong wind of about 45 km/h which, in the hours following, changed from a southerly to a westerly and northwesterly direction and reached velocities in excess of 75 km/h. It was probably the most important reason for the conflagration that occurred.

A further cause of ignition may be a chemical reaction that takes a dangerous course because of an earthquake or which is precipitated by the shaking. The next factor is the molecular concentration of the reactants. The law of mass action as proposed by Guldberg and Waage (1867) states that the velocity of a chemical reaction is proportional to the active masses (i.e. the molecular concentration) of the reacting substances. Obviously the molecular concentration can be altered by the release of reactants due to earthquake shaking, e.g. as a result of equipment failure. Ignition by chemical reaction can also occur if two chemicals are mixed accidentally. A simple example would be bottles of fairly volatile chemicals and concentrated acids falling off laboratory shelves.

Earthquake shaking may produce hammering between objects, such as steel against steel or against stone, etc. and this may strike sparks and so cause a fire or an explosion.

One problematic source of ignition is arson.

Distribution factor

We are here concerned with the three-dimensional distribution of combustible material within a project, leaving aside adequate spacing, however, as this will receive attention elsewhere.

As regards the vertical distribution of dangerous materials the risk increases with the height at which combustible material is kept. In connection with the horizontal distribution, the risk assessment will have to take into account the quantity and the general degree of hazard of combustible material per location, the proximity of sources of ignition, and meteorological conditions, to cite some of the main factors. It should not be overlooked that the multi-locational distribution of combustible material and a similar spread of ignition sources increases the chance of fires occurring and facilitates their spreading unless spacing is such that the fire will stay in the original area even if fire-fighting breaks down.

The assessment of earthquake fire exposure in relation to liquids will have to take into account the original distribution of the materials as regards their vertical and horizontal location. Particular care should be taken with liquids stored or transported some way above ground level, in particular if they are under pressure. Aerosols, fogs, mists and sprays of hydrocarbons which may arise due to earthquake damage to equipment present a hazard which is at least equal to the risk from dust explosions, if only because volatile components have a higher probability of ignition. As even products with a comparatively high flash-point may pose a substantial hazard if the size of particles is sufficiently small, this type of exposure must not be underestimated, in particular if in addition the temperature of the liquid, of the air, and of objects in the vicinity of such mists is high. Liquefied gases which do not evaporate rapidly, and also gases which are heavier than air, will tend to spread and flow like liquids once they are released from their containment. Their movement, however, and the resulting distribution of combustible material, are less predictable than in the case of liquids, even if meteorological factors do not play an important role.

The exposure from explosive air–gas mixtures is seen when comparing, for instance their calorific value with that of a well-known explosive, e.g. TNT. Some examples relating the calorific value in 1 m^3 of a gas at atmospheric pressure with that in 1 kg TNT will illustrate the risk. For each of the following gases the approximate multiple of its energy content to that of TNT is given: hydrogen 3.2, methane 10, propylene 23.7, propane 25.6, butylene 30.6, butane 33.7. This explains the fireball seen in such explosions and the fact that anybody within about half a kilometre of such an explosion is likely to die. People suffering burns will still be found at much greater distances. A volume of gas equal to the contents of an ordinary car tank is sufficient to cause such a disaster.

Exogenic factors

A distinction between correlated and unrelated occurrences has to be made as this is also of probabilistic importance. If, for instance, one is primarily interested in sizeable events to which a project on or near the sea coast is exposed, allowance may have to be made for a concurrent tsunami if such a risk exists in the region. The same is true for the aggravation of earthquake fire losses due to subsoil liquefaction affecting part of a plant. On the other hand, the simultaneous incidence of a flood and/or inundation may be orders of magnitude more remote.

Tsunamis may act thousands of miles from the event which caused them. This puts the factor high on the probability scale if there are extensive tsunami-genic regions off the coast where the project is located, so long as the site is exposed. Tsunami may also indirectly aggravate earthquake fire damage by rendering fire-fighting or rescue impossible.

Experience with liquefaction effects suggests that extensive additional damage may be caused by this phenomenon, which leads to spilling of combustible material and the extensive failure of tanks, vessels, hoppers, pipe systems, etc., with the consequent release and spreading of combustible material and the generation of new sources of ignition. Power failures do not necessarily eliminate electricity as a source of ignition. On the contrary, failures are caused by broken wires, short circuits and arcing, which may themselves generate enough heat or sparks to ignite inflammable material. Failure of telephone systems is common during earthquakes. It may increase the losses indirectly because the lapse of time before fire-fighting begins greatly influences the amount of loss to be expected and the efficiency of the fire-fighting.

One very serious problem is the probability of failure of the water supply.

Passive safety measures

The importance of in-built passive safety cannot be overestimated from the point of view of earthquake fire exposure. In essence it is a matter of reducing the probability and potential extent of fire and/or explosion by proper allowance for all the pertinent aspects in connection with buildings, civil engineering structures and mechanical, electrical and chemical equipment. It is therefore important to check very carefully all items which have to remain operational after a strong earthquake, allowing for all forces and conditions to which they could be exposed. This, however, immediately points to two main weak spots in the system.

Active safety procedures

One of the most important factors is the quality and risk-awareness of the personnel in general, from top management downwards, and especially of those who will have to deal directly with an earthquake fire or explosion. A prerequisite is a good emergency programme which will have to cover all the basic possibilities which can lead to a fire and explosion and/or which determine the course it takes.

The next question is the type and quality of the equipment available on each site. Fire-fighting technology has progressed in recent decades and further advances are likely. Two otherwise identical elements at risk may thus still have to be considered as different because the fire-fighting equipment on one site is modern and more old-fashioned on the other. Automatic fire-fighting equipment, such as sprinklers, equipment using carbon dioxide, halogenated agents, foams, fluorocarbons, surfacting film-forming proteins, etc., or equipment designed to ventilate buildings, such as electrically operated hatches or fans, is likely to fail for lack of electricity and/or water unless specially designed. Under normal conditions assistance can be expected from outside the plant; public fire brigades will be called, their time of arrival depending on distance and traffic conditions. Such help should be discounted where an earthquake has caused considerable damage in the area.

Residual human failure

The general rule that failure is quality-related is true for human beings as well. One aspect, however, must be added, namely training and familiarity with a situation. It goes without saying that personnel conversant with all fire-related aspects of a project and trained to face emergencies will be better prepared to deal with an earthquake fire than people who are not so familiar with the equipment, are not fully aware of the possible consequences of their acts and omissions and have wrongly assumed that an earthquake is impossible in the area.

VOLCANIC ERUPTION-GENERATED FIRES

Explosive volcanic eruptions have caused many casualties in the past. But since Mont Pelée on Martinique killed approximately 30 000 people in 1902 population density has increased dramatically, and also the chance of large numbers of people being affected by burns.

In general the risk of fatalities from tephra falls is small, provided houses do not collapse under the weight. Blocks and bombs as well as large lapilli can certainly cause injuries, and even death, but compared with pyroclastic flows and lahars their overall effect is not alarming. Industrial plants and other facilities, in particular those serving to distribute inflammable and/or explosive material are today ubiquituous near densely populated places. Also this calls for a systematic assessment of the exposure. As ordinary tephra fall generally does not cause burns we will deal here only with glowing avalanches.

During the eruption of Mount St. Helens in 1980, a fairly isolated area was affected which had been at least partially closed to the public. Even so, 35 persons were known to have died by April 1, 1983, and 22 were still missing. If such an event were to take place in a dense high-technology society the disastrous consequences can be readily imagined. It will be remembered that the eruption of St. Helens was not particularly large.

Casualties from burns recorded in the past are not a reliable yardstick for estimating this facet of exposure. Not only are old data often unreliable; the population of the world has about tripled since Mont Pelée wiped out 30 000 lives, and the chances of exposure have changed as well. During the eruption of Krakatau, people suffered burns at a distance of about 40 km, and large blocks of pumice burned holes in cloth about 70 to 80 km from the volcano. Quite a number of other observations indicate that high temperatures may be reached at substantial distances from the source, but observational data are inadequate to permit a reliable estimate, for each magnitude of eruption, the temperature-distance correlation for directed blasts, 'normal' base surges, glowing avalanches, pyroclastic glows or bombs.

The following formula is based on a 10-fold increase of volume ejected per VEI step (Simkin *et al.*, 1981). The formula appears to fit the few observations reasonably well.

$$r_{(km,\,VEI,\,t°C)} = (VEI^{13.6})^{1/3} \; / \; 1.94\, t^{0.67}$$

In this formula VEI is the magnitude of the eruption considered, for instance VEI 5, and t the temperature in degrees centigrade.

The temperatures reached at various distances from the vent relate to glowing avalanches. Its most important parameters are: t = f (Magnitude of the explosive eruption; Time-history of the explosive phases; Temperature of the magma; Directional parameters; Resistance to propagation of the hot cloud; Meteorological conditions).

For the sake of simplicity we will take the VEI-index as a yardstick for the magnitude (Tiedemann, 1992; Simkin *et al.*, 1981). A particular advantage of this scale is its logarithmic volume-magnitude correlation. The time-history of one or more important phases of explosive eruptions is of great importance because it very largely determines the size and distribution of individual 'parcels' of hot tephra. The temperature which may be reached at a certain place also depends on the temperature of the erupted magma. It is obviously not immaterial whether magma is ejected at 900, 1100 or 1300°C.

Under the heading of directional parameters, we understand principally a directed blast, i.e. a release of material in one predominant direction, and the influence of topographical features which may influence the further spreading of avalanches, flows or clouds of hot material. Only comparatively small flows are, however, controlled by topographic features and obstacles: large flows are not impeded by ridges or cliffs dozens of metres high and tens of kilometres from the vent.

The spreading of the hot material meets resistance predominantly from the atmosphere and from the surface over which it is travelling. The spreading velocity in turn depends on several parameters, including resistance from the roughness of the surface over which the cloud is expanding. The spreading velocity also depends on the energy stored in the individual ejected parcels, mostly represented by the mass or volume of the ejected pyroclastic material. The last parameter listed above was the meteorological conditions, in particular wind velocities at the time of the eruption. As the drag or air resistance grows with the square of the velocity, it is not at all immaterial whether tephra is injected into still air or into air moving at, for instance, 20 m/s, as during a storm, or 40–60 m/s as during a cyclone or typhoon. Assuming approximately uniform spreading of the cloud, because of the absence of directional parameters, non-uniform resistance or high winds, we may take it that a 10-fold increase of ejected volume of about identical density produces a cloud which is larger by about the cube root of 10, i.e. about twice as large. In this approximation the fact that the cloud's growth in height is affected by gravity can be neglected, as this is so for all magnitudes, i.e. for all volumes erupted. If, therefore, a temperature of 250°C can be reached 20 km from the source during a VEI 5 eruption, the same temperature could be found 40 km or 80 km from the source during VEI 6 or VEI 7 eruptions.

As regards heat damage to industrial facilities, we must not overlook petroleum refining, hydrocarbon process industries, and chemical plants, which have seen a dramatic increase in investments in recent decades. Such plants can be ignited not only by glowing avalanches but by hot 'bombs' ejected by a volcano. Fires and explosions in such plants will cause additional casualties from burns, in particular if timely evacuation is impossible.

INDUSTRIAL PLANT-GENERATED FIRES

Industrial plants and facilities are today often found near densely populated areas, particularly if we include those which transport or distribute inflammable and/or explosive material. The gas cloud explosion which killed approximately 500 people and injured many more in Mexico City a few years ago and the explosion of petrol in the sewer system of Guadalajara, Mexico, are still fresh in our memory. Therefore a systematic analysis is required to establish the exposure to burns.

In seismic regions the formula and the parameters presented earlier can be used. If the region is also exposed to volcanoes these parameters must be considered in addition. A case in point is the region of Naples, Italy, which is seismic and in addition volcanic, with a larger eruption of Vesuvius apparently overdue. In all other cases, i.e. where earthquakes and eruptions need not be considered, this formula can be simplified but the general validity of the parameters still prevails. It is therefore not necessary to discuss the essential aspects a second time. In such cases, however, technical failures and accidents caused by operators assume an important share and assessments must therefore allow for all essential details.

The parameters which are responsible for accidents and for burns can be grouped into defective design, material and workmanship which occurred in the plant of the manufacturers. Next there are defects introduced during erection and commissioning and thereafter we have to consider problems during operation which can be caused by manufacturing defects, by erection, and during operation and maintenance of the plant. A discussion of these complex aspects is beyond the scope of this chapter.

REFERENCES

Arturson, G. (1992). Analysis of severe fire disasters. In *The Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers.

Simkin, T. *et al.* (1981). *Volcanoes of the World.* Pennsylvania: Hutchinson Ross Publishing Co.

Tiedemann, H. (1992). *Earthquakes and Volcanic Eruptions: A Handbook on Risk Assessment*, Zurich: Swiss Reinsurance Co.

Section II

Fire disasters in society

9
Fire disaster management

G. ARTURSON
Burn Centre, University Hospital, Uppsala, Sweden

The frequency, and therefore the risk, of accidents fulfilling the criteria of disasters have increased significantly during the last decades, parallel to and generated by the development of communities. The reasons for this are obvious:

- increasing population density
- increased settlement of high-risk areas
- increased technological risks.

Every year about 150 disasters of different kinds occur in peace-time all over the world, each with more than 20 deaths at the scene and an immediate cost of more than US$ 8 million. One hundred (60% of the total number) of these disasters are classified as severe fires or explosions due to aeroplane accidents, hotel fires, underground disasters, industrial explosions, etc. The most severe fire disasters are those associated with liquefied petroleum gas (LPG), which is transported and stored in condensed form. If it is exposed to heat the liquid vaporizes. In a mixture with air an explosion will eventually cause a boiling liquid expanding vapour explosion (BLEVE). In the last two 15-year periods, the number of people injured in BLEVE disasters has increased from 100 to 2200 and the number of deaths from 60 to 900.

Fourteen fire disasters occurring in different parts of the world between 1973 and 1990 and causing mass burn casualties were analysed. I made personal observations at the scene of half of these disasters. Data from these disasters suggested that the outcome might be related to the presence of smoke. The material was therefore divided into two groups: disasters which occurred indoors (n=7), and those which occurred outdoors (n=7; most of these were BLEVE disasters). The total number of injured patients was more than six times higher after outdoor than indoor disasters. The total number of casualties admitted to hospital was nearly 20 times higher following outdoor disasters than indoor disasters. Fewer than 50 patients were admitted to hospitals from each indoor disaster, while the corresponding figures for outdoor disasters were

70–2000. While the immediate death rate was very high following indoor disasters compared to outdoor disasters, the hospital death rate showed the opposite pattern.

The majority of victims (60% of all admitted) sustained burns covering less than 30% of the body surface area. Following indoor disasters very few patients were admitted with extensive burns. Following outdoor fires, however, a significant number of patients with very extensive burns (covering more than 70% of the body surface area) were sent to hospitals. Few casualties of either kind of disaster (about 15% of those admitted) had burn wounds covering 30–70% of the body surface area.

Only 25% of those involved in indoor disasters survived, compared with 65% of those involved in outdoor disasters. Nearly all of the deaths occurring after indoor disasters (75%) occurred at the site. After outdoor disasters the total cumulative mortality rate was around 35%.

In the analysis of burn disasters the following four items should be stressed:

1. Prevention
2. Alarm systems
3. Organization, including: resuscitation, triage, early treatment and handling of psychological reactions and transportation
4. Education and training.

Prevention is most important but too often neglected. This is especially obvious when analysing indoor fire disasters in which very high immediate mortality rates at the site are due to the inhalation of smoke and poisonous compounds. Victims unconscious within 2–3 minutes and unable to escape; as illustrated in measurements of toxic gases following research into the Stardust Night Club disaster in Dublin. Oxygen concentration decreased and toxic gases increased to life threatening levels within 2 min. In the King's Cross underground disaster there were no alarm systems, no sprinklers, not enough escape routes and no disaster training for staff.

In the worst industrial fire disaster in the world (the San Juanico BLEVE explosions in Mexico City) there were no alarm systems, no sprinklers, illegal dwellings too close to the spot, no disaster training for staff and it occurred early on a Monday morning. A total 7000 people were injured, and a similar number of rescue workers were involved during the first 2 days. Since by definition a disaster is a situation with a relative lack of resources the goal of our disaster management requires:

- a planned and well trained model of action for the optimal utilization of available resources
- a plan for accurate and rapid reorganization and mobilization of additional resources.

A medical care system that satisfies these demands is thus necessary both on the scene of the accident and during transportation, and within the hospital.

All patients have to pass a collection area before evacuation from the scene. Leading and coordinating the work is the commander-on-scene. He is the senior officer in the rescue service and works in close collaboration with the medical officer in command, and the police officer in command. The medical officer in command is responsible for triage, checking and stabilization of vital functions, priority and destination. The police officer in command is responsible for registration of the injured and also for taking care of the dead and uninjured. In Sweden, we have found Emergency field groups very useful. With every hospital equipped and prepared with a number of such teams, it is possible in a major accident to send out a sufficient number of teams from different hospitals and also primary care stations within a short period of time.

The general principles of the medical work in the field can be summarized as follows:

1. Organized evacuation with the right priority, right destination and registration before transport via the collection area.
2. Checking and stabilization of vital functions before and during transportation.

In Sweden all hospitals dealing with acute patients have a disaster plan according to recommendations from the Swedish Board of Health and Welfare made in 1966. University hospitals in Sweden have introduced a disaster plan which is built on a three-stage procedure as follows:

1. Stage 1, 'stand-by', is used whenever the suspicion arises that the need for medical care will exceed immediately available resources. This stage has very wide indications but is very inexpensive.
2. Stage 2, 'adjusted mobilization', refers to the formation of a commanding group which starts working in close collaboration with the Commander on scene and his medical officer in command.
3. Stage 3, 'Full mobilization', indicates the need for mobilization of all available resources within emergency and operating disciplines.

SUMMARY

It is possible to be prepared for disasters, and preventive measures are possible. Such preparation requires alarm systems, organization of resuscitation, triage, and early management and transportation, and training, especially communication links. The most important principles of disaster medicine are: well-trained leadership for organization and triage, emergency helpers who can work effectively in primitive conditions, modified methods of treatment and medication, standardized and reduced to the basics, and speed and maximum achievement with a minimum of resources. Initial triage is very difficult following inhalation injuries (superheated air, toxic gases, etc.) and injury due to radiant heat. Psychological support (psychologist, psychiatrist, social workers) is always very important.

The two latest disasters in Sweden were the Scandinavian Star Ferry boat disaster, in which almost all the injured died, and an aeroplane crash in which all survived and only three were slightly injured. Disasters are unpredictable.

REFERENCE

Arturson, G. (1992). Analysis of severe fire disasters. In: *The Management of Mass Burn Casualties and Fire Disasters,* M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers.

10
University hospital fire disaster – lessons to learn

W. F. DICK
Clinic of Anaesthesiology, Johannes Gutenberg University Hospital, Mainz, Germany

INTRODUCTION

Reports on hospital fire disasters are only rarely published in medical journals, and then only in journals dealing with fire fighting or hospital management. Blumenhagen found only two English language articles published between 1977 and 1987, according to which 24 500 severe events were registered in the USA, equalling three events per institution per year. However, only 30–40% of these events were reported to the fire department. In the USA only 11% of all registered events caused damage amounting to more than US$ 1 000 000.

CHRONOLOGY OF THE EVENT (Table 1)

Outbreak of fire

On March 31, 1988 at 17:45 h, a small fire broke out in the basement of the surgical building at Mainz Hospital (Germany), a building with

Table 1. Chronology of hospital fire, 31.3.1988 (3 days before Easter)

17.45	outbreak of fire
17.51	fire alert
17.56	first fire truck arrives
18.09	evacuation I starts
19.00	evacuation I ends
	evacuation II starts
19.55	evacuation II ends
21.30	fire under control
1.4.1988	
3.05	fire out
2.4.1988	start of cleaning and recovery

Figure 1.

eight floors containing patient wards and an annex with two or three floors housing intensive care units, operating theatres, as well as the radiology and anaesthesia departments (Figure 1). EMTs transporting a patient through this area discovered the fire and tried to extinguish it using fire extinguishers. This, however, was unsuccessful; a fire alarm was immediately activated by a passing physician.

Fire fighting

The first fire truck and the fire command officer arrived at the scene 5 minutes later. They were informed by the personnel on duty in the ICU (1st floor) that there was no possibility of escape through the other parts of the building. The fire fighters thus had to deal with three major aspects:

- recovery of the intensive care patients and the respective personnel
- fire fighting
- inspection of all parts of the building.

Clearing of the building

Starting at 18:05, all patients and the entire hospital staff were evacuated from the smoke-filled ICUs and operating theatres. For this purpose some patients were placed on stretchers which were attached to the ladders of the fire fighters and evacuated from the buildings through the windows. The fire fighters themselves had to use respiratory assist equipment, while the personnel were protected by smoke hoods. Only 50 minutes after the outbreak of the fire, the ICUs and the operating theatres, where operations had been completed under emergency conditions, were evacuated.

The fire was still burning, and the possibility of it spreading to the patient ward building could not be excluded (Figure 2). Immediately after the ICUs and operating theatres had been evacuated, all patients were transferred from the wards via the staircases into the entrance hall. The whole building was cleared with the help of physicians, nurses and medical technicians as well as that of additional personnel provided by the rescue organizations, the police and the armed forces. At the beginning of the event 377 patients were in the building. Of these, 159 scheduled for discharge on the following day were immediately discharged, as were patients admitted on that day for an elective procedure.

Of the remaining 218 patients 207 were transferred to other buildings within the university hospital complex; 37 of these were intensive care patients, who were transferred to ICUs in other departments. Only 11 patients had to be transferred to other hospitals (Table 2).

At 19:25 the fire had spread to the main patient building, although it was brought under control shortly thereafter; nevertheless, the fire squads of Wiesbaden, Rüsselsheim and Frankfurt/M. airport were also called in. Within 55 minutes the whole building had been cleared in the absence of panic or other undesirable reactions. At 19:30 the fire fighters

Figure 2.

Table 2. Evacuation

Total no. of patients present on 31.3.88	377
Immediately discharged	159
Transferred within hospital facilities	207
regular patients	170
ICU patients	37
Transferred to other hospitals	11

had most of the fire under control and two hours later, at 21:30, the fire was under complete control, to be extinguished at 3:05 the next morning.

Fire fighting

For fire fighting the following resources were used (Table 3): 337 fire fighters, 60 trucks, 450 respiratory assist devices, 20 buses for evacuation purposes and 40 drivers, 200 hospital staff members (physicians, nurses, technicians, etc.) and approximately 100 rescue personnel with 30 ambulances.

Table 3. Resources

Fire fighters	337
Fire trucks and vehicles	60
Respiratory assist devices	300
Respiratory protect devices	150
Escape hoods	80
Bus drivers	40
Buses	20
Hospital personnel	200
EMSS personnel	100
Vehicles	30

DAMAGE AND LOSSES

At the end of the fire fighting and evacuation operations it was established that none of the patients was impaired or injured and seven fire fighters were slightly injured. After complete extinction of the fire, the total loss was estimated at approximately 50 million DM. This consisted of 650 000 DM for fire fighting and evacuation, 16.5 million for medical equipment, 1.6 million for transferring patients, 300 000 for damage to the facilities, 3.7 million for drugs, one-way materials, etc., 450 000 for damage to personal belongings, 7 million for income losses, and the remainder for damage to the entire building (Table 4).

Almost all facilities within the affected part of the building were contaminated by chlorine hydrogen mixtures leaking from electrical leads. This material had to be replaced, representing a further cost factor.

Table 4. Total losses (DM)

Fire fighting	650 000
Medical equipment	11 000 000
Cleaning and restoration of medical equipment	5 500 000
Transfer of equipment	1 600 000
Damage to rooms	300 000
Damage to disposable material and drugs	3 700 000
Loss of private property	450 000
Income losses	9 700 0000
Total losses	33 000 000 (US$22 000 000)

MANAGEMENT

Positive aspects (Table 5)

A number of circumstances contributed to the overall fortunate outcome:

1. Early discovery of the fire.
2. The rapid response of the fire department.
3. Due to a forthcoming holiday and the time of the fire alert (approx. 17:50 h), which coincided with a change in shifts, twice as many staff members were available as during a regular shift.
4. A fire alert was given via radio and television in order to call hospital personnel back on duty in the surgical building; many physicians, nurses, and technicians immediately reported to the hospital.
5. The ideal cooperation between nurses, physicians and other hospital personnel on the ICUs as well as between fire fighters and rescue personnel respectively, meant that all patients could be evacuated either through the windows or via the remaining wards and staircases.
6. After approximately 1 hour the following command institutions had been established:
   a) the technical command reporting to the fire department
   b) the clinical command reporting to the medical director, the administrative director and the head nurse. These were initially located in a rapidly installed container and later in a separate building; various telephone numbers were immediately put into operation.

Table 5. Management: Positive criticism

Early discovery
Short response interval
Two shifts available
Immediate attendance of personnel
Perfect cooperation
Early establishment of command

Negative aspects and points of criticism (Table 6)

Fire prevention measures were only superficially observed. The condition of the building itself, after 20 years of operation, was such that the spread of the fire was unchecked by safety devices. The existing safety devices were insufficient in quantity and quality. This was later pointed out by the fire department.

Table 6. Management: Negative criticism

Preventive measures neglected
Condition of the building outdated
Fire alert plan outdated
Traffic congestion
Overly aggressive media response
Identification problems
Inadequate coordination of patient transport
Access to the hospital open to unauthorized persons

A lack of adequate storage facilities meant that protective measures could not be carried out as required; empty beds and beds occupied by patients as well as medical equipment had to be kept on the floors.

The alarm alert plan of the hospital was completely out of order, most telephone numbers were no longer in operation.

Major confusion occurred outside the university hospital facilities themselves, due to the fact that, in addition to the fire fighters, several rescue vehicles tried to reach the hospital without having been alerted by the disaster command. This resulted in severe traffic jams in the area, as well as on the hospital premises where ambulances with patients on board could not get through to other buildings in the hospital area. This was, however, overcome within a short while due to efficient measures taken by physicians and nurses.

Representatives of the press, radio and television stations demanded continuous detailed information, which added to the confusion. A special media information centre was later established in one of the administration buildings.

In contrast to the fire fighting command, the clinical command could not easily be identified due to lack of the necessary identification materials. Additional problems were created by the fact that ambulances transported patients to other parts of the hospital without informing the clinical command of their operations. During the night the rescue organization and the clinical command cooperated in establishing a record of the patients transported to the different facilities by the various organizations.

Closure of the hospital grounds to unauthorized persons was possible only to a certain extent and resulted in large numbers of spectators entering the hospital area.

IMMEDIATE CONSEQUENCES

Immediately following the event, emergency patient care was severely impaired in the entire region. Two other community hospitals were required to provide emergency services, since the university hospital departments of general surgery, paediatric surgery, cardiac surgery, trauma surgery, neuro-surgery, neurology, and anaesthesiology were unable to admit patients.

Close cooperation between the university hospital and neighbouring hospitals allowed limited patient care by the operative disciplines. The operating procedures were extended to neighbouring hospitals by transferring university hospital personnel to these hospitals.

INTERMEDIATE CONSEQUENCES

Only 3 months after the fire the patient building and a limited area of the other facilities were reopened. This was made possible by

- installation of a fire alert system
- installation of fire prevention devices
- erection of rescue towers at the front and the back of the patient building, because the fire fighters had been unable to reach the 6–8th floors using their regular ladders (Figure 3)
- transfer of operating suites of the trauma and cardiac surgery departments to containers which were set up within 3 months and contained operating facilities, recovery areas, etc. (Figure 4)

Figure 3.

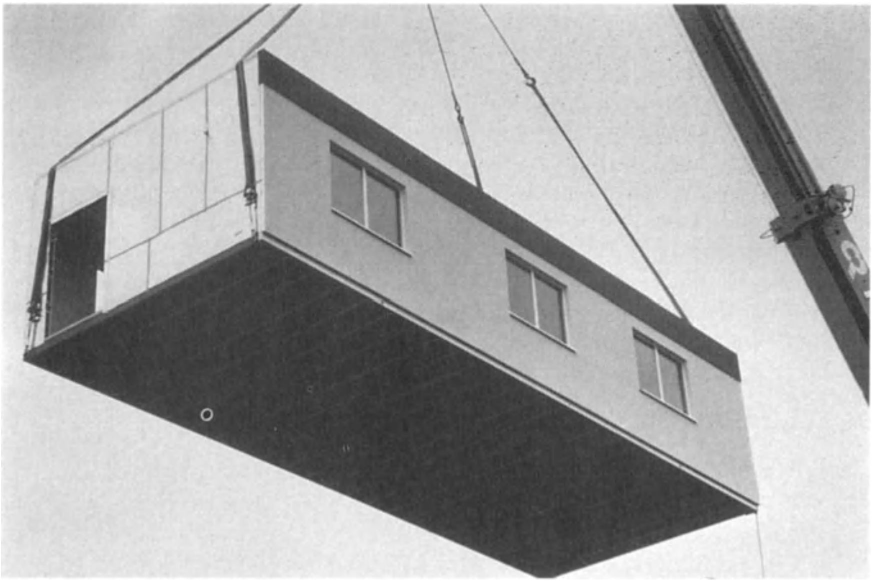


Figure 4.

LONGTERM CONSEQUENCES

By August 1, 1992, i.e. after 4 years, almost all of the facilities damaged by the fire had been completely rebuilt and are now in operation. Nevertheless, renovation of the total building will not be complete until 1995. For the interim (3.5 years) several specialties have to remain in other buildings and improvisation of others is required at additional costs.

LESSONS TO BE LEARNED

Although this event was not a disaster from a medical point of view (no one was severely physically injured), it certainly was one as far as finances are concerned. In addition to the immediate loss of 50 million DM, further income losses, additional provisional measures, deferred patient care and reconstruction costs add up to at least 200 million DM. This means that hospitals should be reinsured to cover the risks described, even if similar disasters occur only rarely.

A hospital alert alarm plan needs to be established, regularly tested and updated every 6 months. The most important information should be summarized on the first three pages. Fire precautions have to be carefully observed, and regular inspections are mandatory. Insufficiencies must be corrected immediately, even if patient care is affected. Fire protection installations need to be regularly checked and maintained.

As new hospitals are constructed or older ones are renovated, care must be taken to provide sufficient space for storage of materials and equipment: nothing should be stored on the ward floors.

All personnel responsible for disaster management must be identifiable, particularly those in command. They have to carry radio communication devices, in order to be mobile and independent of other communication systems. All rescue vehicles should respond only to the medical officer in command. Hospital traffic wardens must be present on the hospital premises, and police officers outside the hospital to direct traffic.

An information centre must be established as soon as possible for relatives and the media. This centre should be at a considerable distance from the disaster area.

A patient transfer centre needs to be rapidly established where all patient movements and operations reported by different rescue organizations can be recorded.

The hospital grounds must be closed by police officers to all vehicles and persons not involved in the disaster relief plan.

11
Organization of emergency rescue

A. FLAUJAT and P. MAILLE
AMELISAP, France

EMERGENCY

For the physician 'emergency' means any disease or lesion that endangers life in the short-term or that may have severely invalidating sequelae. The definition of 'emergency' is made by an expert and requires an initial technical assessment, the rapid employment of resuscitatory procedures and, in nearly all cases, admission to hospital.

To the general public, emergency simply means rapid recourse to assistance and care by an external agency, essentially to resolve a situation that victims cannot manage by themselves, with a response that is as rapid as possible; this does not necessarily mean distress of a medical nature, and even if it does, it may not necessarily require the use of resuscitation ambulances and specialized medical staff.

For the medical profession, response to an emergency requires means of transport and resuscitation together with qualified personnel that come to the victim's aid as soon as possible; however, only a physician or somebody with sufficient medical training is capable of determining whether or not it is an emergency in the medical meaning of the term.

For the general public, response means above all the arrival of an external agency that may or may not be qualified, and that may arrive by chance or in the framework of a rescue organization, and whose role is either to directly resolve the situation that has led to the call for aid or to make an appeal for better qualified personnel or more efficient material means.

The common factor in both these interpretations of the emergency concept is the notion of speed of response. This response may be either individual (family, neighbours or local health professionals such as nurses, paramedics, pharmacists, physicians and volunteers trained in rescue work and first aid) or collective (local health and social services, and charity, health or first-aid organizations). Such immediately available responses may prove to be materially or technically inadequate as soon as we enter the domain of medical emergency in the strict sense, when victims need the assistance of proper rescue services.

Formerly the notion of emergency medical assistance simply meant transport of the victim as rapidly as possible to the care of trained professionals, usually in the nearest hospital or clinic.

The teaching of the armed forces medical services during the Second World War and the Korean war has led many practitioners to study the mortality and morbidity associated with this kind of transport. On the basis of this military experience, emergency medical rescue now prefers to bring health professionals to the bedside of the victims and to prepare patients for transport which will be undertaken under medical surveillance, i.e. medical preparation and transport.

In order to apply these principles it is necessary to have an alarm response centre to receive the distress calls and relay them to the rescue teams. It must therefore have telephone lines with easily memorized numbers, personnel responsible for receiving calls, and means for relaying the calls to the rescue teams. It must also have rescue teams with transport vehicles equipped with advanced resuscitation technology and qualified personnel able to assess the situation and to begin to treat victims. All this must be available 24 hours a day throughout the year and also be in a position to respond in all areas within a reasonable time.

This emergency rescue basic unit can have very different origins. It may be part of a public service (hospital units such as SAMU – Mobile Emergency Medical Service – and SMUR – Medical Resuscitation Emergency Service, fire brigade, police), profit-making private organizations (ambulance services or associations, associations of paramedics or qualified physicians) or non-profit-making non-governmental, charity or social organizations (Red Cross, Order of Malta, Friendly Societies). Different systems based on this scheme exist or have existed throughout the world. They pose two immediate problems:

- What qualifications and training are required by persons who receive emergency calls?
- What qualifications and training are required by persons who actually intervene at the site of the accident?

The emergency call may be received by administrative personnel (secretary, hospital clerk, fire brigade/police/gendarme/office employee) or by medical or paramedical personnel (physician, nurse). Administrative personnel present the advantage of being inexpensive in terms of salary and training and of being meticulous in the taking of bureaucratic information (marital status, exact locality where aid is required, social security cover). The disadvantage of administrative personnel is that it is extremely difficult for them to assess the urgency of emergency calls and to decide on the correct emergency response.

To be reliable and effective the response must be absolutely clear, and in every case a standard rescue vehicle equipped for every type of emergency situation must be used.

Medical personnel present the advantage of being able to make a more precise assessment of the necessary rescue means, the possible evolution of the emergency and therefore the back-up forces that may prove necessary, and the places and hospital facilities where victims can be evacuated for treatment.

The disadvantages of using medical personnel are their expense in terms of salary and training, and the difficulty for the organization of finding staff in sufficient number.

As far as rescue intervention is concerned, besides the medical vehicles and materials required, there is also the question of the qualifications of the rescue team. This may contain:

1. Paramedics, with training approaching that of a nurse, applying predetermined conditioning protocols for the casualties, intended to preserve or maintain vital functions. All sorts of possibilities exist, from the experienced rescue operator accustomed to putting his expertise to good use to the anaesthetist nurse. The rescue workers, on the basis of their training, will decide whether or not to use emergency drugs.
2. Physicians, if possible with specific qualifications in emergency medicine, who can make diagnoses, initiate treatment at the patient's bedside, establish the exact extent and gravity of the lesions, request the sending of necessary material and staff, and predict the type of resuscitation or specialized care the patient may need.

Any emergency organization, whatever its structure and back-up support, may find itself overwhelmed by an influx of appeals for help, the number of victims at the disaster site, or the need for specific care or resuscitation services, and it may indeed be unable to cope with everything. This may be a rare occurrence, but it is not infrequent that the sheer force of numbers becomes a real problem, with the arrival of rescue forces and possible conflicts between different organizations, not to mention the different levels of qualification of the various operators present at the disaster site. For this reason it is necessary that rescue operations should be carefully organized.

ORGANIZATION OF RESCUE OPERATIONS

The organization of rescue operations to coordinate the response of the various units involved in emergency aid has become a matter of politics. The service should aim to provide the best service possible to users, who often lose all sense of personal initiative after a disaster: mobile populations tend to lose all contact with medical agencies and are thus all the more disoriented and helpless.

The organization must therefore take into account the different types of emergency aid available and establish a rescue call reception centre, which analyses the calls and sets into motion the most appropriate rescue operation nearest the disaster area. It must also follow and predict the evolution of the response: the need for possible reinforcements at the disaster site, need for multiple and other forms of transport, admission to specialized hospital facilities.

In France, an organization known as 'Centre 15' has been established. The area covered by a Centre 15 generally corresponds to a French *département*, with a population ranging from 400 000 to several million inhabitants. A Centre 15 comprises an administrative control and management structure in which all involved parties are represented, under the presidency of the Prefect (Tables 1 and 2; Figure 1); this structure is the Departmental Committee of Urgent Medical Aid and Health Transport, which groups together the various emergency rescue operators: local representatives of the Ministries concerned, representatives of territorial collectivities, representatives of health insurance funds, and representatives of the medical professions (physicians, private clinics, ambulance personnel, non-governmental organizations).

This Committee is responsible for setting up Centre 15; compiling registers listing public and private hospital facilities capable of accepting emergency cases, means of medical transport available and physicians willing to respond to emergency calls; monitoring the quality of the distribution of emergency aid and its suitability for actual needs; guar-

Table 1. Structure of the Departmental Committee of Emergency Medical Aid

President: The Prefect
Representing the State
Ministry of the Interior
Departmental Director of Fire and Rescue Services
Chief Physician of Departmental Fire and Rescue Services
Chief of the most important Fire Brigade in the Department
Ministry of Health
Departmental Director of Health and Social Affairs
Medical Health Inspector
Emergency Medical Aid Service (SAMU) physician (appointed by Prefect)
Medical Resuscitation Emergency Service (SMUR) physician (appointed by Prefect)
Director of Hospital provided with SMUR
Hospital personnel trade union representative
Representing the Territorial Collectivities
Two representatives of the Regional Council
Two representatives of the Municipalities
Representing the Health Insurance Funds
Social Security representative
Agricultural Mutual Insurance Fund representative
Artisans and Tradesmen Insurance Fund representative
Representing the Liberal Professions
Two representatives of the National Physicians Union
Two representatives of the Departmental Associations of Emergency Medical Aid
One representative of the Order of Physicians
Two representatives of the private hospitals
Four representatives of the National Ambulance Personnel Associations
One representative of the Departmental Ambulance Personnel Organizations
One representative of the Red Cross Departmental Council

Table 2. Role of the Departmental Committee of Emergency Medical Aid

To facilitate the creation of Centre 15.
To compile a list of public and private hospital structures.
To compile a list of medical transport vehicles.
To compile a list of medical practitioners willing to lend their assistance.
To monitor the quality of the distribution of Emergency Medical Aid and its appropriacy to needs.
To guarantee the cooperation of persons and agencies involved in Emergency Medical Aid.
To honour annual working budgets.
To inform the general public about the Centre 15 service and how to contact it.

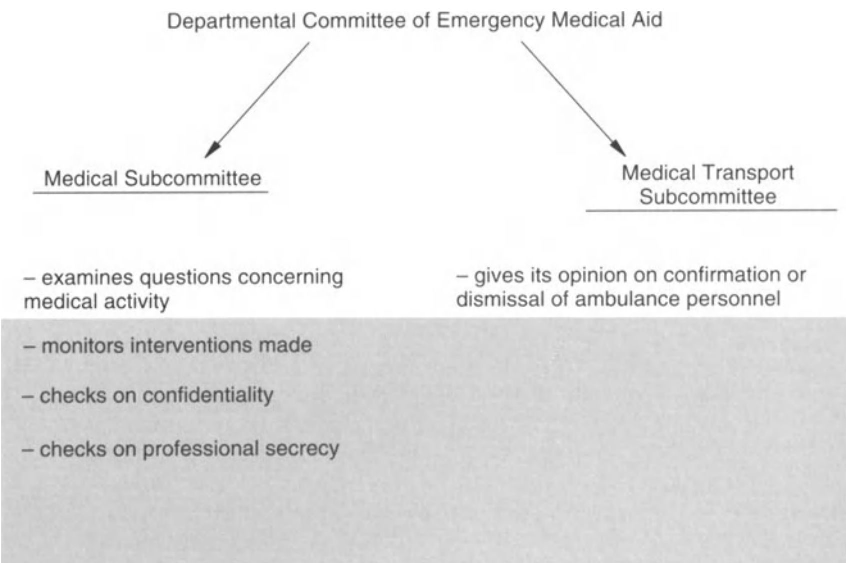


Figure 1. Departmental Committee of Emergency Medical Aid

anteeing the cooperation of persons and agencies involved in emergency medical aid; taking into account annual working budgets fixed by health administration authorities; and informing the general public about ways and means of sending appeals to Centre 15.

The Committee is divided into two technical subcommittees:

1. A medical subcommittee grouping together all physicians belonging to the Departmental committee. Their task is to examine all questions concerning the medical activity of Centre 15 and to check on interventions carried out and respect for medical confidentiality and professional discretion.
2. A medical transport subcommittee which groups together representatives of casualty transport organizations. The task of this

committee is to check on the condition of medical transport vehicles and to confirm or reject ambulance personnel.

We may thus define Centre 15 as an organization that assesses the extent of a disaster and distributes the means of intervention according to their origin (public or private), training (paramedics, physicians, anaesthetists, resuscitators) and the means used (general practitioner or paramedic in own vehicle, ordinary ambulances, resuscitation ambulances, air transport).

Centre 15 possesses its own emergency appeal reception and processing centre. Calls for help may come either directly from members of the public, dialling the telephone number 15 (the call is free of charge from a public phone box and is given priority treatment on the telephone network), or from medical professionals.

The calls are received by experienced administrative personnel, who obtain as much information as possible about geographical location, administrative matters, and the caller's number in case communications are cut off so that he or she can be traced. If medical problems are involved a specialist physician (the processing physician) also follows the call, intervening as necessary (Figure 2).

This physician, on the basis of a simple telephone call, must assess the gravity of the situation, predict the type and quality of rescue workers necessary, and set rescue operations into action. He must follow the response by radio and, on the basis of reports sent by physicians on the spot, plan the evacuation of victims and their admission to specialized services. He will be assisted in his task by computer listings of all available means of intervention, evacuation and hospital admission.

Centre 15 must therefore have more than adequate means of communication – an efficient telephone service to receive calls and a radiotelephone service to maintain contact with the rescue workers.

In France we have two other distress call reception services with two-digit telephone numbers:

- CODIS, for the Fire Brigade: telephone number 18.
- the call reception centre of public order services: telephone number 17.

Current legislation provides for interconnection of these distress call reception centres, and for the transfer of every medical-type appeal to the processing physician.

It might have been possible – as has been proposed within the European Community for the telephone number 112 – to have such calls received by the police. However, possibly because of our Latin temperament or because of historical precedent, we physicians maintain a certain distrust of police services and are of the opinion that the dialogue between physician and patient may touch on facts and information that do not concern the police. This notion of medical secrecy, which is recognized by French law, is the pledge of confidence which the patient gives us.

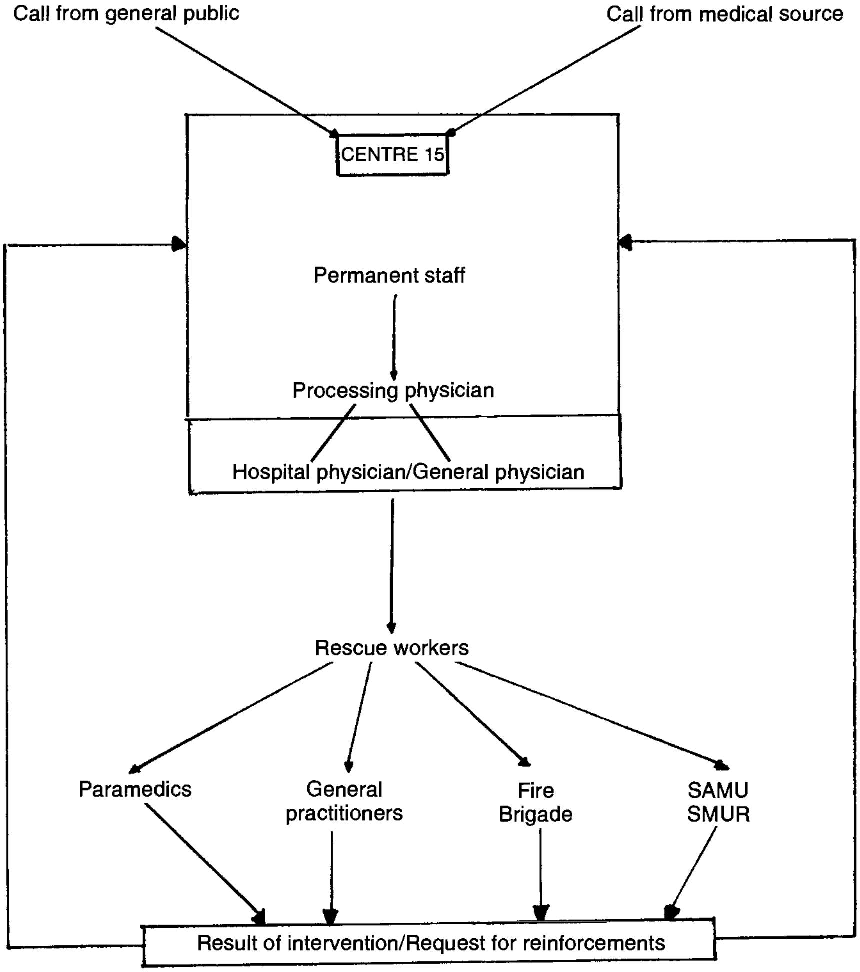


Figure 2. Flow chart of response

12
The main tasks in offering medical aid to a burned patient in the pre-hospital stage

I. E. KOROL
Kherson Regional Hospital, Burns Department, Ukraine

The prognosis for a burns patient greatly depends on the rapidity with which initial medical aid can be offered and the time elapsing before presentation to hospital. The delay in bringing a severely burned patient from a remote district to a regional hospital should not exceed 90 min; within a city, it should be < 30 min. Of the patients seen at our regional burn unit, 38.5% are brought by ambulance, 11% come on their own, 30.9% arrive from district hospitals and 19.6% are transferred from polyclinics.

The following treatment is necessary in the period before arrival at hospital:

- rapid removal of the thermal agent causing the burn;
- removal of any residual effect of the thermal agent on deeper tissues by cooling with water or detergents such as chloether, which also reduces the pain;
- administration of tranquillizers and analgesics to eliminate the central reaction to pain and stress;
- reduction of peripheral pain, which leads to the release of kinases and histamine which can damage the microcirculation. Avoidance of such pathology is of importance not only in the burnt area but also at distant sites.

Endogenous factors released as a result of the stress response reduce the body's non-specific defence mechanisms and delay the migration of leukocytes into the burnt area. This subsequently affects the formation of a protective wall around the lesion, and decreases phagocytosis and other indices of antibacterial activity exerted by neutrophils around the burn and in uninjured areas. It also promotes the development of secondary immunodeficiency: absolute and relative decreases in leukocytes, T cells, IgG and IgA are seen, together with a rise in IgM.

In the last 4 years we have used topical applications of Dnieper, a carbon fibre material based on activated carbon, in the early treatment of burns in the stage of acute inflammation. This material lowers the toxicity of neutral and acidic proteases and allows the gradual accumulation of serum inhibitors in the burn area, increasing non-specific resistance to infection and preventing the development of suppurative infections. It also reduces the incidence of generalized sepsis, lowers interstitial and intracellular oedema, improves local microcirculation and enhances epithelialization of second- and third-degree burns.

In our experience burn patients can be transported to a specialist centre without the need for intravenous antishock therapy if the distance is not more than 40–50 km and the time between injury and admission is no longer than 2 h. If longer periods have elapsed since the injury patients should be transported no more than 20 km. Treatment at district hospitals aims at rapid restoration of circulating blood volume and improvement of microcirculation. The patient is then moved to a specialist unit in a regional hospital 1–2 days later. This system of treatment has reduced the mortality of burn patients to 2.0–2.1%.

13
The role of a tissue bank in disaster planning

PAVEL MĚŘIČKA, LEO KLEIN*, JINDŘICH PREIS and EVA ETTLEROVÁ†**
*Tissue Bank, *Department of Surgery, and **Department of Pediatric Surgery, Teaching Hospital Hradec Králové; †Computer Centre, Medical School, Charles University Hradec Králové, Czech and Slovak Federal Republic*

INTRODUCTION

A well-organized and well-equipped tissue bank can help substantially in the management of disasters. Bone grafts and soft connective tissue grafts, such as dura mater, fascia lata or pericardium, can be used in the treatment of mechanical injuries. Temporary or permanent skin cover is essential in the treatment of burns. The transplantation of preserved autologous bone marrow or progenitor cells collected from peripheral blood can be used in the event of a nuclear plant disaster. The following tasks have to be fulfilled in the preparation of the tissue bank to take part in the disaster management.

1. Establishment of sufficient technological background for the long-term storage of cells and tissues as a stock to be used in the event of a disaster.
2. Elaboration of the methodology for estimating the necessary stock level or graft demand.
3. Solving the logistical problems of sending tissue grafts to the surgical departments involved in disaster management.
4. Organization of a national and international network for graft exchange able to support the local tissue bank after the disaster.

An approach to these problems is demonstrated in the example of the Hradec Králové Tissue Bank and in the authors' own experience of the train–gas pipeline disaster in Bashkiria in June, 1989.

The Tissue Bank of the Hradec Králové Teaching Hospital is a multi-tissue-oriented centre established 40 years ago by Dr R. Klen (Klen, 1952). The bank is equipped for the long term storage of temporary skin covers by deep freezing, cryopreservation and freeze-drying (Klen, 1990; Měřička, 1982; Měřička *et al.*, 1987). Cryopreserved tissue can be stored in mechanical freezers at temperature of –80°C for several months or in liquid nitrogen for several years. The tissue bank prepares routinely allogeneic split-skin grafts (Měřička *et al.*, 1987), allogeneic chorion amniotic grafts (Klen, 1990) and porcine split-skin grafts (Klein *et al.*, 1990; Měřička *et al.*, 1987).

With the financial support of the Ministry of Health of the Czech Republic a programme of epidermal keratinocyte culture as a permanent cover in extensive burns is now being undertaken (Grant No. 1184–2, Internal Grant Agency of the Ministry of Health of the Czech Republic).

CALCULATION OF GRAFT DEMAND AND GRAFT STOCK LEVEL

We calculated graft demand with respect to burn classification in porcine grafts prepared according to the method of Moserová (1980), which were used routinely by collaborating departments (Figure 1). The details of clinical application are described in Klein and Měřička (in press). The study was carried out on 134 adult and child patients treated between 1986 and 1990. The graft demand per 10 patients with confidence and tolerance intervals is demonstrated in Figures 2–5.

Figure 1. Processing of a porcine dermoepidermal graft in the Tissue Bank of the Hradec Králové Teaching Hospital

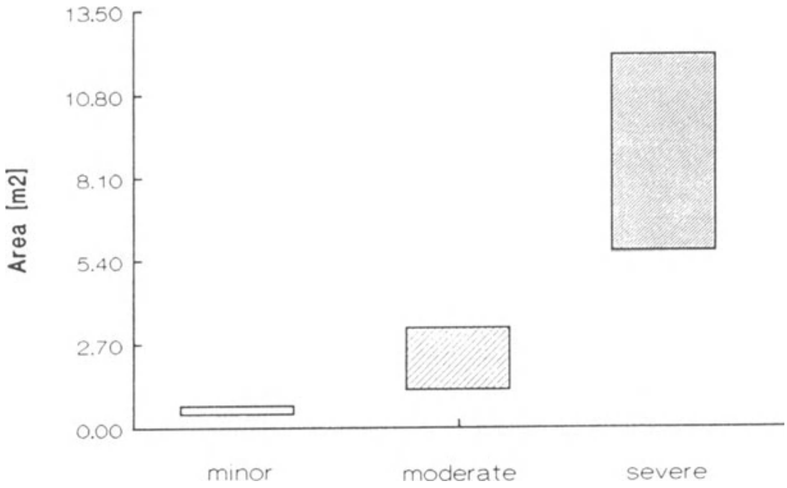


Figure 2. Estimated graft demand per 10 adult patients. Cases of burns classified as minor, moderate and severe. Confidence intervals for $p = 0.95$

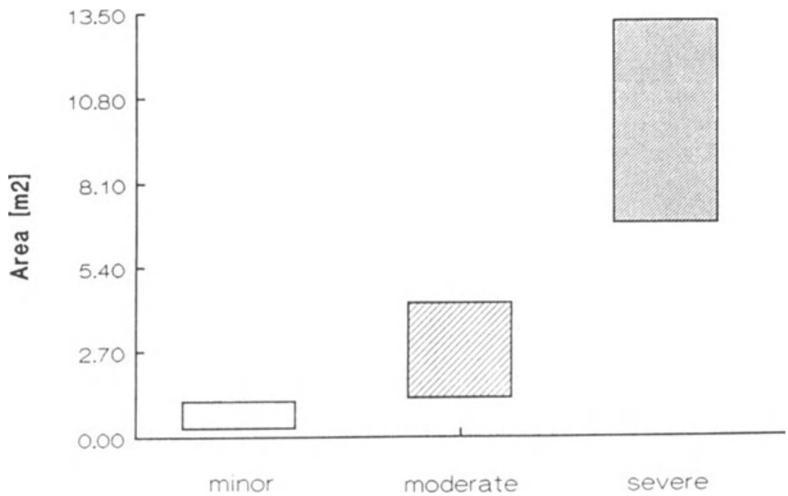


Figure 3. Estimated graft demand per 10 adult patients. Cases of burns classified as minor, moderate and severe. Tolerance intervals for $p = 0.95$. The values of the demand are similar to that in Figure 2, but the tolerance interval has a better prognostic significance

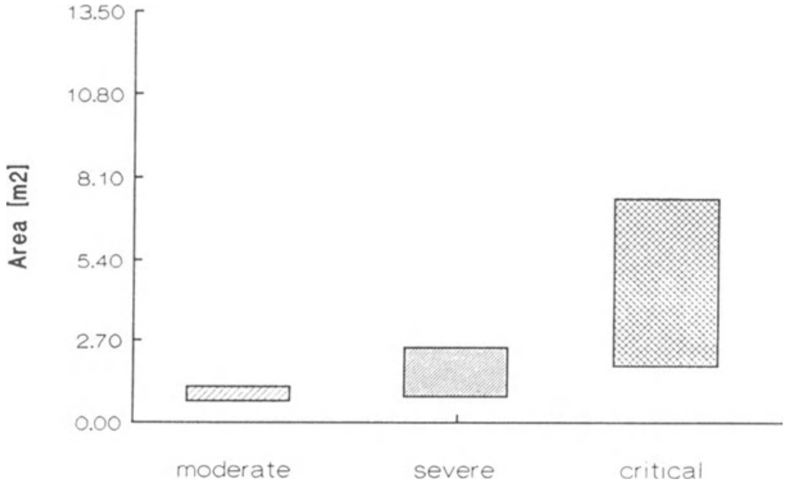


Figure 4. Estimated graft demand per 10 burned children. Cases of burns classified as moderate, severe and critical. Confidence intervals for $p = 0.95$

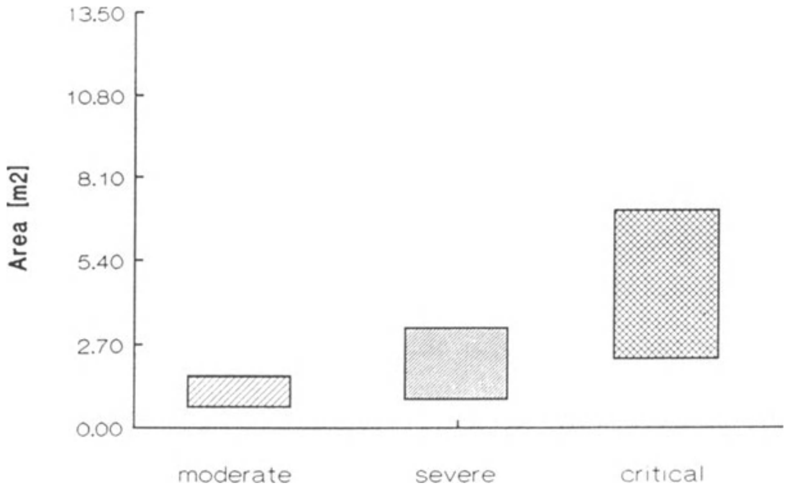


Figure 5. Estimated graft demand per 10 burned children. Cases of burns classified as moderate, severe and critical. Tolerance intervals for $p = 0.95$. The values of the demand are similar to that in Figure 4, but the tolerance interval has a better prognostic significance

An estimation of the necessary stock level is possible by applying the theory of current and security stock used in pharmacy (Šimečkova, 1983).

Current stock can be calculated from the equation:

$$C_s = C \cdot \frac{t}{T} \tag{1}$$

where C = number of days in the delivery cycle, t = turnover in the observed period and T = number of days in the observed period.

Security stock can be calculated from the equation:

$$S_s = K \cdot \langle s \rangle \tag{2}$$

where <s> is the standard deviation of the demand.
For the deficit probability of 0.001, $K = 3$.

The normal stock can be calculated from the equation:

$$N_s = \frac{S_{min} + S_{max}}{2} \tag{3}$$

where S_{min} = minimal stock and S_{max} = maximal stock.

Calculation of the parameters in current practice was demonstrated through the example of the 2nd Department of Surgery and Department of Pediatric Surgery, Hradec Králové Teaching Hospital in 1988. A total of 17.6 m^2 of grafts was used in 35 patients (nine adults, 26 children). The highest demand was in September, when eight patients were treated simultaneously, and the lowest was in January when no patients were treated. The average monthly demand was 1.47 m^2 with a standard deviation of 1.00 m^2. As the graft stock was re-established at regular one-week intervals the theoretical current stock was calculated as an average weekly demand, i.e. 0.36 m^2. The security stock, which should balance the demand fluctuations due to irregular incidence of burned patients, was 3 m^2, and the normal stock 3.18 m^2 (Figure 6).

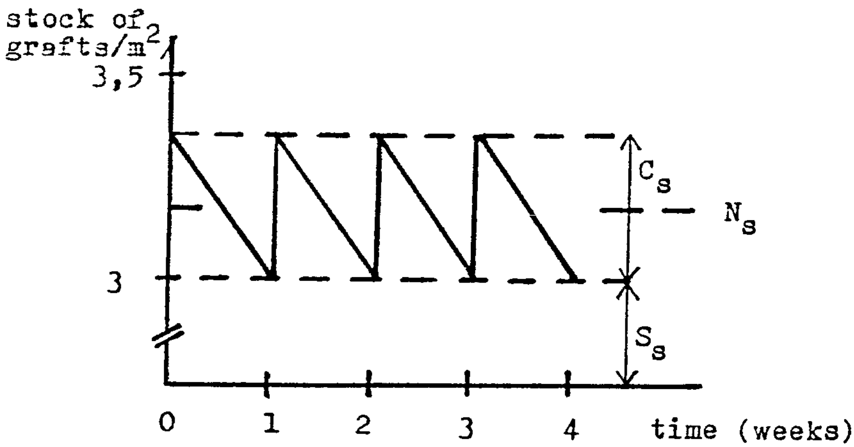


Figure 6. Estimation of the graft stock level sufficient for adequate supply to collaborating surgical departments. C_s, current stock; S_s, security stock, N_s, normal stock

The security and the normal stock are of great importance in disaster planning. It is obvious, however, from comparison of the data relating to graft demand per 10 patients (Figures 2–5) and the security stock calculated from the current practice of our tissue bank that it would be insufficient in the event of a disaster. Establishing a stock of several tens of m^2 of skin grafts excluded from normal graft turnover would require special financial support.

It is much more cost-effective if the Tissue Bank is able to rapidly increase the amount of grafts prepared and to re-establish the stock. For this reason a special set of sterile instruments and material prepared for emergency use at any time is at the disposal of the Hradec Králové Tissue Bank.

LOGISTIC PROBLEMS AND COOPERATION OF TISSUE BANKS

The shipment of freeze-dried tissue grafts does not represent a great technical problem. They can be sent to remote places and stored at ambient temperatures for a long time. Skin stored in a moist chamber can be sent in conventional ice boxes used for transport of transplant organs. The most difficult technical problem is the shipment of viable cryopreserved skin in dry ice or in liquid nitrogen – coolants that may not be available at the place of the disaster.

Our opinion is that the shipment of viable skin grafts to remote places of disaster cannot be effective if no information relating to whether specialists of relief teams are familiar with the proper care of the material and/or with its use is available.

It may be effective, however, if the grafts are sent upon request of the disaster relief team and if proper care of the material is assured until it reaches the relief team specialists.

For this reason we discouraged the spontaneous activity of citizens of the town of Hradec Králové who offered their own skin as donors at the time of the disaster in Bashkiria in June 1989 (gas explosion on 4 June at 0.15 a.m., local time, Figure 7). The data on management of this disaster were published recently by a group of Russian and American specialists (Kulyapin *et al.*, 1990).

The author of this paper preferred to move to Ufa and to help his colleagues from the Ufa Laboratory of Transplant Production (Alloplant Company) to prepare grafts. He arrived in Ufa by air via Moscow on 11 June at 3 a.m. and stayed there until 22 June. He introduced the Moserová method of pigskin harvesting, using his own set of instruments and material (Figures 8, 9). He was also involved in preparing pigskin according to the method of the Ufa Laboratory (chemically treated and radiation sterilized dermo-epidermal graft). These grafts were used in the surgical departments involved in management of the disaster.

This contact was only possible due to previous efforts to establish close cooperation among the tissue banks of Eastern and Central Europe

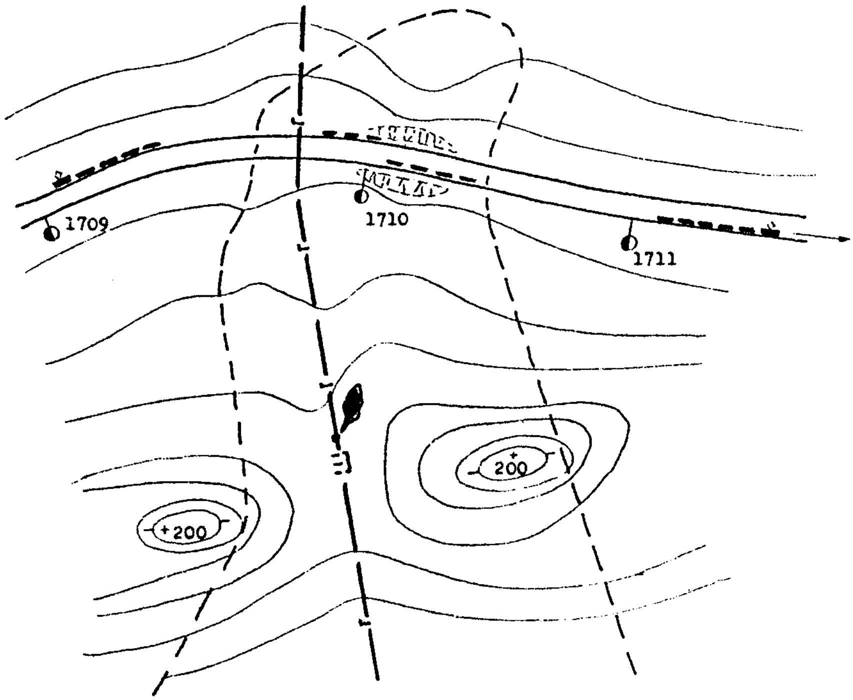


Figure 7. The Bashkiria train-gas pipeline disaster. Plan of accident site (from the *journal Argumenty i fakty*).

and to the resulting personal contacts with the specialists from Ufa. Figure 10 shows the participants of the meeting of tissue bank specialists organized by the Hradec Králové Tissue Bank in October 1988. Sitting on the left is Dr. T. Mavliutov, the surgeon from the Ufa Burn Centre who cooperated with the American relief team that landed in Ufa with a specially equipped aircraft.

Our common experience of supplying only two centres involved in the management of the disaster (Ufa Burn Centre and the Pediatric Hospital of the Republic of Bashkiria) showed that one tissue bank alone was not able to fulfil the demand for grafts and that support at national and international levels was necessary. Various kinds of synthetic and biological materials were applied, including the Czechoslovak freeze-dried porcine skin Suiderm (Bioveta Terezín).

The future cooperation of tissue banks should result in a network of banks using standardized methods of tissue preservation approved by the European Association of Tissue Banks. Such a network would be able to provide early and adequate support for the local tissue bank in any exceptional situation. The European Association of Tissue Banks (EATB)* is a new organization uniting the Tissue Banks of the European Community with those of the states of Central and Eastern Europe.

Figure 8. Instruction in harvesting of porcine dermoepidermal grafts in the Ufa Laboratory of Transplant Production. Dr A. S. Guryianov, assisted by nurse G. Antipina, is trying to collect a dermoepidermal graft with a Humby knife blade. The author is in the front

Figure 9. Harvesting of a porcine dermoepidermal graft by the author. The grafts were used in the Pediatric Hospital of the Republic of Bashkiria

Figure 10. Participants of the conference of tissue bank specialists held in Hradec Králové in October 1988. Second from left: Professor E. R. Muldashev, head of the All-Russian Centre of Plastic Ophthalmosurgery in Ufa. First from right: Ass. Professor R. Nigmatullin, Head of the Laboratory of Transplant Production in Ufa. The Laboratory is part of the Centre of Plastic Ophthalmo surgery. Seated left: Dr T. Mavliutov from the Burn Centre in Ufa

REFERENCES

1. Klein, L., Konĕcný, B., Mĕřička, P., Pintér, L. (1990). Naše zkuše nosti s léčbou popálenin. *Suppl. Sbor. vĕd. prací LF UK Hradec Králové*, **33**, 405–410
2. Klein, L., Mĕřička, P. Clinical experience with skin xenografts. In press
3. Klein, R. (1952), Tkáňová ústředna (TÚ). *Čs. nemocnice*, **20**, 118
4. Klen, R., Skalská, H. (1976). A comparison of dermoepidermal and chorion-amniotic grafts in the treatment of burns. *Acta Chir. Plast.*, **18**, 225–232
5. Kulyapin, A.V., Sakhautdinov, V. G., Temerbulatov, V. M., Becker W. K., Waymack, J. P. (1990). Bashkiria train-gas pipeline disaster: a history of the U.S.S.R./U.S.A. collaboration. *Burns*, **16**, 339–342
6. Mĕřička, P., (1982). Tricet let Tkáňové ústředny Fakultní nemocnice KÚNZ v Hradci Králové. *Lékařské zprávy (Hradec Králové)*, **27**, 195–206
7. Mĕřička, P., Hušek, Z., Straková, H., Vávra, L., Vinš, P., Schustr, P, Dudek, A., Kerekeš, Z. (1987). Cryopreservation of dermoepidermal grafts for treatment of burns. Proceedings of the 18th International Congress of Refrigeration, Commission C-1, Vienna 24–29.8.1987, pp. 1–8
8. Moserová, J. (1980). *Kožní ztráty a jejich krytí.* Prague: Avicenum, Albertova sbírka
9. Šimečková, E. (1983). A study of the graft stock in the tissue bank, Diploma Thesis, School of Pharmacy, Charles University, Hradec Králové

*EATB address:
Dr. R. von Versen, President of the EATB, German Central Tissue Bank, Medical School, Humboldt Univ., Schumannstr. 20121, D-1040 Berlin, Germany

14 Civilian and military burn injuries: a comparative study

A. W. REDA MABROUK
Burns and Plastic Surgery Unit, Heliopolis, Egypt

The aim of this study was to compare two systems of management of dealing with civilian and military burn injuries. 'Military burn injuries' means injuries sustained during war.

AETIOLOGY

The causes of civilian burn injuries can be classified as domestic, industrial and traffic. The causative agents may be hot liquids, fire, the results of use of petrol, gas or other burning agents, abuse of chemicals and electricity. The causative agents of military burn injuries are numerous and include flame-throwers, burning shells, napalm, petrol, and chemical agents including phosphorus and nuclear weapons.

Civilian injuries usually affect individuals, sometimes a family, but are rarely en masse. The extent and depth of the injury differ according to the causative agent and to the observation of prevention rules. Combined injuries are rare in civilian practice. War injuries are usually extensive and deep, may affect individuals in mass, and patients frequently have combined injuries. The only preventive factor is the capacity of the armed forces to prevent the enemy from using burning weapons.

MANAGEMENT

The management of civilian burn injuries varies according to the available personnel and the facilities and equipment supplied to them. The construction of burn units and centres is an important landmark in the development of burn management. That is why success in management differs from one area and from one country to another. Burn treatment is very expensive, and finance is a vital factor in its success. The worst situation is that in which management depends on personal or family financial resources. Ideally responsibility is taken by an able government or by medical insurance organizations. For this reason we are forced in many cases to be satisfied with success achieved in one of the three stages of management – acute stage, rehabilitation stage and reconstruction stage – postponing the management of the other stages until economic and social conditions allow. Prevention of burn injuries in civilian practice entails propagation of knowledge and safety measures in the form of protective rules and laws and in the form of propaganda delivered to the public by different information channels.

The management of military burn injuries is considered a national responsibility to be fulfilled by the armed forces. The plan of management is widely discussed as a part of war strategy and tactics. The different stages in management, once agreed upon, are issued as standing orders to be dogmatically executed, starting with first-aid management, sorting, evacuation and treatment at different levels of care until the victim reaches base hospitals and specialized centres. The aim of management is to save as many lives as possible and to reserve enough places for further expected casualties. Expense is never considered a crucial problem in treatment, this depending on the nation's ability to proceed with the fighting. The armed forces' responsibility for treatment is considered a life-long responsibility, the injured being treated in military and veterans' hospitals, if necessary permanently.

RESEARCH

Research work differs according to needs and circumstances. In civilian life economy is a vital goal, and research should therefore aim at improving the management of the acute stage, i.e., the treatment of shock, correction of metabolic disturbances and wound care. This type of research convinced us of the vital importance of the construction of burn units and centres with highly sophisticated ICU facilities and other equipment. Much research work also remains to be done to improve management during the stages of rehabilitation and reconstruction.

When on the other hand we consider war injuries, research work has to be directed towards the improvement of the standard of care at the different levels of evacuation, starting from the military unit medical office, the field hospitals and the base hospitals. All these levels are affected by battle conditions and by whether the battle is defensive or offensive.

CONCLUSION

Although there may be slight differences between the management of civilian burns and that of military burns the exchange of experience and the improvement that can be derived from research work are common to both, and they may be considered to be two dependent systems that aim at the proper care and preservation of man's well-being.

BIBLIOGRAPHY

Bull, J. P. (1958). Causes, prognosis and prevention of burns. *Med. Press*, **939**, 205

Foerster, D. W., Richardson, W. R. (1959). Causes of burns in Oklahoma. *J. Okla. Med. Assoc.*, **52**, 713

Feller, I., Crane, K. H. (1971). *Planning and designing a burn care facility*. Ann Arbor Michigan Institute for Burn Medicine

Pruitt, B. A. Jr, Moylan, J. A. (1972). Current management of thermal burns. *Adv. Surg.*, **6**, 237

Moylan, J. A., Pruitt, B. A. Jr. (1973). Aeromedical transportation. *J. Am. Med. Assoc.*, **224**, 1271

Reda Mabrouk, A. W. (1988). Burn injuries in Egypt, incidence and management. *Ann. Medit. Burns Club*, **1**, 21

Reda Mabrouk, A. W. (1990). The management of burn injuries in mass casualties. *Ann. Medit. Burns Club*, **3**, 112

15
The Army Medical Corps and its response in fire disasters: ultralight field units

VITO CONTREAS
Army Medical Corps, Italy

Different types of disaster require different responses: there are specific ways of tackling earthquakes, floods, war emergencies and mass nuclear contamination. In the specific case of fire disasters one of the priority problems is the extremely serious nature of the casualties' injuries. The condition of burn patients deteriorates rapidly. In the immediate post-burn phase it is necessary to initiate all possible measures to combat hypovolaemic shock, which is associated with a clinical picture of extreme panic and intense pain. The complex nature of the care required by such patients necessitates their admission to burns centres with highly specialized facilities.

These considerations stress the importance of two basic necessities: first, that rescue operations should be performed immediately and with means and equipment suitable for treatment of burns; and second, that there should be an appropriate organization for the targeted triage of casualties.

It is therefore clear that rescue operations must be performed by complex and complete organizations such as the Armed Forces, which are capable of transporting casualties, by air if necessary, and which are well integrated into national and international communications networks. They also possess mobile health units which can rapidly be brought into use as well as specialized medical teams which in a few hours can provide fire disaster victims with adequate assistance.

The Italian Army Medical Corps has adopted a series of technologically advanced solutions and developed a number of new methods particularly designed to make its mobile units more versatile and more efficient. These mobile units are easy to manage, simple to transport, equipped with the latest technology, and above all flexible in their use: this last quality is due to their characteristic modular structure.

Essentially, the unit consists of a self-contained surgical nucleus surrounded by 14 rubberized tents supported by a framework of pneumatic tubing. These other tents completing the hospital are used mainly for diagnosis, beds for the patients, and services.

The whole complex is based on a 'continuous canvas' philosophy, i.e. that of an integral structure with optimal conditions of isolation and the logistic rationality of a single structure. This has the shape of a central trunk into which it is possible to insert series of accessory modules, which may be used for specialist purposes (paediatrics, gynaecology, etc.) or may serve to increase bed space.

The basic structure is itself far from rigid. The distribution of the functions of the various sections has been designed so that the unit can be effectively used either as single tents or as small groups of tents. Practically speaking, the hospital is created around a basic nucleus consisting of Admissions and First aid, to which other units (radiography and echography, operating section with intensive care, wards and services) are added in successive stages, in three different directions off the central body.

Because of its modular nature, this type of unit is clearly useful in emergency situations which for a variety of considerations – limited number of casualties, severity of victims' conditions, difficulty of access due to geographic reasons – prevent the deployment of full-scale health facilities.

The modular structure, with its possibility of gradual expansion through successive subunits into the complete unit, is an important ally of the need for rapidity in the rescue response, as it is not necessary to wait for the setting-up of the operating theatre or the ward tents in order to provide first aid or to perform diagnostic screening of the first casualties.

An 'ultralight health unit' has been defined on the basis of these principles. This unit, which can be brought immediately into action, is proposed as a first choice instrument for immediate aid in fire disasters.

The unit consists of the first four tents of a mobile unit, i.e. admission/resuscitation, triage, immediate surgical and orthopaedic care, and the first of the ward tents. This structure permits the simultaneous treatment of four critical patients and/or injured patients requiring immediate care. At the same time it is possible to assist 16 other patients and to administer fluid therapy. In other words about 20 patients can be given adequate respiratory and cardiac/circulatory support within about 30 minutes by a team of four physicians and six nurses.

All the material, tents included, can be packed for air-drop in palettizable waterproof boxes. The material can thus reach the destination on any kind of vehicle in a very short time.

In the light of the fact that the majority of severely burned patients die in the first few hours after injury as a result of respiratory failure due to inhalation of smoke or toxic gases or following the onset of severe shock syndrome, it is clearly important to proceed with properly equipped vehicles with means for cardiorespiratory resuscitation and fluid therapy.

The unit is not intended to be used as a hospitalization structure – 20 beds would in any case be too few in a serious fire disaster. Its main purpose is to constitute a temporary post for immediate treatment and especially for targeted triage. For this purpose it is essential that there should be the possibility of a rapid radio link-up with Civil Defence organizations, which have specific responsibility for providing information about the availability of hospital beds throughout the national territory.

For maximum rapidity of response with these mini-health units, it is clearly of extreme importance to programme the packing of the various modules according to a set protocol. The utility of the module, as a single element that can be used individually, depends on its complete functional autonomy: every tent must therefore be transported together with its own electricity plant and its technical and structural fittings.

These latter considerations are not always easy to realize on a practical level because of problems of storage and transport.

I would say in conclusion that if we are to take full advantage of the modular structure of our modern units we must organize container systems comprising the individual modules complete with all the necessary logistic and technological support necessary for their complete functional autonomy.

These structures – like those already realized for the transport of service systems for the surgical nucleus – could consist of metal mini-containers lifted by an integrated system or by special jacks and loaded autonomously on to trucks, aeroplanes, ships, etc.

BIBLIOGRAPHY

Contreas, V. (1986). Primo soccorso medico nelle maxi-emergenze: le attrezzature in funzione del soccorso, dello sgombero e del transporto. Atti del Congresso Internazionale di Medicina Militare, Rome

Contreas, V. (1989). Complesso Sanitario Campale anni '90. Atti del XCI Congresso della Società Italiana di Chirurgia

Contreas, V. (1989). Emergenze Sanitarie nelle pubbliche calamità: filosofia dell'impiego modulare. VI Congresso Nazionale della Società di Chirurgia del Mediterraneo Latino, Cagliari

Contreas, V. (1990). La Sanità Militare dell'Esercito in ambito Campale: flessibilità dell'Organizzazione Mobile. First International Conference on Burns and Fire Disasters, Palermo

Contreas, V. (1990). Soccorso sul campo, organizzazione e coordinamento. Atti delle Giornate Medico Chirurgiche Internazionali, Turin

Contreas, V. (1992). Emergenza in Kurdistan: esperienza di soccorso. Emergenza V, Tarquinia

Cucciniello, G., Anaclerio, M. and Contreas, V. (1988). Strategie di intervento della Sanità Militare nelle grandi emergenze. Incontri Internazionali Multidisciplinari sullo Sviluppo, Turin Cucciniello, G. and Contreas, V. (1988). La Sanità dell'Esercito in situazione campale: recenti innovazioni technologiche. Atti del XC Congresso della Società Italiana di Chirurgia, Rome

16
Medical strategy and tactics for fire disasters in Russia

V. V. AZOLOV, V. A. ZHEGALOV, G. I. DMITRIEV and
V. A. SASCHENKOV
Republican Burns Centre, Research Institute of Traumatology and Orthopaedics, Nizhniy Novgorod, Russia

---

Technological and transport accidents, natural disasters and military conflicts are often accompanied by explosions and fires that result in thermal injuries. Burns are a main feature of emergency situations in developed countries. This is also true for Russia.

Seventy-six specialized Russian burns centres are considered to be national establishments capable of carrying out the immediate work in the event of an emergency. These burns centres are based in large hospitals and medical and research institutes are the most appropriate in this respect. According to the special duty schedule each burns centre has rapid response teams comprising seven persons: burns specialists, an anaesthesiologist-resuscitator, nurses and a driver. It is supplied with a stock of resources including drugs, bandages and simple anaesthetic and resuscitation equipment. While acting autonomously (for example, on the scene), the work is planned for 12–24 h to provide immediate care for 40–50 victims.

The tasks for specialists from burns centres, army rescue teams, police (militia) and fire brigades in the event of disasters with mass burns are as follows:

- preparedness for arrival on the scene within 1–2 h after receiving an urgent call-out;
- priority of organization work (search, concentration, triage, evacuation to primary hospitals and to burns centres) to medical care;
- minimal immediate care: in shock, bleeding, asphyxia, acute disturbances of the peripheral blood flow in deep circular burns, limb fractures with fractured fragment displacement (decompressional necrectomy, fasciotomy, transport immobilization). The primary removal of burned individuals to the nearest organized and non-

specialized medical establishments in one or two large cities must be considered a temporary and forced measure. Our experience of the primary concentration of more than 600 injured in the Bashkirian tragedy of 1989 in two cities of the Southern Urals, Ufa and Cheliabinsk, showed all the negative consequences of these tactics.

First, it was impossible to carry out overall and adequate therapy because of the large number of injured individuals, the evident discrepancy between the requirements for medical care and the lack of sufficient means for its provision, and the inexperience of the medical staff in the establishments for primary hospitalization;

Second, there was a large number of infectious complications in burned patients as a result of the inevitable spread of the nosocomial bacterial microflora in hospital where it was impossible to isolate the most severely burned patients. There was a high mortality rate and poor functional and cosmetic results in the disaster victims.

Evacuation of all victims requiring hospital treatment to burns centres would be an ideal solution in Russia. However this is limited by the large-scale casualties, the distant location of the main burns centres from the place where the disaster occurs, and the limited possibilities of sanitary and civil air transport.

After finishing treatment of burns and endotoxic shock, i.e. 5–10 days after the accident and primary hospital admission, most of the patients had to be transported by sanitary air transport to specialized burns centres.

In emergency situations caused by major technological and natural disasters, large-scale casualties are similar to those in wartime. That is why we are sure that medical care, triage and evacuation of the injured in the first hour and the first day after the disaster must be just the same as in the wartime and the medical services of the armed forces should participate in the rescue work. In the warm period of the year, tent (or airmodule) field army hospitals must be developed in airports of the large cities nearest to the place of the disaster to carry out triage, first aid and medical care of the burned individuals. Later these patients (in groups of 30–40 people) can be evacuated directly to the burns centres without being first admitted to non-specialized hospitals.

Elimination of the medical and social consequences of major disasters is impossible without government support and the participation of international rescue teams. The consolidation of such services in the whole world to solve the practical problems of cooperation is a vital and noble mission.

17
Toxicological management of fires

C. MANNI, S. I. MAGALINI and A. BARELLI
Department of Anaesthesiology and Intensive Care,
Department of Toxicology, Poison Control Centre,
Catholic University School of Medicine,
Rome, Italy

Fires can have life-threatening effects resulting from the inhalation of heated air and fire gases. The inhalation of heated air results in thermal damage to the respiratory tract with the risk of oedema, airways obstruction and impaired pulmonary function. In general, the management of thermal injury does not require a toxicologically oriented treatment. The inhalation of combustion products, however, may cause many different toxicological problems depending upon the substances involved in the combustion process.

More than 100 chemical species have been identified from the burning of different materials. Inhalation injury is therefore a far more complicated matter than a single-product intoxication. In most cases, the nature of the toxic gases that causes death from smoke inhalation is not known. The nature of the products of combustion depends on the oxygen levels present and the nature of the combustible materials.

Common combustible materials contain carbon which in the presence of sufficient oxygen burns to form carbon dioxide. In the event of limited ventilation or insufficient oxygen supply, incomplete oxidation occurs with the resulting formation of carbon monoxide. Carbon monoxide is thus a product of essentially all fires and may cause death. Carbon monoxide levels in the range of several thousand parts per million are common in fire atmosphere, but even significantly lower concentrations of carbon monoxide may impair some individuals' ability to escape from fire. For instance, exposure to carbon monoxide sufficient to produce carboxyhaemoglobin saturations in the 3–5% range has been reported to alter cardiovascular function in patients affected by cardiovascular disease as well as in normal subjects. Diagnosis and therapy of acute carbon monoxide intoxication is a fundamental part of the toxicological management of fires.

As far as therapy is concerned, hyperbaric oxygen therapy has been proved to reduce mortality and the rate of neurological sequelae. It should be applied to all patients who have or have had any signs of severe carbon monoxide poisoning. Hyperbaric oxygen therapy is considered the primary therapy in cases of carbon monoxide intoxication; furthermore, current information suggests that hypoxic encephalopathy secondary to carbon monoxide poisoning results from a reperfusion injury. Products of lipid peroxidation from the reperfusion injury contribute significantly to the morbidity and mortality of this condition. For this reason carboxyhaemoglobin levels are poor indicators of the severity of the intoxication, and this explains why patients with significant carbon monoxide poisoning may have low levels.

Hyperbaric oxygen therapy decreases the half-life of carbon monoxide from 5.5 h to 90 min at 1 ata and to 23 minutes at 3 ata. Animal studies have shown a reduction of morbidity and mortality rates using hyperbaric oxygen therapy even if lipid peroxidation is not significantly reduced when using oxygen at 1 ata.

The role of cyanide in human fire fatalities is less clear than that of carbon monoxide. Cyanide is metabolized continually, and is normally present in blood. Blood cyanide concentrations are often measured only long after exposure and consequently the analysis of blood for cyanide must be interpreted with caution.

Cyanide poisoning may result from the inhalation of gases produced by burning synthetic materials. Many smoke inhalation victims have significantly elevated blood levels of cyanide.

Treatment of cyanide poisoning after inhalation of fire gases includes oxygen and other symptomatic therapy (controlled ventilation, correction of acidosis and circulatory support) as well as specific antidote compounds. Unfortunately most cyanide antidotes are *per se* toxic; sodium thiosulphate and hydroxycobalamine are probably the safest products currently available and should be administered, in addition to oxygen, in cases of documented or suspected cyanide poisoning. Sodium thiosulphate enhances and facilitates endogenous detoxification of cyanide. For this reason, it is regarded as a safe and efficient antidote and is always indicated in fire victims with suspected cyanide poisoning. Unfortunately, the endogenous process of detoxification is rather slow; more rapid and efficient detoxification is achieved by chelation therapy. Hydroxycobalamine combines with cyanide to form cyanocobalamine, which is excreted by the kidneys. Hydroxycobalamine is usually well tolerated and can be considered the future drug of choice in cases of exposure to fire gases and combustion products when cyanide poisoning is suspected. Plasma lactate concentrations >10 mmol/l have recently been reported as a sensitive indicator of cyanide intoxication.

Burning material may release irritant gases that damage ocular, rhinopharyngeal and tracheobronchial mucosa as well as pulmonary parenchymal tissue. Irritant gases include acroleine, ammonia, bromic acid, hydrogen chloride, hydrogen fluoride, isocyanates and sulphur dioxide. The potential roles of sensory and pulmonary irritants contained in fire atmospheres have been studied using laboratory animals. In general the main effect is a reduction of the respiratory rate, which often leads to severe hypoxia.

In humans, symptoms of irritation may include intense coughing, bronchoconstriction and chest pain. These signs may appear immediately after exposure and they are in general directly proportional to the concentration and duration of exposure. Toxic pulmonary oedema may be an early sign of alveolar damage, but more often pulmonary oedema occurs after a symptom-free period that may last from a few hours to two days.

Management of victims exposed to irritant gases includes optimal symptomatic therapy, i.e., oxygen, assisted ventilation and broncholytic agents. The use of corticosteroids in these situations is controversial. Some animal studies have indicated both positive and negative effects of cortisone. Clinical experience suggests that topical or systemic corticosteroid therapy may be helpful in decreasing irritation, although controlled clinical trials are not available. Inflammatory reaction and capillary hyperpermeability, which characterize the damage after exposure to irritant gases, should theoretically respond to corticosteroid therapy. However, there is no convincing evidence that corticosteroid therapy is useful either to improve acute chemical injuries or to prevent the development of long-term sequelae. In injuries with concomitant thermal burns corticosteroid therapy may well have negative effects. It may be sufficient that topical (inhalation) corticosteroid therapy is indicated in patients with signs of respiratory tract irritation.

In conclusion, escape from a fire is always the key to survival. Escape should theoretically be possible, assuming sufficient time, unimpaired faculties and the absence of physical restraints. However, fire is an exceedingly hostile environment in which a series of time-dependent variables reduce the possibility of escape. Inability to escape leads to exposure of the victims to combustion products and fire gases. The final effects of exposure almost always include hypoxia, carbon monoxide and cyanide poisoning and the patient has to be treated accordingly. In this regard, it is fundamental to suspect the presence of all likely combustion products because, in some cases, not only symptomatic therapy but also antidotes and other specific treatment are required.

BIBLIOGRAPHY

Abdi, S., Traber, L. D., Herndon, D. N., Redl, G., Curry, B., Traber, D. L. (1990). Bronchial blood flow reduction with positive end expiratory pressure after acute lung injury in sheep. *Crit. Care Med.*, **18**, 1152–1157

Cioffi, W. G., Jr, Rue, L. W. III, Graves, T. A., McManus, W. F., Mason, A. D., Jr, Pruitt, B. A., Jr. (1991). Prophylactic use of high-frequency percussive ventilation in patients with inhalation injury. *Ann. Surg.*, **213**, 575–582

Demling, R. H., LaLonde, C. (1990). Moderate smoke inhalation produces decreased oxygen delivery, increased oxygen demands, and systemic but not lung parenchymal lipid peroxidation. *Surgery*, **108**, 544–552

Fitzgerald, K. A., McLaughlin, E. G. (1990). Inhalation injuries. *AACN Clin. Issues Crit. Care Nurs*, **1**, 535–542

Herndon, D. N., Traber, D. L. (1990). Pulmonary circulation and burns and trauma. *J. Trauma*, **30** (12 Suppl), S41–44

Kinsella, J., Carter, R., Reid, W. H., Campbell, D., Clark, C. J. (1991). Increased airways reactivity after smoke inhalation. *Lancet*, **337**, 595–597

Large, A. A., Owens, G. R., Hoffman, L. A. (1990). The short term effects of smoke exposure on the pulmonary function of firefighters. *Chest*, **97**, 806–809

Levin, B. C., Rechani, P. R., Gurman, J. L. *et al.* (1990). Analysis of carboxyhemoglobin and cyanide in blood from victims of the Dupont Plaza Hotel fire in Puerto Rico. *J. Forensic Sci.*, **35**, 151–168

Li, B. G., Hsu, W. S., Shih, T. S. (1990). Causes of death in aged burn patients: analysis of 36 cases. *Burns*, **16**, 207–210

Mayes, R. W. (1991). The toxicological examination of the victims of the British Air Tours Boeing 737 accident at Manchester in 1985. *J. Forensic Sci.*, **36**, 179–184

Meyer, G. W., Hart, G. B., Strauss, M. B. (1991). Hyperbaric oxygen therapy for acute smoke inhalation injuries. *Postgrad. Med.*, **89**, 221–223

Moisan, T. C. (1991). Prolonged asthma after smoke inhalation: a report of three cases and a review of previous reports. *J. Occup. Med.*, **33**, 458–461

Niehaus, G. D., Kimura, R., Traber, L. D., Herndon, D. N., Flynn, I. T., Traber, D. L. (1990). Administration of a synthetic antiprotease reduces smoke-induced lung injury. *J. Appl. Physiol.*, **69**, 694–699

Pruitt, B. A., Jr, Cioffi, W. G., Shimazu, T., Ikeuchi, H., Mason, A. D., Jr (1990). Evaluation and management of patients with inhalation injury. *J. Trauma*, **30** (12 suppl), S63–S68

Riyami, B. M., Tree, R., Kinsella, J., *et al.* (1990). Changes in alveolar macrophage, monocyte, and neutrophil cell profiles after smoke inhalation injury. *J. Clin. Pathol.*, **43**, 43–45

Schenk, W. G. III, Aldridge, S. C., Farley, P. C. (1990). Experimental inhalation injury with concomitant surface burn: dextran resuscitation improves lung water and oxygenation. *J. Trauma*, **30**, 813–819

Shimazu, T., Ikeuchi, H., Hubbard, G. B., Langlinais, P. C., Mason, A. D., Jr, Pruitt, B. A., Jr. Smoke inhalation injury and the effect of carbon monoxide in the sheep model. *J. Trauma*, **30**, 170–175

Sugi, K., Theissen, J. L., Traber, L. D., Herndon, D. N., Traber, D. L. (1990). Impact of carbon monoxide on cardiopulmonary dysfunction after smoke inhalation injury. *Circ. Res.*, **66**, 69–75

Theilade, P. (1990). Carbon monoxide poisoning. Five years' experience in a defined population. *Am. J. Forensic Med. Pathol.*, **11**, 219–225

Wu, W. X. (1990). Effect of carbon monoxide on hemodynamics and oxygen metabolism in inhalation lung injury. *Chung Hua Cheng Hsing Shao Shang Wai Ko Tsa Chih*, **6**, 290–293, 318

Zhao, Z. D. (1990). Experimental treatment of smoke inhalation injury with anti-lipid peroxidation agents. *Chung Hua Cheng Hsing Shao Shang Wai Ko Tsa Chih*, **6**, 294–298, 319

18
Disaster medicine exercise

B. NICOULET, M. COSTAGLIOLA and C. VIRENQUE
Centre Hospitalier Universitaire Rangueil, Toulouse, France

THE EXERCISE

Consider the following scenario. A serious accident has just happened at Air Base 101. A jumbo jet has left the runway during takeoff. Some of the passengers are still trapped in the smashed cabin and casualties lie all around among the scattered wreckage. The wing tanks explode and the fire spreads rapidly. The control tower gives the alert and the first rescue services arrive rapidly on the spot. In view of the gravity of the disaster the 'Red Plan' is activated under the responsibility of the Base Commandant. The Air Base rescue teams are mobilized and medical reinforcements are simultaneously requested from the Emergency Medical Aid Service (SAMU) and the fire and Rescue Service of the local Département. The SAMU helicopter carries out reconnaissance flights over the accident site, and the Air Base rescue workers, despite the threat of explosion, explore the extinguished cabin of the aircraft and proceed to initial triage of the victims.

The Rescue Operations Director, his assistant (a SAMU physician) and a Fire Brigade officer will now set up a rescue chain which we will call Petite Noria. A hangar about 500 metres away will be used as an Advance Medical Post where casualties will be assembled out of danger from the fire. Materials and ambulances arrive from all parts of the Base.

Triage tags with a specific computer number simplify identification of the victims and assessment of their injuries. Thanks to the efficiency of the identification systems there is optimal synchronization of all operations.

A temporary morgue is set up on site. The deceased are identified by a forensic surgeon and the Air Police authorities.

Reinforcements set up a SAMU Medical Support Detachment for resuscitation of casualties. A fully stocked dispensary in the vicinity of the Base makes it possible to use medical fluids and emergency drugs. The Medical Support Detachment is fully operational 35 minutes later with the arrival of 50 physicians. Conventionally, as part of the exercise, they represent the emergency physicians who would be mobilized in a real emergency. The first resuscitation procedures are performed on site before evacuation of casualties.

Some casualties will be evacuated by air. A Puma aircraft will evacuate up to eight casualties. The Grande Noria equipment includes an Air Force Alouette 3, a SAMU Ecureuil, two Gendarmerie Ecureuils and a Transal C 160. These aircraft will perform the actual evacuation of 43 casualties. Ten severely burned patients are evacuated in the Transal, to be transferred to Burns Centres elsewhere.

Evacuation by road is effected by the Fire Brigade Officer under the escort of the National Police, who clear the roads to accelerate access to the hospitals.

The two Toulouse hospitals Rangueil and Purpan begin to admit casualties. The creation of a Rescue Director Post in each C.H.U. (University Hospital Centre) and the opening up at Rangueil of the entry hall will make it possible to cope with the great number of admissions.

The first casualties are admitted two hours and thirty minutes after the accident (at a distance of 15 km). After clinical, biological and radiological tests the injured are sent on to specialized departments. The transformation of the Rangueil entry hall into an Evacuation Medical Centre takes the pressure off the emergency services, accepting less urgent and stable emergencies: 50 beds are available.

From the very beginning of the alert, the Emergency Call Reception and Processing Centre has set up its specialized post, called its personnel into action and employed a special frequency: this is the strong point of the exercise.

RESULTS

The realization of the exercise proved to be extremely complex. The problems of synchronization were very difficult to manage. There was a bitter discussion of the financial considerations and the distribution of the cost of the exercise. The assessment of the state of the burn victims was often incorrect.

On site, the civil and military authority medical teams, with their enormous logistic means, showed their complementary nature. The identification systems – uniforms, armbands and special smocks according to the functions performed – facilitated cooperation between the teams.

On the level of hospital admission, the creation of the Rescue Director post, tried for the first time at the Toulouse C.H.U., would seem to be equivalent to the foundation of a hospital emergency committee.

The Emergency Call Reception Centre provides information, speeds up mobilization procedures and acts directly on large-scale hospital structures. All the medical and surgical hospital departments capable of admitting large numbers of patients assisted the Rescue Director in his task, collaborating with him in every way.

The increase in hospital efficiency in relation to the recall of paramedical staff posed few problems.

The transformation of the Rangueil entry hall into a SAMU (Emergency Medical Aid Service) proved extremely useful.

Problems encountered

The difficulties were all of an unpredictable nature.

1. The exact identification of the victims. Despite the creation of a specific computer number and the prenumbered identification triage tags only 50% of patients admitted were correctly identified; 30% of the mistakes were never corrected, leading to grave confusion in diagnoses and paramedical tests.
2. Inaccuracies and illegible written communications at all points of the chain.

A comparison between theoretical triage and the triage actually performed shows some significant differences that are probably due to a slowing down in the evacuation procedures during the exercise.

The performance would certainly be improved upon in the event of a real disaster.

The difficulties encountered indicate the importance of the annual repetition of disaster medicine exercises.

19
The ARGO satellite system: Severely Burned Patients Network

G. MARTINELLI
Department of Civil Defence, Telecommunications Service, Rome, Italy

GENERAL DATA

The Italian Department of Civil Defence has adopted an up to date system for emergency telecommunications and territorial data collection. This satellite system, known as ARGO, enjoys all the exceptional advantages offered by satellite systems, such as:

- The ability to set up local stations within the satellite's coverage area, without any restrictions
- The independence of the means of communication from the disasters striking the territory
- The quality, flexibility and reliability of the link-up.

With regard to emergency communications, the basic features of the project include the ability to establish extremely rapid links, even over great distances, between Central Headquarters and the emergency areas in order to collect information; to organize immediate intervention teams to make a rapid assessment of the situation; and to send in rescue teams immediately and on the basis of valid information. The communications are also independent from ordinary means of communication that may be damaged or destroyed or be unavailable for use because of the exceptional load on communications to and from the disaster area. The communications system is stable and reliable and can be rapidly reconfigured in relation to the situation. It also contains high-capacity channels suitable for transmission of video signals.

Key elements that have been identified in the field of data collection and monitoring of the territory include:

- Control of a vast range of parameters related to the cause of the disaster and rapid transmission of information from the sensors
- Centralization of collection and processing of data in order to have updated information for complete and efficient reference models

- Optimal choice of sensor position in order to have quality data
- Sensors distributed in significant points in the monitored area
- Continuity of monitoring during the critical period.

CONFIGURATION OF THE ARGO SYSTEM

The system is illustrated in Figure 1. It comprises:

1. A *control centre* in the headquarters of the Department responsible for checking and relaying all communications between the Department and peripheral stations in the system (Figure 2).
2. A *master station* in the Fucino Space Centre which undertakes technical surveillance of the whole system and communications to and from the satellite (Figure 3).
3. Twelve *TLC stations* on off-road vehicles and engineered for CH-47 helicopter transport, with autonomous electric supply.
4. Three *video camera systems* in helicopters on stabilized platforms and a radio bridge for despatch in real time of images from the disaster area to the Department.

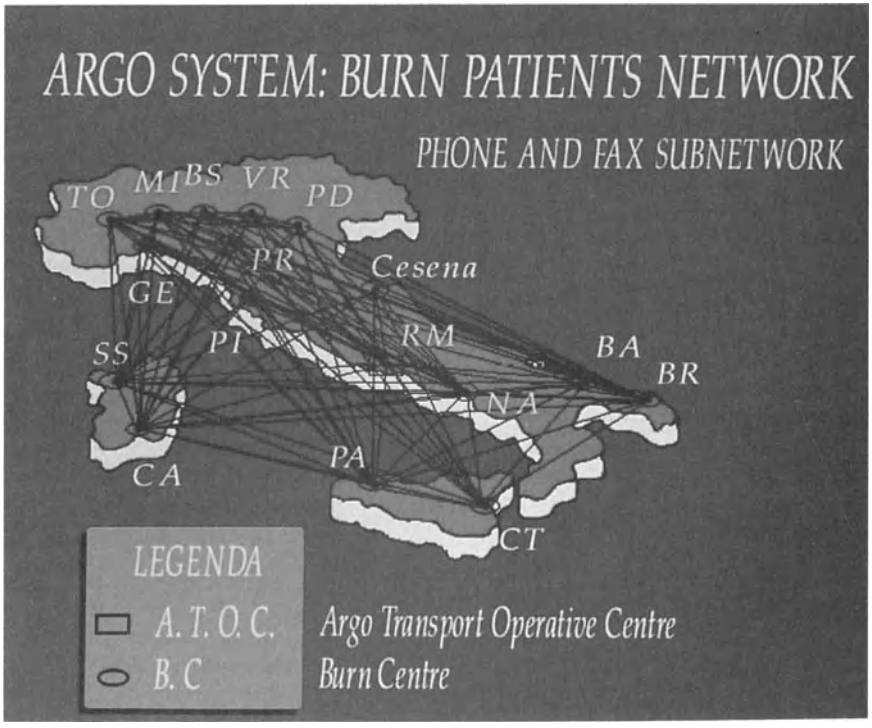


Figure 1.

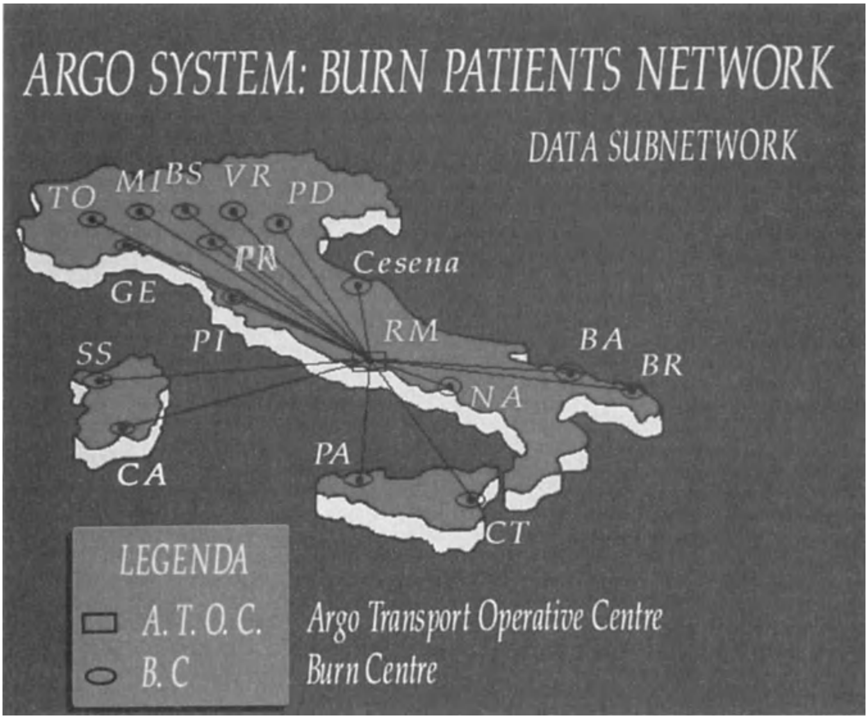


Figure 2.

5. About *100 small fixed stations* for the collection of data transmitted by sensors located in areas considered at high risk for disasters such as earthquake, volcano, floods and fire, and in particular health structures.
6. A radio-bridge *link-up* between the control centre and the master station, duplicated by coaxial cable circuits of the State Agency: a back-up system is vital in disaster management.
7. A *space segment* in the EUTELSAT European satellite (EUTELSAT = European Union Telecommunications via Satellite).

The system, as already mentioned, consists of an emergency telecommunications network and a territorial data collection network. The former permits the simultaneous link-up of the Department with any 12 localities in the national territory by means of the 12 mobile stations, each of which provides two two-way telephone and two fax (or data) channels and a video channel with audio commentary from the peripheral stations to the control centre and the operative centres.

ARGO's main function is to re-establish communications as rapidly as possible in order to reduce intervention delays to a minimum. The mobile stations have therefore been located primarily in the vicinity of

Figure 3.

high-risk areas so that they can be effectively deployed in the event of a disaster within 3–4 hours.

The mobile stations can also be transported by helicopter, which means that intervention times are further reduced, with the possibility of bringing in stations from areas not affected by the disaster.

The data collection network, articulated in various subnetworks (seismic, volcanic, hydrogeological) will make it possible to convey all data collected to the headquarters of the various scientific Agencies concerned. Here the data will be processed and transformed into information with significance for Civil Defence.

After initial financing in 1986, the project was realized in September 1987. The system was divided into various functional sections in order to accelerate the activation of each single section. Despite its absolute originality and the technological complexity of some of its major components, the telecommunications network has already been completed. It went into service in June 1991, while the data collection network is in the realization phase and will be completed in 1993.

The technical and operative management of the system requires about 60 staff specialized in telecommunications with experience in field networks. These operators came from the Ministry of Defence and the Fire Brigade (for two mobile stations) and were trained in the use of ARGO equipment in courses held at Societá Telespazio. The management of the master station and the specialized preventive and corrective maintenance work of the entire system have been entrusted to Societá Telespazio, which has undertaken to intervene with extreme rapidity.

In order to extend the services offered by the ARGO system, plans are being perfected:

- To set up further mobile and fixed stations in order to triple the present dimensions of the telecommunications and data collection networks
- To create new services, such as videoconferences, X-25 environment transmissions
- To employ mobile technico-operative control centres.

This extension of services clearly presupposes the availability of new equipment, the installation of transponders in the satellite, and adaptation of the station master hardware and software.

In conclusion, when the ARGO system goes into service it will enable the Italian Civil Defence Service to improve its activities of prediction and prevention with regard to the main disaster risks in the national territory, and to carry out more rapid and more efficient rescue operations.

In addition, as the fly-over area of the satellite used by the system covers nearly all Europe and the Mediterranean basin, Italy – in accordance with the objectives of community Civil Defence which include an advance telecommunications system for the prevention and management of disasters in European states – has offered ARGO as an emergency telecommunications resource for the European Community and the Mediterranean countries.

SEVERELY BURNED PATIENTS NETWORK

The idea of a Severely Burned Patients Network was conceived in the light of the necessity to make maximum use of the resources for the hospitalization and care of burn patients. These resources, in the opinion of the health authorities concerned, are generally sufficient to satisfy a country's average requirements, but in emergency situations it may be difficult to establish their exact location without loss of time, inevitably complicating the transfer of patients to hospital facilities capable of admitting them.

The solution to this problem was to provide means for establishing in real time the exact entity and location of the resources and to set up a nationwide organization capable of mobilizing the necessary transport facilities for transfer of burn patients.

To achieve this objective with as little financial outlay as possible it was originally planned:

1. To divide the national territory into operational areas, each containing a number of hospitals organized for treatment of

severely burned patients, and to designate within each area one of the hospitals as the coordination centre.

2. To create at the Department of Civil Defence a Patient Transport Operational Centre and a Severely Burned Patient Data Collection Centre, respectively responsible for the transport of patients (integrating or substituting local services) and for collecting data about the situation in the hospitals for distribution to the coordination centres.
3. To set up a telecommunications system to link burns centres and field health units to the coordination centres, and the latter to the Situations Centre at the Department of Civil Defence, in order to ensure continuous flow of information about resources and communications as regards patient transport, exploiting the ARGO system's capacity for expansion and its flexibility and total coverage of the national territory.

Subsequently it was thought more advantageous for each burns centre to have direct access to the Department's Data Collection Centre and Patient Transport Centre and more efficient to have direct contact between hospitals sending on and receiving patients. Accordingly, after the extra expenditure had been approved, the Severely Burned Patients Network was replanned and divided into two subnetworks:

1. A telephone and fax mesh subnetwork linking all the burns centres together and with the Patient Transport Operative Centre.
2. A subnetwork for data communication to link all hospitals with a burns centre to the Civil Defence Department's Data Collection Centre for continuous updating and information about resources in the hospitals.

The project provides for the installation of a radio satellite composed of a 3-metre parabolic aerial, radios and user terminals (telephone or telephone exchange interface, fax and data terminal) at every burns centre.

The organs of the Department (Patient Transport Centre and Data Centre) will use the existing ARGO and Data facilities.

The investment cost of the entire system is just over 4 billion lire (about $2.5 million), while annual expenses for management and maintenance, including rent of the space vectors, are about 10% of the investment cost.

The proposal has been approved by the relevant technical and financial authorities and is already being realized by the administrative affairs office. It is thus almost certain that these deadlines will be met. If this forecast proves accurate the Severely Burned Patients Network should be a reality by 1993.

CONCLUSIONS

The Severely Burned Patients Network makes use of structures of great flexibility and potentiality capable of conveying information of any kind. As the system functions continuously, the more it is used the more advantageous it is to the state, both operationally and economically. It is important that health organizations should propose every possible further use of the system, in order to improve the national health service, with particular reference to the emergency sector.

BIBLIOGRAPHY

Martinelli, G. (1992). The ARGO satellite system: a network for severe burns and fire disasters. In: *The Management of Mass Burn Casualties and Fire Disasters,* M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers.

20
Planning and management of rescue operations in the event of fire in a city

GIUSEPPE MONTESANTO
Regional Fire Brigade, Sicily

In the distant past, people believed that disasters such as fires were a divine punishment brought down upon them because of mankind's sins. Sincere repentance was therefore required, together with an appeal for general pardon.

At the same time, however, it was generally believed that in addition to praying everybody should act positively to prevent and limit the damage caused by the divine punishment that rained down from heaven. A civic organization for rescue operations has existed in Palermo since the year 1300, along with regulations for fire prevention. One of these regulations, deriving from an ancient custom, prohibited the sale of firewood in particularly narrow streets, such as the Cassaro (one of Palermo's main thoroughfares), while it was allowed in the open square of St Cataldo (the present-day Piazza Bellini). Bakeries with their ovens were considered 'high-risk activities' especially because of their stores of firewood.

The most dangerous fires were those that broke out at night because the city was wrapped in darkness, causing difficulties for rescue workers and general panic in people in the neighbourhood.

The Palermo City Council, in its sittings of 5 May and 2 September 1864, created what was known at the time as the *Firemen and Roadmen Brigade*, with 122 men. In 1889, at the request of the then Commandant, Cavalier Rodolfo Moreno, the *Firemen and Roadmen Brigade* was dissolved and the *Fire Brigade* was created. In 1935, the Provincial Fire Brigades were set up, each with a local Commander in the provincial capital and depending directly on the Ministry of the Interior. With the creation of the National Fire Brigade (Law 1570 of 27 December 1941) the management of rescue operations was entrusted to Fire Brigades which had headquarters in provincial capitals with authority over the province, coordinated with the Regional Inspectorate and the Operative Centre instituted at the Civil Defence General Management in Rome.

In Palermo today, fire alarm calls, made by dialling the number 115 from any telephone, are relayed directly to the Fire Brigade operations room at Via Scarlatti 16.

The Fire Brigade Operations Room is composed of:

- A telephone exchange operating 24 hours a day
- Fax equipment for transmitting and receiving documents and emergency communications
- A computer message transmission system
- A receiving and transmitting radio system capable of linking up with all rescue teams
- An amplification system to alert personnel
- A system of signal lights to indicate the type and gravity of the fire
- A large-scale map system.

The operator receives the distress call and immediately elicits information relating to the nature of the fire (type of material burning), its severity, the presence, even if only suspected, of persons in danger and the exact location of the fire. The operator then gives instructions for the despatch of men and fire engines from the Central Station or one of the three Area Stations (North, South, Port), each of which has a precise area of responsibility.

Meanwhile the alert is relayed to the Operations Room at the Regional Inspectorate and the General Headquarters which in the case of serious fires has elaborated a computer system to manage fire emergencies.

This system reproduces the scene of the accident as soon as information has been received about the location of the emergency, type of fire, substances involved and weather conditions. The system makes it possible to give the necessary assistance to operative personnel in relation to the development of the fire.

Unfortunately, the success of fire-extinguishing operations is often incomplete because of a number of negative factors:

- Lack of preventive and protective measures
- Difficulty reaching the fire rapidly because of traffic conditions
- Lack of hydrants for water supply
- The fragmentary nature of the city, particularly in residential areas, which makes it practically impossible for fire engines to reach the fire.
- The presence of high-rise buildings (over 32 metres in height) located in positions where it is impossible for fire ladders to be used to save people.

As a result of increasing public awareness and insistence, there is a growing demand for adequate fire security measures throughout the city of Palermo. The fundamental concept is that preventive measures should be able to contain risks within reasonable limits.

The general public must be given adequate information and receive clear instructions so that they can learn to live with the risk of fire and know how to behave when the risk becomes reality. There must also be proper programming and management of fire safety in industry. It is essential to overcome the widespread attitude to fire emergencies according to which any plans made in order to be better prepared are soon forgotten as they can only bring bad luck.

Information campaigns have to be conducted to inform about the problems of fire security.

In the future, if Palermo is to be safe from fire, it will be necessary to design 'intelligent buildings' with the following specifications:

1. Structures and materials with combustion characteristics appropriate to the intended use of the building.
2. Internal furnishings (curtains, carpets, moquette, furniture coverings) with good fire resistance qualities.
3. Fixed automatic sprinklers with the dual function of detecting a fire in its initial stage and of keeping flames under control until arrival of the Fire Brigade.
4. An efficient system of communication and centralization of fire information so that the most appropriate firefighting procedures can be put into operation as rapidly as possible, making use of well-tried means of up-to-date transmission techniques such as electronic equipment, computers and telecommunications.

In conclusion, the municipal authorities need to draw up a 'City Civil Defence Plan', i.e. a document based on activities of prediction and prevention which, after identification of the risks present in the territory and an accurate census-taking of the resources available, will define the operations to be carried out in the event of a fire disaster.

21
Emergency medical services: rescue potential for mass casualties in urban fire disasters

J. POKORNÝ, P. GETLÍK and J. ŠKACH
Prague Rescue Service, Chair for Emergency and Disaster Medicine, Postgraduate Medical Institute, Prague, Czech Republic

---

The Prague Rescue Service, established 139 years ago by the Lord Mayor of Prague, now comprises 177 ambulances (32 of them MIC Units) 22 physicians, 42 nurses and 220 drivers. The Emergency Medical Service cars with their squads form a network of 12 points in Prague – a city of 1.4 million inhabitants.

In 60% of urgent calls, the time for the ambulance to reach the place of accident is on average 8.5 min. In the year 1991 the Emergency Medical Service responded to 17 139 urgent calls with a doctor in the squad. Since 1988, after an experimental period, the Helicopter Rescue Service has supplemented the E.M.S. with daily availability. In 1991, the Emergency Medical Flight Service provided 847 flights, of which 57% were primary rescue actions (482). The occurrence of burn injuries in the last 5 years has been low in Prague: no more than 1% of all urgent calls.

The Prague Rescue Service is at present able to offer qualified emergency medical care in mass accidents in a reasonable time to as many as 70 critically injured patients and to transport them to hospital.

The former structures of the Civil Defence Medical Service, in order to become functional for disaster medicine, had to be transformed. It has now been reorganized in order to achieve better functional flexibility. The former Medical Relief Units were transformed into Rapid Relief Teams. This renewed system works with the Emergency Medical Service Prague as an additional structure in the event of mass casualties. The Ministry of Health of the Czech Republic has ruled that the Rapid Relief Teams should be formed exclusively of medical professionals, with up-to-date equipment and able to move into action after an emergency call within 60 min. Responsible medical professionals manage the teams and send them into action. The mutual cooperation of both systems under one management has thus been achieved. Also, the considerable means of Civil Defence have been put at the disposal of the citizens in peacetime.

Thanks to the cooperation between experts of the Civil Defence Medical Service and the Prague Rescue Service, the equipment of Rapid Relief Teams has been greatly improved. This unit consists of two physicians and two nurses equipped with medical material and technology sufficient for the care of 30 casualties. The group is activated and transported to the accident site within 60 minutes. Any ordinary car with trailer can transport all the necessary material. The equipment of the Rapid Relief Team is planned to satisfy the requirements of prehospital medical care for burn patients. Dressings for burned surfaces as well as intravenous infusion therapy and analgesia are available.

Rapid Relief Teams are organized in ten different territorial areas of Prague. Thus, in addition to the basic capacity of the Prague Rescue Service, the Civil Defence System is able to extend the volume of medical care to a further 300 casualties in 60 min. The operational centre of the Prague Rescue Service is fully competent to require the immediate supplementation by a Rapid Relief Team. On the spot, the medical response is under the command of the Rescue Service physician, who is skilled and experienced in emergency and disaster medicine. The Rapid Relief Team is subordinated to his authority. This management decision could be accepted because the technical and medical equipment of the Rescue Service and the Civil Defence Medical Service is fully compatible and uniformly packed in sets.

A similar reorganization of the Civil Defence Medical Service structures in Rapid Relief Teams to supplement the E.M.S. is proceeding in regions and districts throughout the whole state territory.

The material of the Rapid Relief Team fits into two specially designed knapsacks and three sports bags (Figure 1). According to the internal arrangement, eight functional sets are available:

- Sets 1, 2 and 3 are placed into one bag and comprise aseptic dressing and surgical material, surgical instruments individually prepacked in sterile covers, splints, A1-folios, bed-sheets and other auxiliary material (Figure 2);
- Set 4 is placed into a knapsack and contains drugs, most as injections, for providing medical support in surgical and medical cases and in intoxications, with a corresponding number of disposable syringes, needles and basic medical aids (Figure 3);
- Set 5 is placed into another knapsack and contains a source of oxygen with a semi-automatic lung ventilator. In the near future this set will be supplemented by a defibrillator (Figure 3);
- Set 6 contains 20 sets of material for providing layman first aid and (Figure 4) one extrication canvas;
- Set 7 contains shock drugs, infusion solutions, infusion sets, a suction unit and a hand-bag respirator;
- Set 8 contains eight stretchers which are freely loaded.

Figure 1. Equipment of the Rapid Relief Team in three sports bags and two knapsacks (without 8 stretchers)

Figure 2. View into a bag containing sets 1, 2 and 3 with the identification card

Medical documentation is performed on identification cards containing identification data and other basic data regarding the type of injury, the care provided, transport priority and the destination of the patient. The cards are part of the set.

Figure 3. Sets 4, and 5 in two knapsacks containing drugs and oxygen source

Figure 4. View of first-aid worker's bag

Emergency and Disaster Medicine, due to its increasing importance, is now given more and more space in programmes for postgraduate medical education. Through common efforts we will succeed in preparing physicians and nurses and in training medical teams capable of working in extreme disaster conditions in defence of the highest of values – human life.

BIBLIOGRAPHY

Ahnefeld, F. W., Dick, W., Kilian, J., Schuster, H. P. (1986). *Notfallmedizin.* Berlin: Springer-Verlag

Manni, C., Magalini, S. I. (1985). *Emergency and Disaster Medicine.* Berlin: Springer-Verlag

Pokorny, J. *et al.* (1981). *Rychlá zdravotnická pomoc (E.M.S.).* Avicenum Praha

Prescriptions and orders of the Ministry of Health for the Civil Defence Medical Service and for the E.M.S.

Section III

Burn prevention

22
The use of a multimedia system in domestic burn prevention campaigns

M. M. FERRARA
Divisione di Chirurgia Plastica e Terapia delle Ustioni, Ospedale Civico, Palermo, Italy

---

Home sweet home! The phrase conjures up the image of an oasis of serenity and safety, a bulwark against the outside world, which is seen as a jungle full of traps and dangers. All this is, however, a myth that cannot survive for long, as statistically the home is the most dangerous place of all for the safety of children, the elderly and the handicapped.

Thirty-six per cent of all accidents happen in the home, and this percentage has increased in recent years with improvements in socio-economic conditions, the prolongation of the average lifespan and the reduced supervision of children in the home.

Every year in Italy 1.7% of the population suffers burn accidents: 45% of these are children between 0 and 12 years of age. Most of the accidents occur in the home, the most frequent cause being boiling liquids, contact with hot objects and electricity.

Hence the need for a domestic accidents prevention campaign, particularly with regard to small children – a campaign that is not easy to realize as it can only make partial use of safety standards prescribed by the law which are applied in industrial plants, factories and the working world in general.

In view of the fact that the fundamental mechanism in all accidents involving young children is a combination of imprudence, inexperience, impulsiveness, curiosity and a desire to imitate the behaviour of older people, we have always believed that an effective prevention campaign should exploit the same approach for both children and adults.

Children have to learn the consequences of performing certain actions. In this way their capacity for learning through direct experience is not limited and their curiosity is in fact satisfied. Adults, meaning all those persons who may find themselves responsible for the health and safety of children, have to be trained in safety-consciousness, informed about the possible risks in the home and the outdoor environment, and instructed in the first-aid measures to be performed on the spot in the event of an accident.

For these reasons, educational, informative and instructive campaigns are of great importance; they must however be conducted according to well-defined protocols and have precise final goals.

In the context of *Perspectives 2000,* it seemed to us to be extremely useful in a childhood burn prevention campaign to use not only educational promotional material already produced, such as posters, pamphlets, albums and videotapes, but also a multimedia system based on the possibilities of presenting the same kind of material through different media coordinated by a personal computer.

This approach presents clear advantages compared to traditional educational means (conventional audiovisual material, courses based on the written word and photographs, etc.) because of the interactivity between learners and the teaching instrument and because of the multimedia presentation of the subject.

Some very significant studies in the field of human learning have shown a relationship between an increase in the number of media employed in transmitting a message and the length of time that it remains in the memory. After 3 days a person can remember 5% of a message that has only been heard, 10% of a message that has only been seen, 50% of a message that has been both heard and seen and as much as 90% if the person has repeated what has been seen and heard.

The multimedia system proposed consists of a personal computer, a videodisk reader, and a touch-screen, i.e. a monitor that reacts to finger pressure on particular parts of the screen. The system helps the user by adding a considerable number of formative and educational potentials to the merely informative input of a conventional audiovisual instrument.

Learners view a videodisk concerning for example the prevention of industrial accidents and by use of an articulated question-and-answer program they are enabled to obtain information – in an aimed and not sequential manner – about the standard procedures of prevention, behaviour and first aid.

The program makes it possible to make active use of the normally passive content of an audiovisual aid, because of the presence of a phase of self-teaching and a phase of self-testing.

The self-teaching phase enables users to follow their own autonomous learning route corresponding to their personal learning capacity, and to revise the various procedures and suggestions made. The self-testing phase enables users to test the validity of their learning route and their level of learning by answering a series of specially designed questions, simply by touching the screen with a finger.

In an accident prevention campaign directed at children, the teachers may operate the system themselves or they may allow the children to use it, in order to check the level of learning attained. This approach makes use of the technique of learning through playing, and incorporates many of the latest technological advances which transform the system into a kind of videogame with increasingly more difficult ability tests that the children have to resolve.

In conclusion, the system will contain a complete program on the prevention of domestic accidents and on the norms of immediate behaviour when they occur, a program characterized by an up to date and dynamic formula that will be popular among its intended users because of its use of techniques that are already in favour. The effectiveness of the system is integrated by a series of files and programs aimed at a wider public including parents, teachers and appropriate authorities.

23
A burn prevention programme

P. VERRIENTI, G. DE DONNO, P. DE SANTIS and A. SAVOIA
Divisione di Chirurgia Plastica e Centro Ustioni, Ospedale Regionale A. Di Summa, Brindisi, Italy

INTRODUCTION

The Department of Plastic Surgery and Burn Centre of the A. di Summa General Hospital in Brindisi, Italy admits as in-patients an average of 340 burn victims per year. This high number is due both to the large area served by the hospital (Figure 1), which includes Apulia, Basilicata, Calabria and Campania, and sometimes even Abruzzi, Marche and Lazio, and to the constantly high incidence of burns in the whole area.

In order to reduce the human and social costs of this endemic disaster we initiated a multimedia prevention campaign (Figure 2) directed at groups of the population considered most at risk. The first step in this campaign was a retrospective epidemiological study of the population of burn patients hospitalized between 1 January 1986 and 31 December 1991.

EPIDEMIOLOGICAL STUDY

A total of 2050 burn patients were admitted between 1 January 1986 and 31 December 1991 (Figure 3), two-thirds to the Department of Plastic Surgery and one-third to the Burns Centre.

The annual distribution (Figure 4) shows a certain variation in the number of patients admitted to the Plastic Surgery Department, while the number admitted to the Burns Centre remained fairly constant, with an annual average of 108 cases, which corresponds to the maximum availability of bed places in intensive therapy. This is demonstrated by an analysis of the monthly average distribution of patients admitted (Figure 5): the number is not steady throughout the year but has two peaks, in winter and summer. This trend is related to the seasonal use of intrinsically dangerous heating systems (e.g. open fires and braziers), school holidays and the use of outdoor barbecues. In the summer period

Figure 1. The geographical area served by the Brindisi Burns Centre

all the beds in the Burns Centre are continuously occupied and a new patient can be admitted only when a bed is vacated. In some months of the year it is therefore necessary to send a considerable number of patients, despite the relative gravity of their wounds, to the Plastic Surgery Department, as shown by the high monthly admissions rate.

An examination of the distribution by age and aetiology of the burn (Figure 6) shows that up to the age of 11 years about 75% of burns are due to the action of liquids, while in older age groups flame is the prevalent cause. The home is the most common site where the burn takes place, the overwhelming majority of burns being due to improper or careless use of widely used objects and substances. In our territory there is a significant difference between the accident rates in the two sexes.

Industrial burn accidents affect almost exclusively males (about 25% of burn patients admitted, in our case histories), while 94% of the women, who normally do not work in dangerous trades with a high burn risk, suffer their burns in the home (Figure 7).

Figure 2. Multimedia campaign

PREVENTION PROGRAMME

On the basis of these findings we identified certain population categories that were more exposed to the risk of burns: inadequately supervised or protected children (Figure 8) and careless or badly informed adults, particularly with regard to improper use of ethyl alcohol (Figure 9).

Certain targets were therefore defined in the prevention campaign:

- adults looking after children or elderly people;
- adults prone to carelessness;
- schoolchildren.

The campaign was promoted multimedially, with brochures for general circulation, televised videotapes and slides to be shown in

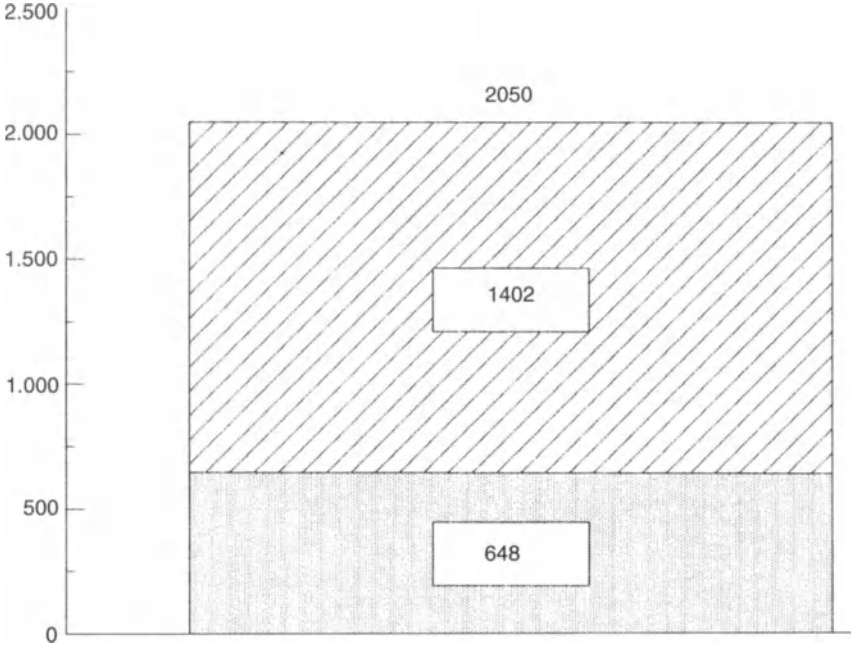


Figure 3. Burn patients hospitalized (1986–1991) ▭ Department; ▨ burns centre

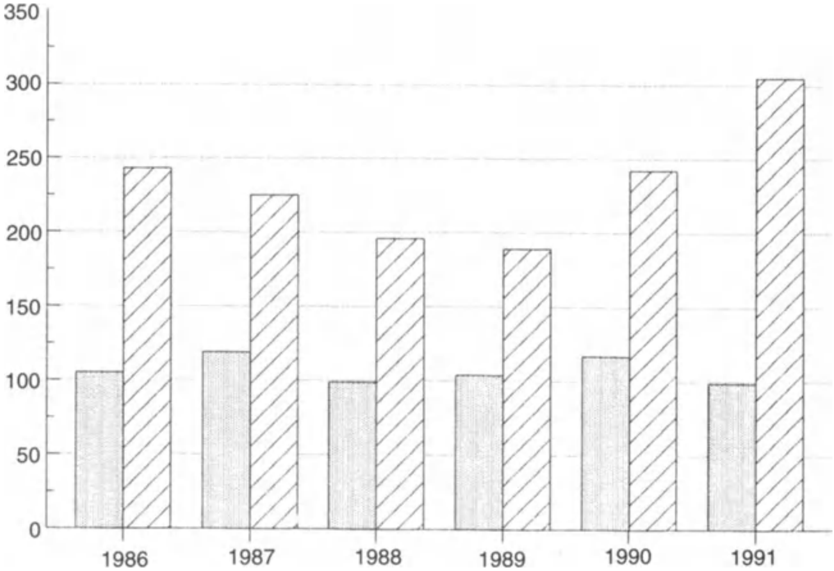


Figure 4. Burn patients hospitalized yearly. Number of burn patients admitted. ▭ Department; ▨ burns centre

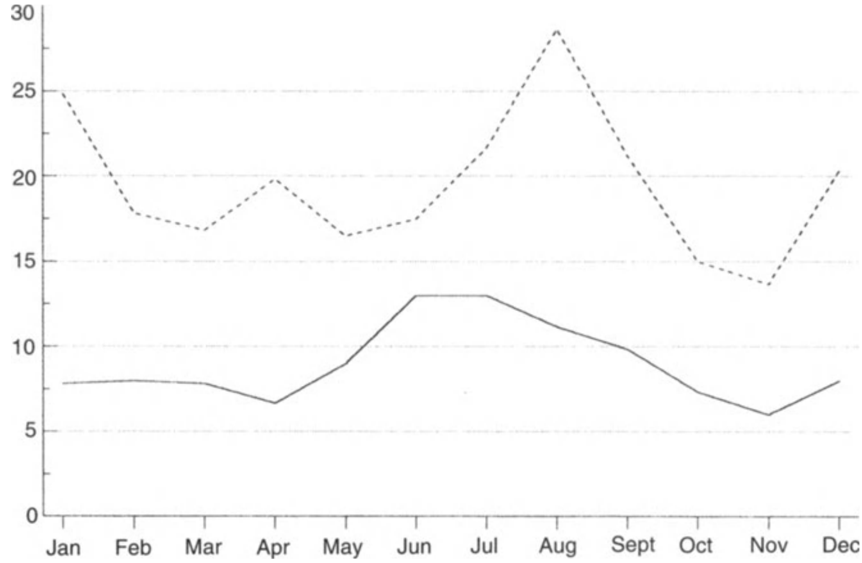


Figure 5. Distribution of admissions per month (1986–1991). Number of burn patients admitted to Department (- - - -) or burn centre (——).

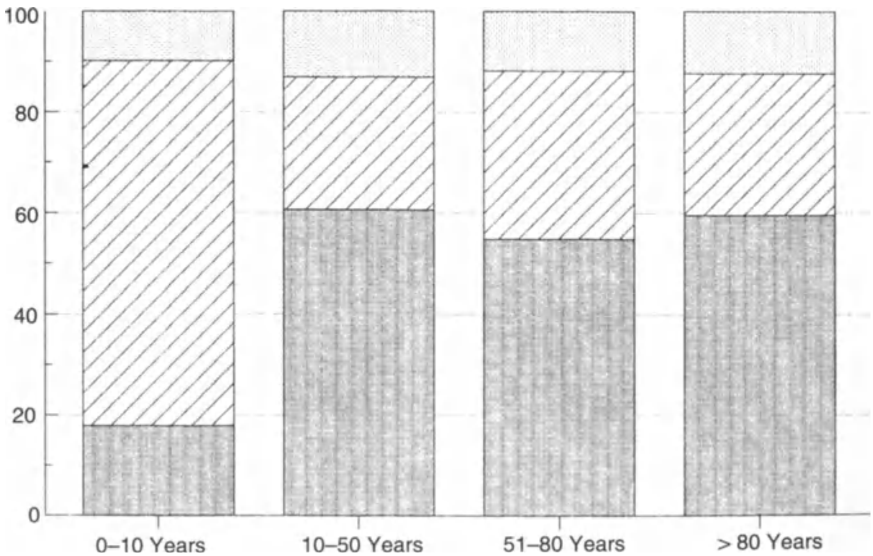


Figure 6. Distribution by age and aetiology (1986–1991). Percentage of burns due to Other, / / Liquids, Flame

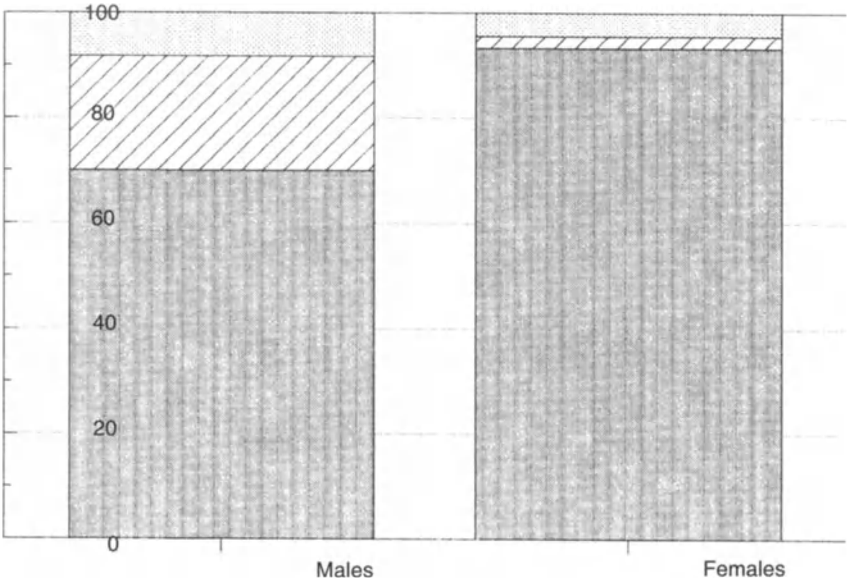


Figure 7. Distribution by sex and site of accident. Percentage of patients with burns suffered. Other, At work, At home

Figure 8. Unsupervised children

public meetings. Particular attention was paid to denatured ethyl alcohol, which might be called the burn specialist's number one enemy. Many serious burns are caused in our territory by careless use of this substance, which is improperly used as a cleaning fluid or as fuel. From this point of view we would draw attention to the extremely dangerous custom of bottling the alcohol in containers made of elastic plastic material, which encourages the custom of squirting the alcohol directly on to flames. One long-term objective of the prevention programme is to lobby for a change in the law regarding the sale of this kind of alcohol and for the abolition of the use of plastic containers. Such a measure could prevent a number of deaths and about 100 other accidents each year in our territory alone.

Figure 9. Improper use of ethyl alcohol

BIBLIOGRAPHY

Barisoni, D., Peci, S., Governa, M., Sanna, A. and Furlan, S. (1990). Mortality rate and prognostic indices in 2615 burned patients. *Burns*, **16**, 373
Benito Ruiz, J., Navarro Monzonis, A. and Baena Montilla, P. (1990). An epidemiologic study of burns. *Ann. Medit. Burns Club*, **3**, 170
Brienza, E., Di Leonardo, A., Minervini, C. and Portincasa, P. (1988). The prevention of accidental burns at home: a proposal for a new protocol. *Ann. Medit. Burns Club*, **1**, 29
Cabanes, J. (1991). Prévention des brûlures électriques. *Ann. Medit. Burns Club*, **4**, 39
De Donno, G., Savoia, A., Mavilio, D., Ostuni, G., Verrienti, P. and Fiume, D. (1992). Studio epidemiologico sugli ustionati ricoverati nel quinquennio 1986–90. *Riv. Ital. Chir. Plast.*, **24** (Suppl.), 133
Elberg, J. J., Schroder H. A., Glent-Masden, L. and Hall, K. V. (1987). Burns: epidemiology and the effect of a prevention programme. *Burns*, **13**, 391
Gilardino, P., Peri, A., Ronchi, A. and Donati, L. (1990). Epidemiologia e prevenzione delle ustioni: esperienze a confronto. *Riv. Ital. Chir. Plast.*, **22**, 79
Linares, A. Z. and Linares, H. A. (1990). Burn prevention: the need for a comprehensive approach. *Burns*, **16**, 281
Lindbald, B. E. and Terkelsen, C. J. (1990). Domestic burns among children. *Burns*, **16**, 254
Marshall, W. G. and Dimick, A. R. (1983). Natural history of major burns with multiple subsystem failure. *J. Trauma*, **23**, 102
Mostafa, M. F., Borhan, A., Abdallah, A. F., Beheri, A. S. and Abul-Hassan, H. S. (1990). A retrospective study of 5505 burned patients admitted to Alexandria Burns Unit. *Ann. Medit. Burns Club*, **3**, 269
Panayotou, P., Alexakis, D., Striglis, Ch. and Ioannovich, J. D. (1991). Epidemiological data on burn injuries in Greece: a statistical evaluation, *Burns*, **17**, 47
Rossignol, A. M., Locke, J. A. and Burke, J. F. (1990). Paediatric burn injuries in New England. *Burns*, **16**, 41
Scott-Conner, C. E. H. and Meydrech, E. (1988). Quantitation of rate wound closure and the prediction of death following major burns. *Burns*, **14**, 373
Sørensen, B. (1976). Prevention of burns and scalds in a developed country. *J. Trauma*, **16**
Tejerina, C., Reig, A., Codina, J., Herrero, J. and Mirabet, V. (1991). An epidemiologic study of gunpowder wounds. *Ann. Medit. Burns Club*, **4**, 177

24
Burn injuries in children

M. HABERAL and N. UÇAR
Turkish Transplantation and Burn Foundation, Ankara, Turkey

INTRODUCTION

Burn injury is one of the main medical and socio-economic problems facing societies throughout the world, the number of casualties and causes varying from country to country (Dobrokovsky, 1984; Haberal, 1987a). At our Centre, approximately 100 patients are admitted due to burn injury each year. The majority of these burn injury victims are children. The frequency of burn injury is fairly high in almost every country but fortunately the majority of burns range only minor to moderate (Haberal, 1987b; McDougal, 1978). However, the subject of burn injury still remains a world-wide concern for physicians and health care personnel, as well as for the victim, from a psychosocial, economic and emotional perspective. It is therefore mandatory that burn treatment should be handled by well organized prevention and rehabilitation teams and collective education programmes on a national and international basis. This study portrays the treatment of 512 children admitted to our Centre during an 11-year period.

MATERIALS AND METHODS

Between 1 January 1979 and 31 December 1992 a total of 1005 patients with various burn injuries were treated at our Centre, including 579 children (aged 0–15 years) who were admitted (Figure 1). These children were analysed with respect to age, burn area, duration of hospital stay, cause of burn and treatment results. All patients were treated with the Parkland formula, namely Ringer's lactate solution, of which 2–3 ml/kg/percent burn area was given during the first 24 h. The amount of fluid administered was calculated from the time of admission to the hospital.

During the second 24-h period, if the patient could not be fed orally, plasma was administered according to the patient's weight, which was augmented by at least 1 g of protein per kg, and providing that the patient was responding well to treatment, he or she was mobilized as soon as possible. The three methods of treatment for moderate and severe burn wounds were open, with a dressing, and biological treatment. As in many other centres around the world, mafenide acetate (sulfamylon) cream was used for open wound treatment. Silver sulphadiazine was mainly used on it. Severe infection occurred, with sulfamylon being used occasionally in order to decrease the growth of resistant bacterial colonies and the side-effects of sulfamylon.

Since 1978, 0.5% silver nitrate-incorporated amniotic membrane (SNIAM) has been used as a biological dressing (Haberal, 1987c).

RESULTS

Of the 579 paediatric patients, 301 were male and 278 were female (mean age 4.47–3.68 years). While 68% of the major burns occurred in the 0- to 6-year-old category, only 32% concerned children in the 7- to 15-year-old category (Figures 1 and 2). A total of 517 patients with non-electrical burn injury and 62 patients with electrical burn injury were admitted to hospital. The causes of non-electrical burn injuries were: hot water, 272 (52.61%); flame, 161 (31.14%); hot milk, 47 (9.09%); hot meal, 20 (3.86%); LPG gas explosion, 17 (3.28%); hot olive oil, 7 (0.96%) and hot metal, 2 (0.38%) (Figure 3). Most of the children were from rural areas and belonged to a low socio-economic level.

Mean burn surface area (TBSA%) in these patients was 26.61 ± 16.55% of total body (range, 0.5–100%). The mean duration of hospital stay was 26.5 ± 34.5 days (range, 1–270).

The most common cause of burns in children was hot water (52.61%). In the non-electrical burn injury group, 160 patients (30.94%) died, whereas in the electrical burn injury group 12 patients (17.35%) died.

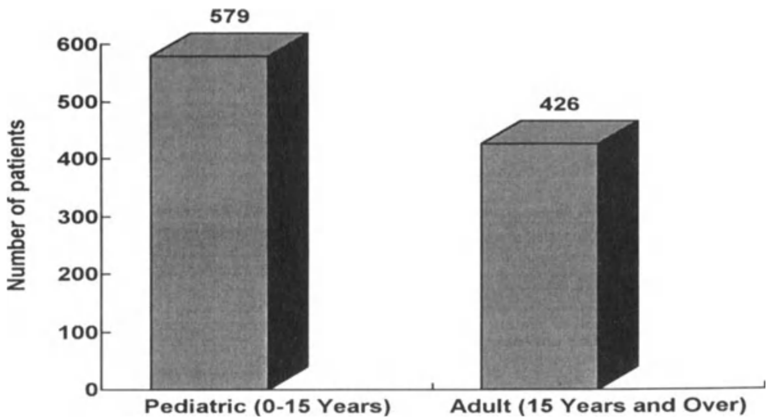


Figure 1. Number of paediatric and adult patients

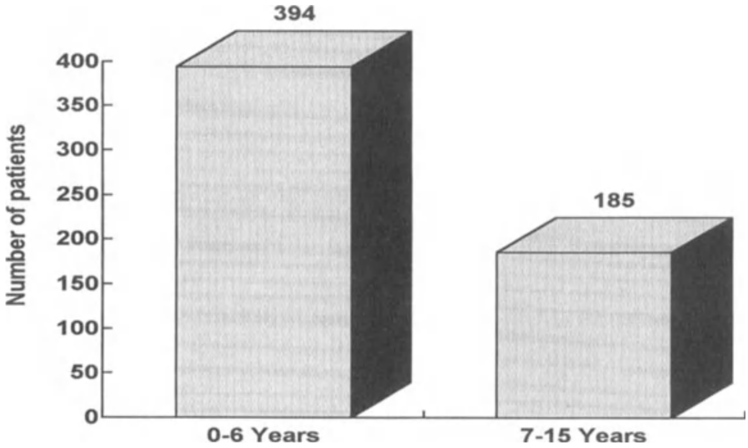


Figure 2. Age distribution of paediatric patients

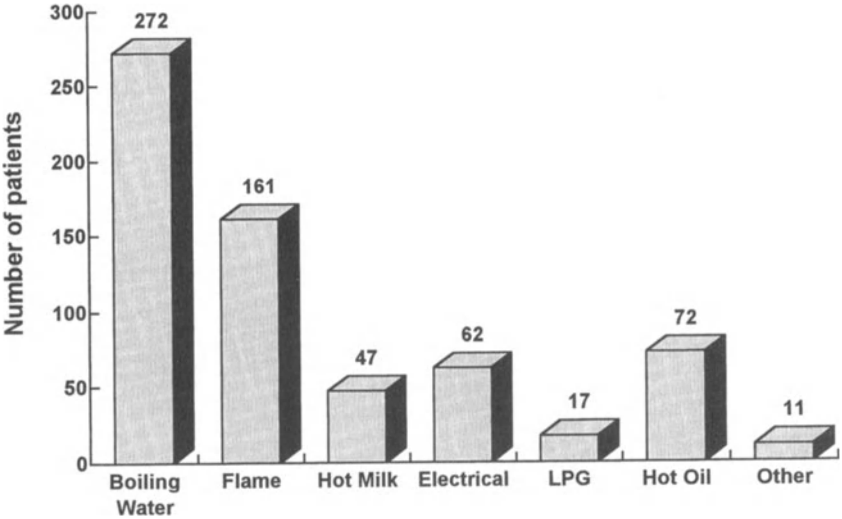


Figure 3. Causes of burn injury

With regard to the incidence of death, the most important cause of non-electrical burn injuries was found to be hot milk (61.70%). The overall mortality rate was 29.7% (172 patients).

DISCUSSION

Although most burn injuries treated at our Centre were classified as minor, requiring brief or no admission, burns remain one of the most important problems existing in our society (Haberal, 1987b; McDougal, 1987). The majority of hospitalized patients were children aged 0–6 years, with injuries due mostly to scalding. These injuries were attributable to lack of parental supervision and improperly placed heating devices in kitchens and bathrooms. The mean hospitalization period was from 1 to 270 (26.5 ± 34.5) days, which is considered quite a long time for a child, when all the emotional factors that affect the patient and the family are taken into consideration.

Hot milk casualties led to the highest mortality rate. The cause of death in these cases was generally sepsis.

In Turkey, burn injuries continue to claim hundreds of young lives (Haberal, 1987b). In order to prevent this life-threatening event, measures must be taken by health care officials and physicians regarding the education of the public for further burn prevention through every available means of communication possible.

In conclusion, the reduction of the overall mortality rate of 31.4% in paediatric burn patients is vitally necessary and requires the establishment of organized treatment, prevention and rehabilitation and collective education programmes on a national and international level. Otherwise society will continue to be plagued by burn casualties claiming many lives. Most accidents are due to lack of parental supervision, and to non-awareness of the dangers that lie within reach of children, such as improperly placed heating devices in kitchens and bathrooms.

REFERENCES

Dobrokovsky, M. M. (1984). Burn survivors in Canada. *Dial. Transplant. Burn*, **2**, 22

Haberal, M., Öner, Z., Bayraktar, U., Bilgin, N. (1987a). Analysis of 745 hospitalized burn patients. *Ann. Medit. Burns Club*, **1**, 45–47

Haberal, M., Öner, Z., Bayraktar, U., Bilgin, N. (1987b). Epidemiology of adults' and childrens' burns in a Turkish burn center. *Burn*, **13**, 136

Haberal, M., Öner, Z., Bayraktar, U., Bilgin, N. (1987c). The use of silver nitrate-incorporate amniotic membrane as a temporary dressing. *Burn*, **13**, 159

McDougal, S., Slade, W. (1978). *Comprehensive manuals of surgical specialities. Manual of Burns*. Berlin: Springer-Verlag, p. 3

25
Burns prevention in a paediatric population

ZORAN GOLUBOVIC, GORDANA JANJIC, DRAGOSLAV PARABUCKI and IVANA PETRONIC
University Children's Hospital, Tirsova 10, 11000 Belgrade, Yugoslavia

INTRODUCTION

Burns have an important place in the pathology of children due to their frequency and gravity. Thermal trauma is second only to car accidents as a cause of death during childhood and is still a leading cause of accidental death in the home among children aged 1–14 years.

About 50% of all burns treated concern children under the age of 14 years. The number of burns recorded in children's school medical centres in Belgrade in the last 3 years vividly shows how widespread these burns are in our environment. Figure 1 shows that children in the 0–6 years age range are most affected.

MATERIALS AND ANALYSIS OF THE DATA

During a 1-year period, at the University Children's Hospital, Clinic for Paediatric Surgery, we treated 124 burn patients as in-patients and 456 as out-patients (Table 1). An analysis of our study of these patients (aged 0–14 years) shows that infants and youngsters up to the age of 3 years have a disproportionately high number of burn accidents. This group accounts for nearly 61% of all children's burns (Table 2). This age group is characterized by rapid motor development and great interest in the environment, with learning about the surroundings primarily being

Table 1. Number of treated patients

Hospitalized	124
Out-patients	456
Total	580

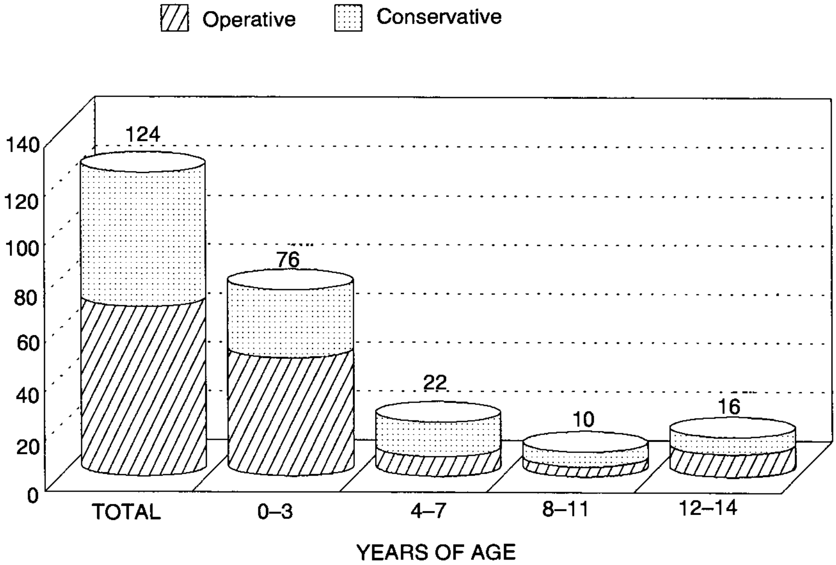


Figure 1. Age and treatment of hospitalized patients

Table 2. Age and treatment of hospitalized patients

	0–3 years	*4–7 years*	*8–11 years*	*12–14 years*	*Total*
Operative	48	8	4	9	69
Conservative	28	14	6	7	55
Total	76	22	10	16	124

conducted by the sense of touch (which is the oldest with regard to phylogenetic development). Infants aged 1–2 years learn to walk with the aid of anything they can hold to pull themselves into a standing position. The number of burn injuries reduces in each period from 3 to 12 years, but rises again as older children become more active in the use of electric devices and the improper use of flammable materials.

An analysis of burns must consider not only their frequency but also their extent and depth (Figure 2, Table 3). The extent of burns in children is also influenced by the fragility of the child's body: a burn surface which does not represent a serious injury in an adult and does not require surgery, will cause a more serious pathophysiological disturbance in a child and require adequate general and surgical treatment. Comparing the types of agent causing the burn injury we can see that the most frequent cause of burns in children treated and hospitalized in our clinic over 1 year is related to scalds caused by boiling water, soup, milk and coffee (Figure 3). The majority of burns in the 0–3 years age group were sustained by pulling on an object or during play and play-

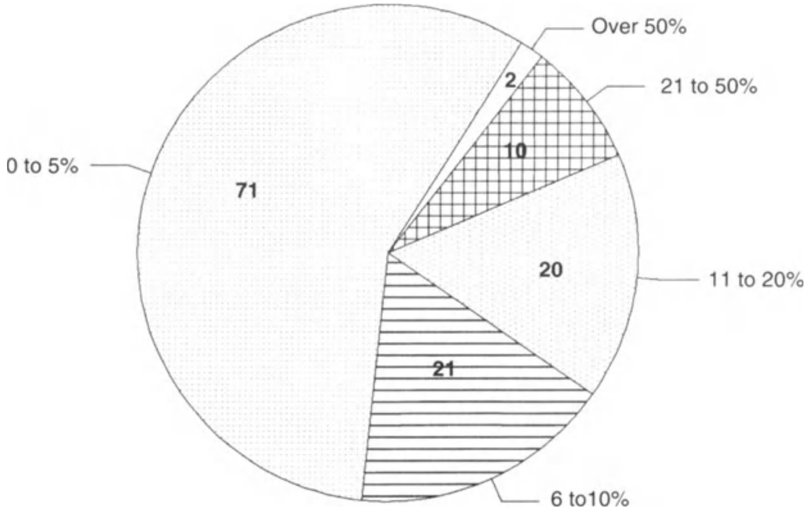


Figure 2. Percentage of body surface burned in hospitalized patients

Table 3. Thickness of burns (hospitalized patients)

Thickness	*No. of patients*
Superficial partial (epidermal)	55
Deep partial (dermal)	56
Full thickness (subdermal)	13
Total	124

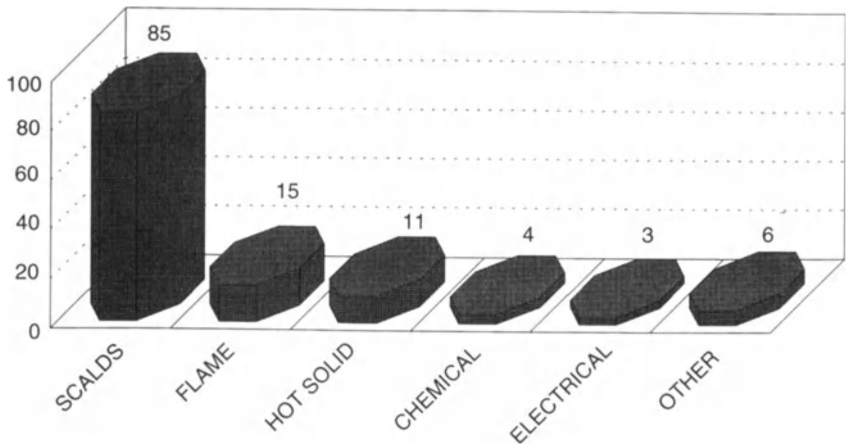


Figure 3. Cause of burns (hospitalized patients)

learning behaviour. Contacts with hot solids come second. In the same period burns caused by flame were of significant importance in the older age groups. The extent and most frequent localization of such burns in our patients are shown in Figures 5–9.

PREVENTION

In spite of the developments achieved by modern plastic and reconstructive surgery, which allow the recovery of the majority of burn patients, children are often left with physical and psychological sequelae. Anyone who has cared for or seen a child with severe burns appreciates the need for vigorous preventive activities. The prevention of burns requires accurate epidemiological and other research in the field, plus evidence of the causes and programmed health education work for the public. The mass media may be effective for developing positive behaviour. Educational programmes should be directed against flame burns because of their severity and against scalds because of their frequency.

Figure 4.

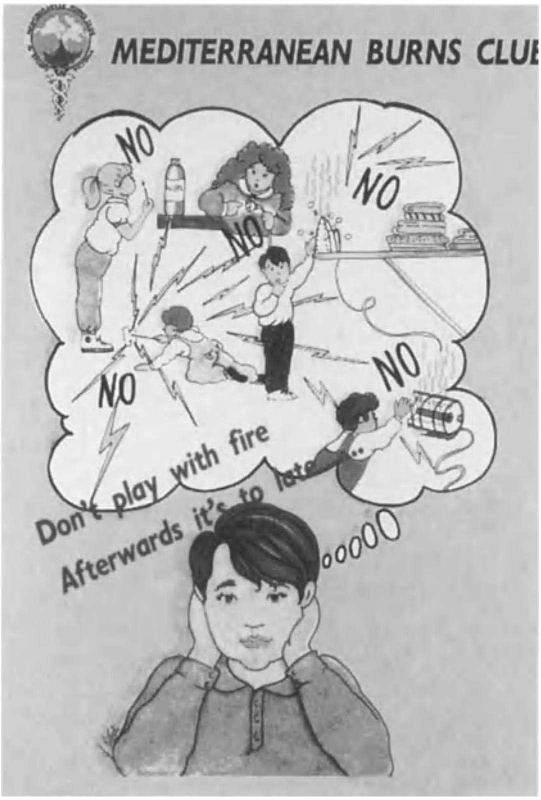


Figure 5.

A specific mixture of historical hazards that affected children in the past, who grew up in an environment less complicated than our technologically developed world, and of some advanced environmental modifications is presented in our population. For this reason children require supervision and education by parents or other responsible members of the family. It is important to use practical demonstrations of the safe way of using technological innovations and of indicating their potential hazards. The child's hazardous environment can be modified by means of educational programmes focusing on where and how accidents occur. Parental awareness of the dangers should help to reduce accidents. Strategies to eliminate the risk of burns in the kitchen include: storing electric appliance cords out of reach of small children, avoiding the use of tablecloths when hot items are served, placing hot food containers in the centre of the table, and not holding young children in the lap while drinking hot beverages.

In order to prevent infection and to reduce the burn depth, parents should be taught how to give first aid and informed of the importance of correct medical treatment given as soon as possible.

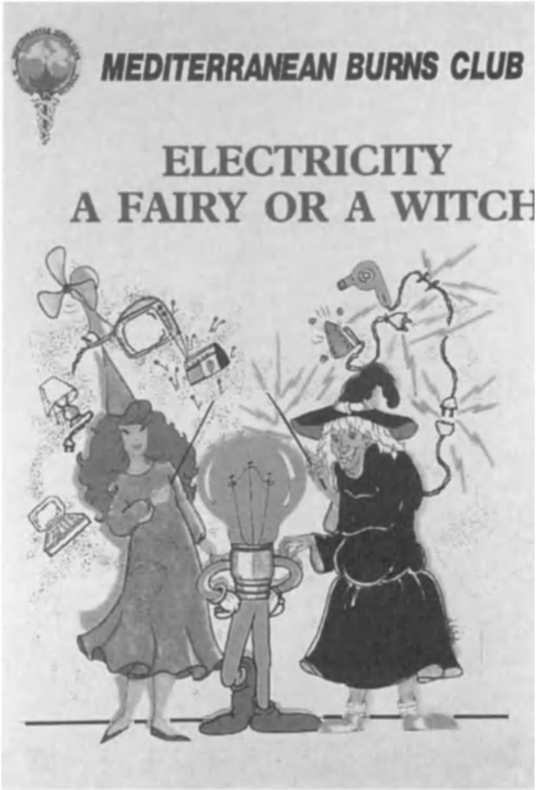


Figure 6.

The prevention of injury-related invalidity requires the initiation of medical rehabilitation during the phase of medical treatment, together with the training of parents so that they can continue treatment at home.

CONCLUSION

The aim of this work is to point out that, in spite of progress in successful treatment, a number of contemporary consequences may subsequently affect the burned child, and we must therefore cast a wide net of measures for prevention of burns. Preventing burns in children is more complex because as a result of their young and more vulnerable age it can be done only by educating the parents; it can be done directly only with children of school age. Health education provides new knowledge and forms new habits, but young children cannot receive the knowledge or form new habits without the assistance of their parents.

Our experience in treating burns has revealed inadequate first aid given by parents and sometimes even by medical staff, which points out

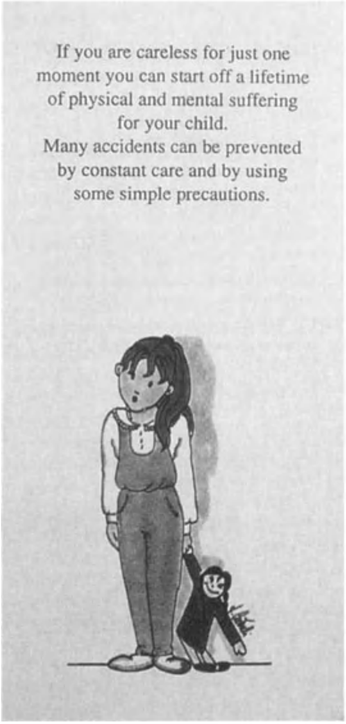


Figure 7.

Figure 8.

Figure 9.

the need for the education of parents and the updating of medical knowledge for operators in the field of elementary first aid for burns. Established burn centres should recognize their obligation to teach burn and fire prevention, in addition to providing care for patients once they have been injured.

BIBLIOGRAPHY

Rivlin, E. (1988). The psychological trauma and management of severe burns in children and adolescents. *Br. J. Hosp. Med.*, **40**, 210–215

Walker, A. R. (1990). Fatal tapwater scald burns in the USA, 1979–86. *Burns*, **16**, 49–52

Warden, G. D., Brinkerhoff, C., Castellani, D., Rieg, L. S. (1988). Multidisciplinary team approach to the pediatric burn patient. *Qual. Rev. Bull.*, **14**, 219–226

NOTE

The educational posters illustrated here and burn prevention literature can be obtained from the Mediterranean Burns Club.

26
In-depth investigation of the causes and prevention of minor burns treated at a Turkish burn centre

N. UÇAR and M. HABERAL
Turkish Transplantation and Burn Foundation Hospital Ankara, Turkey

INTRODUCTION

Although the majority of burns are minor and can be treated on an out-patient basis, epidemiological studies concerning minor burns in our region have rarely been performed. The present study was carried out in order to focus on the causative factors of minor burns and subsequently to emphasize the recommendations for multidisciplinary prevention of these burns.

PATIENTS AND METHODS

A total of 100 consecutive burns, treated between 1 February 1992 and 4 July 1992 on an out-patient basis at the Turkish Organ Transplantation and Burn Foundation Hospital, were investigated, in order to define the possible causative factors and their prevention. Since our out-patient department is one of the most important referral centres for out-patient burns, the results may provide information regarding the epidemiological pattern of minor burns occurring in our region. Patient data were evaluated according to age, sex, site of injury, depth of the burn, place of occurrence and detailed causes. All patients were treated according to a treatment protocol consisting of premedication and topical therapy with nitrofurazone-embedded fine mesh gauze following cleansing with povidone iodine solution (Uçar and Haberal, 1982). All the patients were followed up until complete healing occurred.

Results

Fifty-four patients were children up to the age of 15 years and 46 were over 16 years of age. The female to male ratio was approximately one to one (Figure 1). Six patients had burns on the head and neck region, one on the trunk, 31 on the upper extremity and 35 on the lower extremity. In 27 cases burns occurred in multiple parts of the body. Fifty-seven out-patients sustained second-degree burns. Thirty-two and 11 had first-degree or superficial second-degree burns and deep second-degree or third-degree burns, respectively. The majority of the burns (85%) occurred at home. Twenty-three home accidents happened in the kitchen and two in the bathroom. Eleven cases were due to occupational accidents. Sixty-seven and 12 patients had scalds and flame burns, respectively. Three electrical and two chemical burns, plus one severe sunburn were observed. Seven patients had burns caused by hot metal (Figure 2).

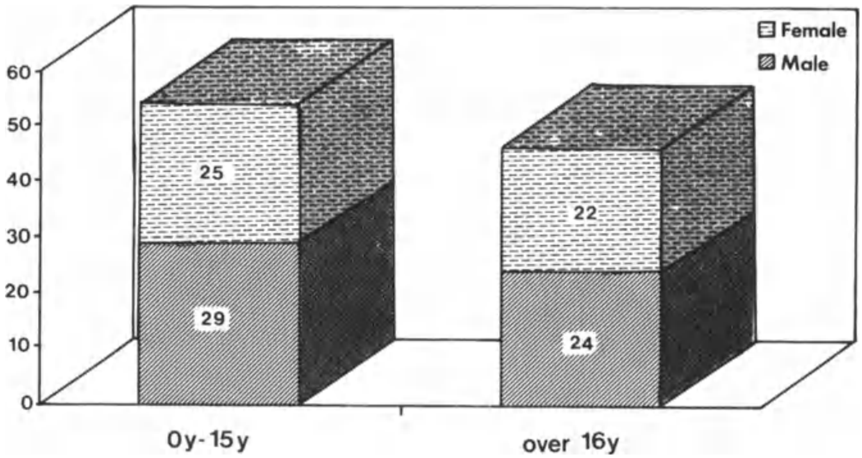


Figure 1. Distribution of the patients according to age and sex

The majority of scalds (33 cases) were due to hot tea or water boiled for the preparation of tea. Tap water scalding was observed only in one case following a syncopal attack. Eight burns were caused by spilling of hot oil or fat (Figure 3). Flame burns were caused by a variety of agents, including oil (two cases), LPG (four), thinner (one), gasoline (two), flammable gas (two), alcohol (one).

DISCUSSION

The causes of the burns were related to habitual actions, inappropriate product design, lack of burn prevention education, and negligence.

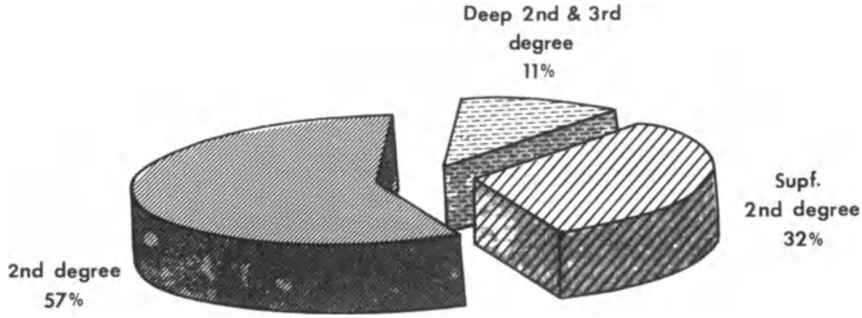


Figure 2. Distribution of patients according to causes

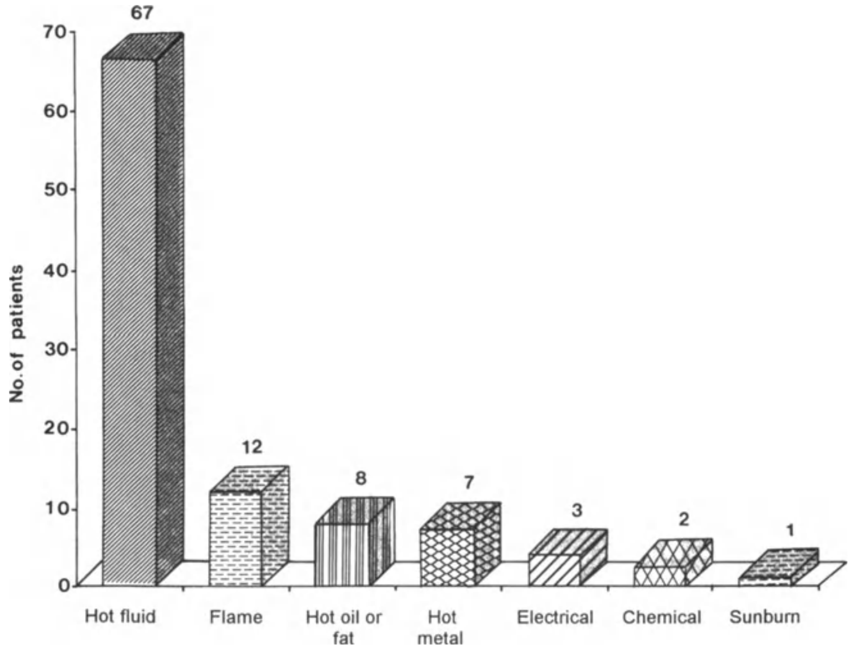


Figure 3. Causes

Scalds were usually caused by spilled hot tea or water boiled for making tea, and most of the accidents could have been prevented by not serving tea too hot and by redesigning the dangerous, conventional tea maker, which consist of one pot on top of the other, as with the dramatic reduction in the number of scalds achieved following the redesigning of coffee makers and the introduction of automatic coffee machines (Sorensen *et al.*, 1976; Klasen, 1986).

The home was found to be the main place where thermal injuries occurred, as a result not only of carelessness but also of inappropriate interior design and the design of kitchen equipment. However, the absence of burns due to ignition of clothing and the occurrence of only one tap water scald may be attributed to the success of environmental control in recent decades. These findings correlated with those reported by McLoughlin (1987), Lyngdorf (1986) and Katcher (1987).

Lack of parental supervision also had to be considered in the present study, since children accounted for more than half the out-patients. They were mostly toddlers and preschool children, similar to findings reported previously for hospitalized patients (Haberal *et al.*, 1987, 1988). Flame usually caused burns of the hands and face together, when the victim tried to throw out the flaming LPG tube or pan because of lack of knowledge as to how to extinguish the flame. LPG containers still continue to be a causative factor, although risk could be eliminated by giving up the irrational method of checking for leakages using a match or lighter. The use of small containers at home is another aspect of the problem. Occupational accidents commonly occurred owing to negligence of daily checks and to the employment of unqualified young apprentices without any education about burn prevention.

CONCLUSION

The present study stresses that a comprehensive approach is necessary for the prevention of minor burns. The multifactorial occurrence of burns should be considered when preventive measures are taken. These should include improvement of the environment by the redesign of home interiors and certain products, as well as educational programmes. Occupational accidents can be prevented only by insistence on strict safety measures.

REFERENCES

Haberal, M., Oner, Z., Bayraktar, U., Bilgin, N. (1987). Epidemiology of adults' and children's burns in a Turkish burn centre. *Burns*, **13**, 136

Haberal, M., Oner, Z., Bayraktar, U., Bilgin, N. (1988). Analysis of 745 hospitalized burn patients. *Ann. Medit. Burns Club*, **1**, 44

Klasen, H. J. (1986). Changing pattern in the causes of scalds in young Dutch children. 7th International Congress on Burn Injuries. Melbourne, Australia, 23–28 February 1986, p. A46

Katcher, M. L. (1987). Prevention of tap water scald burns: evaluation of a multimedia injury control program. *Am. J. Public Health*, **77**; 1195

Lyngdorf, P. (1986). Epidemiology of scalds in small children. *Burns*, **12**; 250

McLoughlin, E. (1987). Update on clothing flammability and burns. *Proc. Am. Burn Assoc.*, **19**, 71

Sorensen, B., Werner, H., Asmussen, C. F. (1976). Coffee scalds – pursuant prophylaxis. *Burns*, **3**, 166

Uçar, N., Haberal, M. (1992). Evaluation of the conservative ambulatory burn treatment with nitrofurazone-embedded fine mesh gauze in 100 consecutive patients. 2nd International Conference on Burns and Fire Disasters: Perspectives 2000. Palermo, Italy, 30 September–3 October 1992, p. A85

Section IV

Epidemiology, geographic pathology

27
Burns in Russia: The statistics and organization of specialized medical care

V. A. ZHEGALOV, N. A. PONOMAREVA, V. A. SASCHENKOV and A. V. RAZUMOVSKIY
The Republican Burns Centre, Research Institute of Traumatology and Orthopaedics, Nizhniy Novgorod, Russia

---

The first specialized burns departments in Russia were opened in 1938–1939 at the Emergency Medical Care Institute in Leningrad (St. Petersburg) and at the Experimental Surgery Institute of Moscow. The burns department of the Nizhniy Novgorod Research Institute of Traumatology and Orthopaedics opened in 1961 and the Russian Burns Centre was organized in 1966. The main tasks of the centre were investigations into burn epidemiology, the pathogenesis of the burn disease, improvement of conservative and surgical treatment of burns and their sequelae, and provision of methodical and consultative help to the burns centres in Russia.

The burns rate both in Russia and in the rest of the world is constantly increasing. Over 700 000 burned patients are registered in Russia every year, of whom 170 000 to 180 000 are hospitalized (40% children). About 15 000 (2%) die of their burns either immediately or in hospital. As a rule, burned patients, including those who die, are the able-bodied and children, and the management of burns is a long and expensive process. Burns, both in Russia and in other countries, are therefore of great social and economic importance.

At present 75 burns centres with 4000 beds (0.27 beds per 10 000 people) are operative in Russia. Most of the burns departments (88.6%) have 40–85 beds, and the rest less than 30. Most of the burns centres (77.2%) are in large hospitals and research and medical institutes, which makes it possible to use up-to-date methods of diagnosis and treatment of burns and their complications. The formation and development of the burn service in Russia are shown in Figure 1.

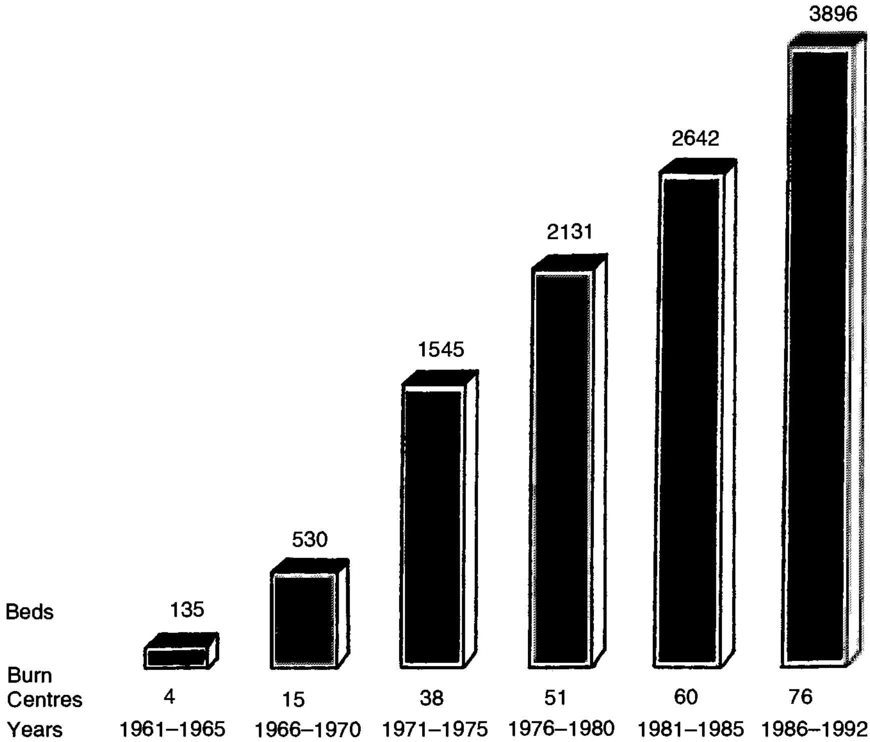


Figure 1. Development of specialized burn service in Russia

Among the hospitalized burned patients, 75–80% have superficial and limited-area full-thickness burns, which can be treated in surgical and traumatological hospitals. The remaining patients with superficial and full-thickness burns of the head, face, neck, feet, large joints, perineum and genitalia and patients with extensive burns of second, third and fourth degree are admitted to specialized burns centres.

The proportion of patients with both surface and full-thickness burns ranges from 25 to 35%. Though small, this group causes the staff much trouble with respect to management and requires the largest financial and material spendings.

Mostly, patients with burn sequelae are treated at the Russian Burns Centre in Nizhniy Novgorod and the Vishnevskiy Surgical Institute in Moscow. In other burns departments such patients are very few (4.5–9%). The problem of the adequate management and rehabilitation of patients with burn sequelae is, however, becoming more critical because of the growing number of patients surviving severe extensive burns and the lack of specialized beds and experienced surgeons. Every year the number of patients requiring plastic surgery increases by 8000–10 000. In the last decade, the primary invalidity rate among burned patients has been 0.1% (or 0.5% of all individuals with full-thickness burns).

The most significant sign characterizing the efficiency of specialized burns centres is the reduction of the indoor treatment period (until final epithelialization of burn wounds and donor sites) due to more active management of patients with full-thickness burns (Figure 2). In 1986–1990 the treatment period was 6.5 (from 46.7 to 40.2) and 17.8 days shorter than in 1981–1985 and 1970–1975 respectively.

In the last decade (1981–1991), total mortality rate both among all hospitalized burned patients and those treated only in burns departments greatly decreased (Figure 3, lines I, II). The large reduction in mortality due to full-thickness burns played a major role (Figure 3, line III). The reduction in length of hospital treatment and the drop in mortality were due to the introduction of active surgical management of severely burned patients, especially those with full-thickness burns. Such active surgical treatment is a complex of different methods aimed at restoration of the skin within 1–2 months of the trauma, i.e. before the manifestations of irreversible changes that cause severe complications and death.

This aim has been achieved by:

- rapid release of burn wounds from necrotized tissues by early necrectomy (with single-step or delayed autodermoplasty) or necrolysis with chemical, enzymatic or bacteriological agents;
- performing the initial autodermoplasty on prepared wounds of the functional parts of the body, without the total release of the whole, often very extensive, burned surface from mummified burn crusts within 16–20 days post-trauma;
- maximum reduction (to 5–7 days) of the intervals between repeated

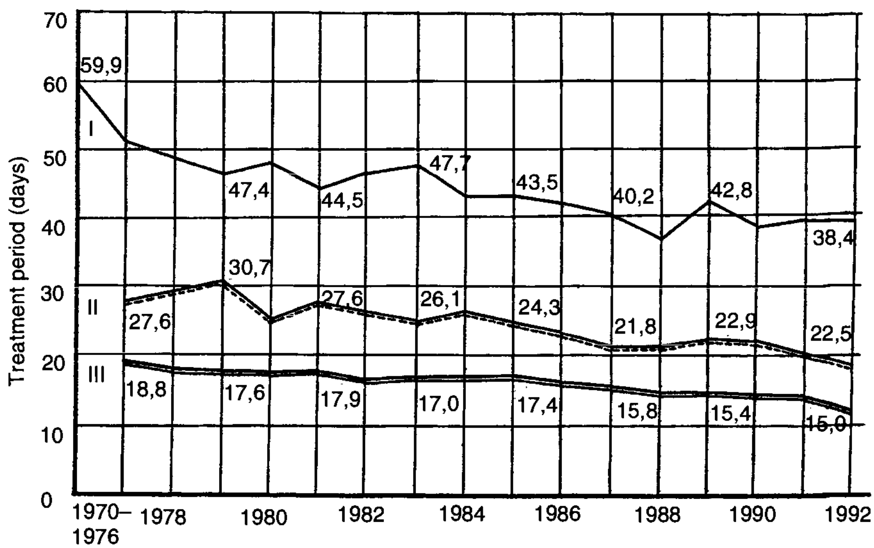


Figure 2. The dynamics of the treatment period of burned patients in Russia. I – patients with full -thickness burns in specialized departments; II – all burned patients in specialized centres; III – all burned patients in Russia

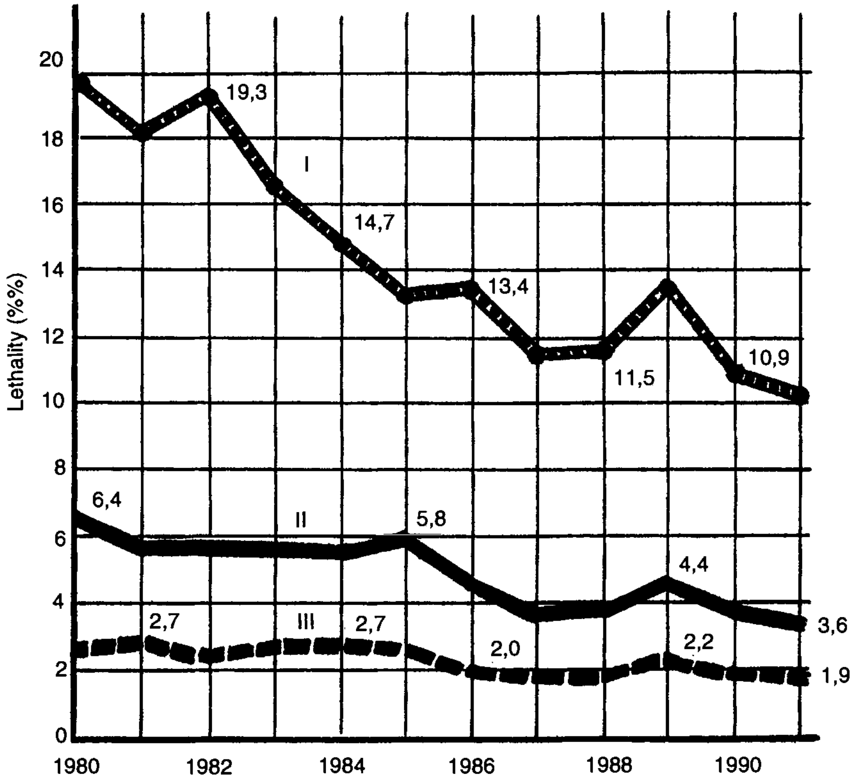


Figure 3. The dynamics of lethality in burned patients in Russia

skin grafting in order to prevent the autoimmune destruction of autografts and their lysis from aggravating results of the operation;

- enlargement of the maximum volume and transplantation area during subsequent operations by improvement of the general condition of severely burned patients and of homeostatic stability;
- providing aseptic donor site wound healing with artificial wound coverage and biological and other bandages, plus rational use of the undamaged donor skin;
- use of sparing general intravenous anaesthesia methods during multiple plastic surgery operations, and prophylactic intravenous infusion of media and blood in the most traumatic moments of the operation in order to prevent the development of shock;
- early contracture prophylaxis and functional rehabilitation of the joints during and after skin integument recovery.

The Russian Burns Centre carries out a large amount of methodical and consultative work in order to help the provinces. The further development and improvement of specialized medical care of burns and their sequelae are restrained by considerable organizational drawbacks: financial insufficiency for burn patient maintenance, the number of staff in burns centres, their geographical distribution, and their medical and material supplies. Special efforts and financial support are required to develop burns departments in those parts of Russia that lack them. It is necessary to organize new regional centres for early postburn rehabilitation with hospital–clinic complexes for severely burned adults and children. The question of outpatient care to burned individuals remains unsolved because of the lack of burns specialists.

The inpatient treatment of individuals with burns and burns sequelae is considered to be the most difficult and expensive medical care in the world. It is not surprising that in highly developed countries the treatment of burned patients is provided by the state at high level. This is not the case in Russia. The specialities of burns expert and plastic surgeon are not distinguished in the Health Ministry list of medical professions, which prevents our organizing and publishing a journal on burns and their sequelae, research work and achievement of more successes in the treatment of patients.

The Russian burns experts and plastic surgeons are fully aware of their tasks and they will do their best to fulfil them successfully. We hope that the commercial and scientific cooperation with specialists in the leading foreign burns centres that is now being developed will help us in our noble joint efforts and produce its mutual benefits.

28
Domestic burns due to butane gas explosion in Algeria

B. MITICHE and R. BOUAYAD AGHA
Service des enfants brûlés, C. H. U. Bab-El-Oued, Algiers, Algeria

INTRODUCTION

Domestic burns in children due to explosion of gas are relatively common in Algeria. Reasons for this include:

- Poor housing conditions.
- Widespread use of butane gas which is often defectively bottled (absence of joints, overpressure), inducing imprudent persons to open up the bottles to decompress them in the open air, with the risk of disastrous explosions.

These accidents are always serious (in the present series the death rate was 40%). Again, there are several reasons:

- Frequency of associated respiratory burns.
- Young age of children.
- Frequently considerable extent of burns.
- Inadequate facilities for admission of burned children in our country (only one centre for burned children and two for adults in the whole national territory).
- Burns centres not corresponding to basic standards and not possessing all the necessary equipment, means and professional staff; this is related to the economic situation of the country.

MATERIALS AND METHODS

In the 10-year period 1982–91 156 children burned in butane gas explosions were admitted to the Algiers Burns Department. There was a prevalence of females, which can be explained by the fact that girls spend more time at home helping their mothers (Figure 1). Pre-school

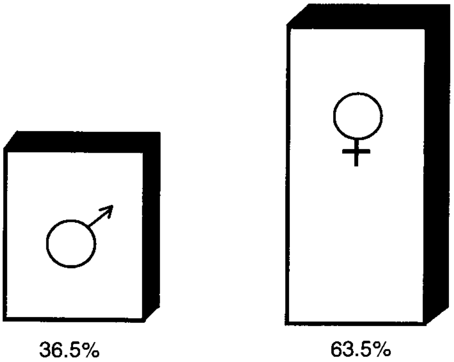


Figure 1. Sex distribution of patients

children (age 5–6 years) were the most commonly affected: this worsens prognosis (Figure 2).

Most patients suffered burns to an extensive body surface area (BSA) : in 75% this was >20% BSA (Figure 3). The majority of patients spent <15 days in hospital (Figure 4). Sixty-three children (40% of cases) died. This is a high death rate (Figure 5).

A study of the relationship between deaths and age, BSA and length of hospital stay showed that the majority of deaths (60%) occurred in children who were <5 years old and suffered burns to >40% BSA. More than 84% of deaths occurred before day 8 post-burn. This raises the problem of the frequently associated respiratory burns and of blast injuries.

In this type of domestic disaster, several members of the same family are often involved together. The following findings were made:

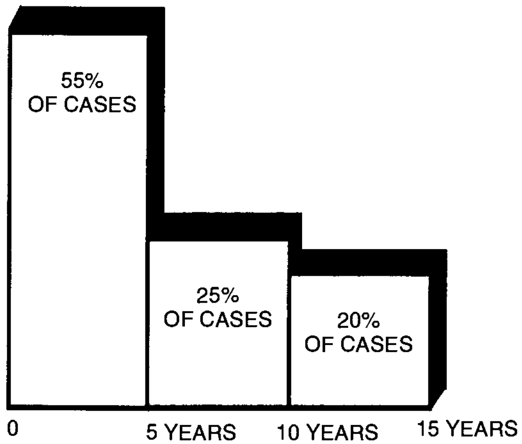


Figure 2. Age distribution of cases

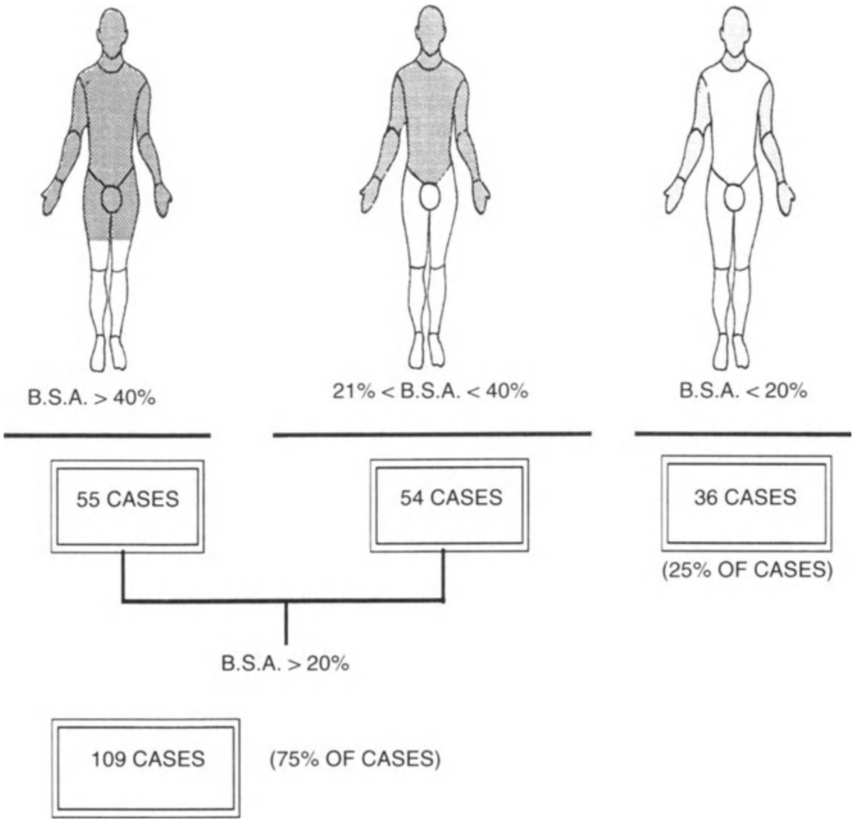


Figure 3. Percentage body surface area burned

- five members of one family burned nine times in the series.
- four members of one family burned 25 times in the series.
- three members of one family burned 25 times in the series.
- two members of one family burned 41 times in the series.

OBSERVATIONS

The following conclusions can be reached

1. The frequency of domestic butane gas accidents is essentially due to socioeconomic reasons.
2. The gravity of prognosis is due to:
   a) frequent association with respiratory burns.
   b) frequently very extensive burned surface.
   c) young age of the children.
   d) insufficient number of burns centres and inadequacy of means and equipment in existing centres.

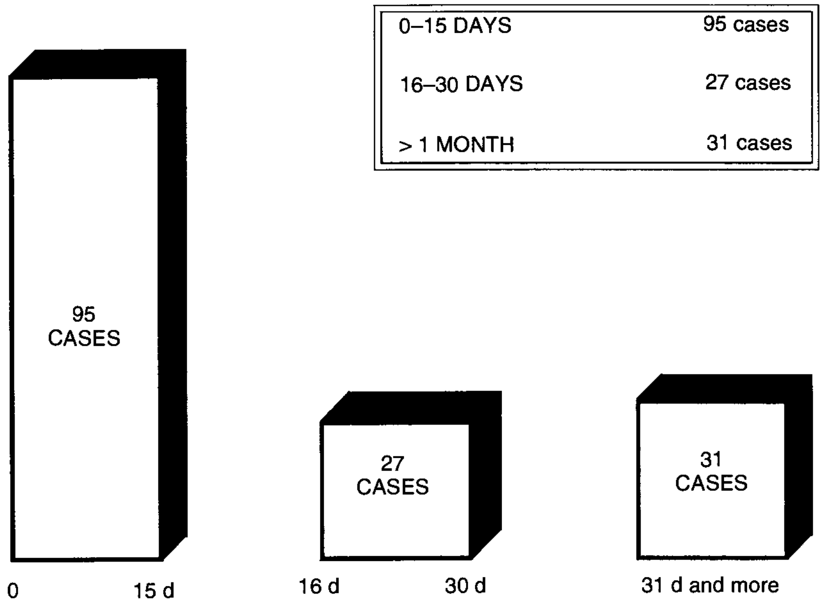


Figure 4. Duration of hospital stay

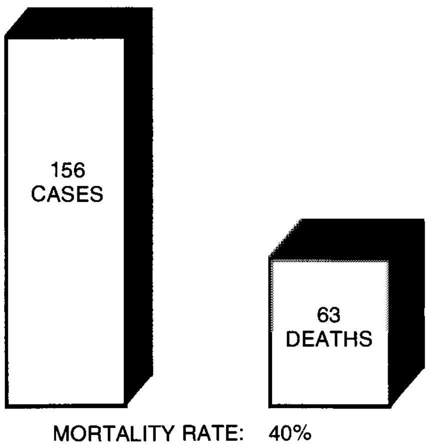


Figure 5. Deaths

The best approach to this type of accident is prevention. This depends on improvement of the living conditions of the less favoured social classes and on improvement of the taking in charge of burned children, which requires a more realistic awareness of this type of almost daily disaster.

29
City fires: group burn trauma

OKSANA D. DMITRIENKO and MOPR N. FARSHATOV
Institute of Advanced Medical Studies, St Petersburg, Russia

INTRODUCTION

Cases of group burn trauma are typical results of city fires, occurring seven times more often than in country areas.

Fire burn injury is characterized by its specific pathology, and great severity and mortality, and special methods are required to help the victims.

METHODS

An analysis is presented of burn injuries in St Petersburg over the 10-year period 1981–1990, together with an investigation of 500 cases of fire burn injuries.

RESULTS

Annually, between 23 000 and 42 000 burn injuries occur in St Petersburg (7.4 cases per 1000 inhabitants), representing 5.2% of the total number of all traumas. Domestic burns constitute 80.9% of all burns; 5% of the patients are admitted to hospital. Mortality in burns centres ranges from 8% to 11.7% in adults and from 0% to 1.7% in children (Table 1).

Injuries occurring during fires accounted for the most severely injured patients in burns centres, accounting for more than half of all cases

Table 1. Burn statistics in St Petersburg (1981–1990)

Population	5 000 000
Burns per year	23 000–42 000
Hospitalized	5–6%
Mortality	8–11.7%

Table 2. Victims and financial damage caused by fires

Russia, 1990	
Total number of fires	>500 000
Fatalities	>10 000
Dangerously traumatized patients	>13 000
Financial losses	0.5% of national income
Fires in St Petersburg	
Total number of fires	30 000 per year
City:country ratio	7:1
Domestic fires	92%
Fires in public buildings	8%
Number of victims (1981–1990)	3892
Fatalities *in loco* (1981–1990)	1079
Fatalities in hospital	39.8%

(55%). Annually, 30 000 fires occur in St Petersburg, 92% of which are domestic accidents, and 300 persons are burned. One-third of the victims die *in loco*, while the mortality rate in burns centres is 39.8% (Table 2).

The main types of group burn trauma are shown in Table 3: fires in apartment houses and public buildings; explosions and fires in factories and work places; electrical trauma; traffic accidents; and breakdowns at central heating plants.

Table 3. Main types of group burn trauma in St Petersburg

Domestic fires and public buildings	44.0%
Electrical trauma	27.8%
Explosions and fires in factories and work places	17.6%
Traffic accidents	5.6%
Breakdowns at central heating plants	5.0%

Injuries in burn patients may be caused by a combination of several factors (Table 4). In 402 patients with multiple injuries, 300 (75%) of these had multifactorial causes and only 102 (25%) were due to a single cause. The most frequent multifactorial injuries were flame burns com-

Table 4. Causes of injury in fires

Main	flame
	high temperature
	thermal radiation
	toxic products of combustion
Subsidiary	mechanical injury
	electric current
	chemicals
	low temperature
	nuclear injury

bined with lesions in the respiratory organs and poisoning caused by toxic products of combustion. Combinations of burn injury with severe mechanical trauma were rather rare.

The large extent of total body surface area (TBSA) burned was characteristic (see Table 5). More than 20% TBSA was burned in 69.7% of patients admitted to hospital. With regard to severity, 95.3% had full-thickness injuries, and 39.2% had fourth-degree burns. As shown in Table 5, areas of the body in which burns represent a life-threatening risk were often affected (face, 75.2%; chest, 67.0%; hands, 96.2%; perineum, 40.2%), as well as areas that are cosmetically and functionally important and a cause of invalidity (face, 39.9% third-A and third-B degree burns; hand, 76%).

Table 5. Injuries during fires

	No.	%
Thermal burns (Total = 500)		
TBSA >20 %	348	69.6
Full-thickness (third-B degree burns)	479	95.3
Fourth-degree (subcutaneous tissue, muscle, fascia, bone)	196	39.2
Burns location		
Face	376	75.2
Hands	481	96.2
Chest	335	67.0
Perineum	221	40.2
Inhalation trauma		
Thermal chemical injuries of respiratory tract	150	30.0
CO poisoning	37	7.4
Combination of above	313	62.6
Classification of CO poisoning		
Mild (HbCO < 30%)	255	51.1
Moderate (HbCO 30–60%)	225	45.0
Severe (HbCO > 60%)	20	3.9

All 500 fire victims suffered inhalation trauma: 30% suffered burn injuries in the upper airways and damage to the respiratory organs due to the products of burning; 7.4% had CO poisoning; and 62.6% a combination of both. The degree of severity of CO poisoning is also illustrated in Table 5. A total of 22.2% of patients with CO poisoning had ethanol in their blood.

Multifactorial injuries were characterized by mutual aggravation of injuries that resulted in a more severe state of health than would be expected in skin burn injuries (Table 6). In accordance with the general rule of its course, shock was followed by the rapid development of severe pathological changes. The clinical signs that prevailed were early psychosis, respiratory organ disease complications (shock lung, pulmonary oedema, pneumonia) and disturbances of the protection and resistance functions of the organism.

Table 6. General clinical damage

	No.	%
Shock	425	85.0
Disturbances in haemodynamics	500	100.0
Disturbances in consciousness	150	30.0
Disturbances in diuresis	278	55.6
Disturbances in respiration	104	20.8

Considerable differences were found between the survival of patients suffering from skin burn injuries and that of patients with inhalation trauma. The relationship between mortality and different burn injuries was established according to their degree of gravity (Figure 1). A brief period of survival is characteristic of inhalation trauma (Figure 2): 65.6% of patients with inhalation trauma died during the first 4 days and 30.5% on the first day (two-thirds within the first 12 hours). The basic causes of death were shock, pneumonia and sepsis.

The influence of the demographic conditions of St Petersburg is revealed by the significant proportion of elderly persons involved in burn accidents, for whom even minor burns may be critical and to a greater extent also multifactorial. There are one million elderly inhabitants in St Petersburg, and 20% of those hospitalized were in the burns centres. In pregnant women severe injuries are more dangerous for the fetus than for the woman. The level of morbidity in the general popula-

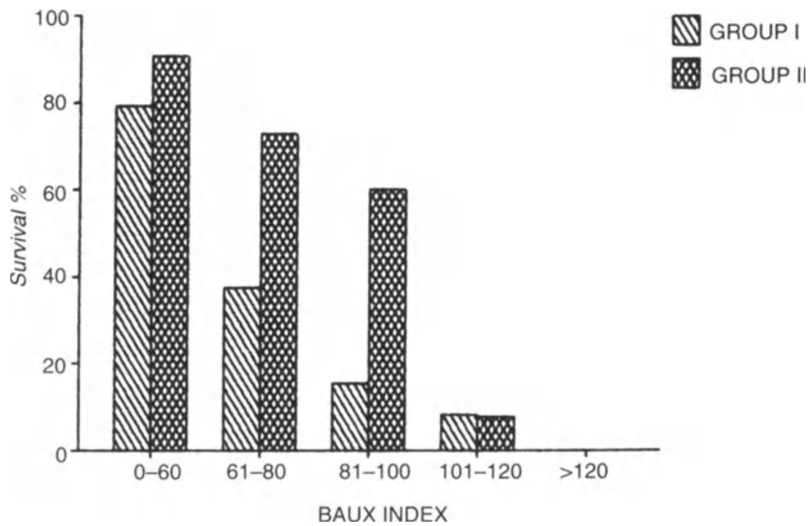


Figure 1. Estimation according to Baux index

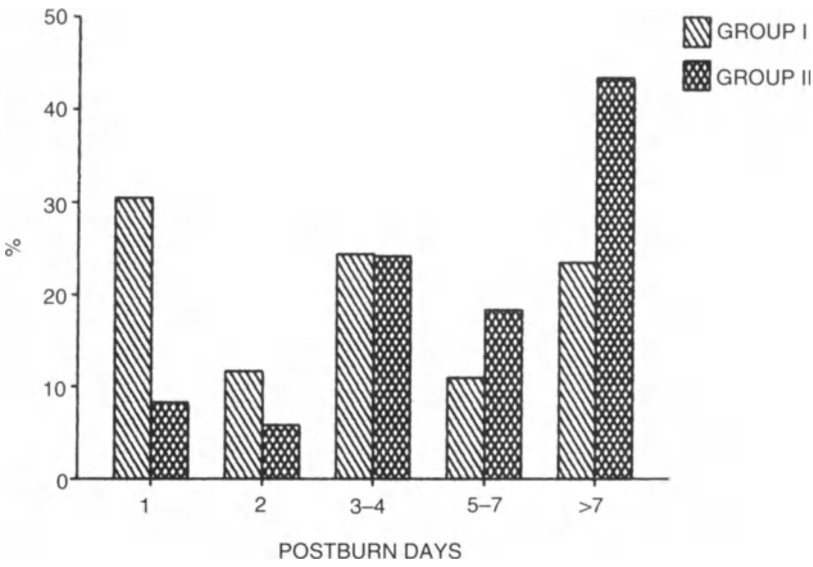


Figure 2. Mortality

tion must also be taken into consideration, as most patients aged over 60 presented marked concomitant pathologies.

The system of medical aid in St Petersburg works in two stages: first at the place of the accident by the emergency service and second in one of the three city burns centres, where 92% of victims arrived within two hours of the trauma.

DISCUSSION

Severely injured fire victims create a distinct clinical problem as they represent a qualitatively independent category of trauma patients. The concrete quantitative designation of trauma severity is a complicated problem that has not yet received an optimal and unambiguous solution. The influence of the general overheating of the body and intoxication by numerous poisonous products of combustion have not yet been fully investigated. We need further research in the field of more effective diagnostic approaches and in medical and technical methods of treatment.

The main difficulties, i.e. the fulfilment of primary medical measures and of transportation, increase significantly in cases of group trauma. The simultaneous medical treatment of several patients creates difficulties during reception in hospital. Strict observation of the rules of medical triage is necessary. Treatment according to general plans reveals the necessity for the careful preparation of medical means and reserves and for the training of additional teams of physicians and nurses.

Table 7. Fire disasters in St Petersburg (1986–1991)

	Disasters	*Victims*
Major (> 100 victims)	–	–
Moderate (10–99 victims)	3	51
Minor (2–10 victims)	181	553

Our experience showed that on the basis of the WHO classification large-scale burns disasters were rare (Table 7). Moderate and minor disasters are typical of city fires. Group thermal injuries due to fires should be regarded as minor burn disasters. In contrast to everyday trauma to individuals they require more comprehensive recommendations as to the organization and performance of pre-hospital and special care for the victims than are generally adopted. It would appear to be a useful proposition to prepare action and training algorithms for all levels of personnel.

The prospect of improving aid to fire victims in St Petersburg demands further development in the organization of the burns service, the creation of burns centres nearer residential areas, the institution of regional burns centres and the reorganization of existing burns centres.

The introduction of the *Ozog* computer program for forecasting life expectancy will make it possible to define prognosis (survival or death) and the period of life and treatment. This is especially valuable in the event of mass arrival of patients as regards triage, orders for evacuation, the amount of first aid required and the estimation of the severity of the disaster.

BIBLIOGRAPHY

Arturson, G. (1990). Analysis of severe fire disasters. *International Conference on Disaster Medicine, Moscow*, p. 470

Baux, S. *et al.* (1981). Réflexions à propos de la catastrophe de Los Afalques. *Ann. Chir. Plast.*, **2**, 185–187

Boswick, J. A. (1990). Problems in the management of burn disasters. *International Conference on Disaster Medicine, Moscow*, p. 425

Demling, R. H. (1987). Smoke inhalation injury. *Postgrad. Med.*, **82**, 63–68

Dmitrienko, R. H. (1991). Burn disasters – problems of organization of medical aid to burned people. *Vestn Khir.*, **146**, 143–146

Griffiths, R. W. (1985). Management of multiple casualties with burns. *Br. Med. J.*, **291**, 917–918

Masellis, M. and Gunn, S. W. A. (1991). Thermal agent disaster and burn disaster: definition, damage, assessment and relief operation. *Ann. Medit. Burns Club*, **4**, 215–218

Silverstein, P. and Lask, B. (1987). Fire prevention in the United States. *Surg. Clin. N. Am.*, **67**, 1–14

30
Analysis of 1005 burn patients treated in one centre in Turkey

M. HABERAL, N. UÇAR, U. BAYRAKTAR and Z. ÖNER
Turkish Transplantation and Burn Foundation, Ankara, Turkey

INTRODUCTION

Burns still represent one of the leading causes of accidental death. Severe non-fatal burns can be considered to be among the most devastating of injuries, provoking emotional and physical scarring. In order to overcome this problem that threatens public health, prevention is more important than the establishment of high-technology burn units. The first step in prevention is the investigation of the epidemiological pattern of the burns affecting people in a given region. The present study therefore aimed to evaluate the epidemiological pattern of the in-patients treated in the Burn Unit at the Hacettepe University Hospital, which has been a leading centre in Turkey, since its establishment by the senior author of this paper.

PATIENTS AND METHODS

Between 1 January 1979 and 31 December 1991, 1005 burned patients were admitted to our unit. The data obtained from the charts of the patients were analysed in order to ascertain the distribution of the patients according to age, sex and socioeconomic level, as well as the distribution of the burns according to place of occurrence, complications and mortality rate.

All patients were treated according to a treatment protocol consisting of resuscitative measures by means of fluid and electrolyte therapy according to a modified Parkland formula, dialysis and surgical procedures, together with various topical treatments, including the application of silver nitrate incorporated into amniotic membrane (Haberal, 1984, 1986; Haberal *et al.*, 1987).

RESULTS

Over a period of 12 years, 1005 patients with moderate or major burns were admitted to our burn unit. Of these, 339 (33.7%) were female and 666 (66.3%) were male. Four hundred and twenty-six (42.4%) were under the age of 15 years (Figure 1A, B). The socioeconomic status of the patients was low, middle and high in 29.7%, 63.5% and 6.8% (Figure 2).

Since the incidence of electrical burn injuries in this series was very high, when compared with other series in the literature, the causes of the burns were investigated in two groups: electrical burn injuries and non-electrical thermal injuries (Figure 3). Electrical burn injuries were found in 208 (20.1%) patients. In the patients with non-electrical burns, flame burns constituted 52.5% of the injuries, including burns secondary to LPG explosion (9.9%). Scalding was the second leading cause of thermal injuries (35.6%, 5.9% and 2.8% of the burns were caused by hot water, hot milk and hot meals, respectively). The remaining thermal injuries were due to chemical materials (1.8%), hot metals (0.6%) and hot olive oil (0.8%) (Figure 4).

The majority of burns were domestic injuries (64.0% of the patients), while 25.4% of the burns were occupational and 10.6% occurred elsewhere.

The overall mortality rate was 34.4%. Non-electrical thermal injuries were fatal in 303 (38.0%) patients, while 21.6% of patients with electrical

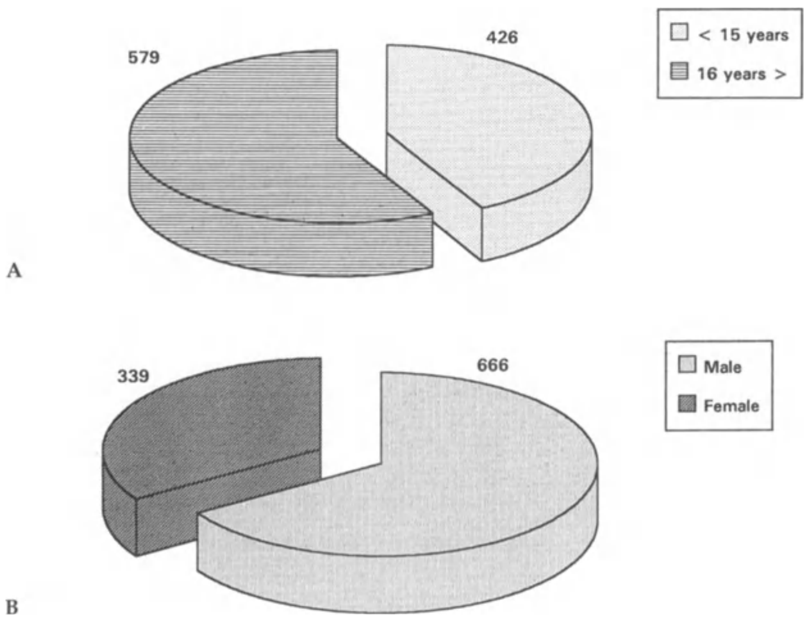


Figure 1. Distribution of patients (n = 1005) by (**A**) age and (**B**) sex

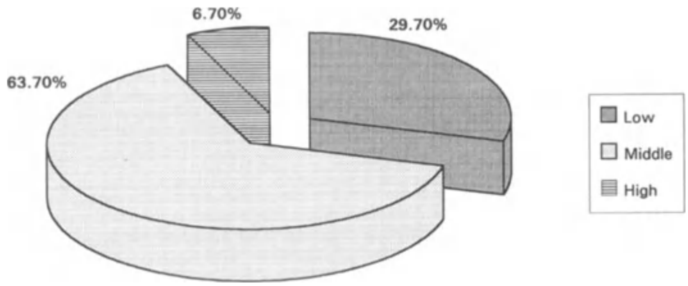


Figure 2. Socioeconomic level of patients

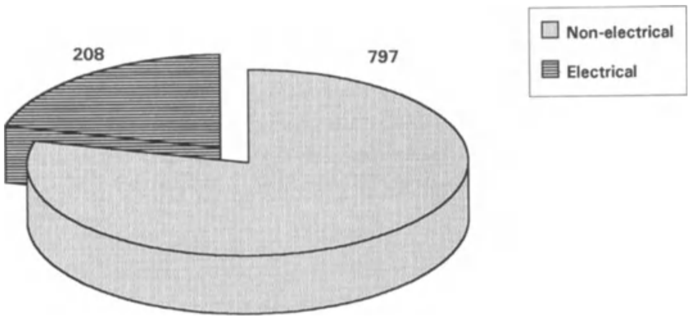


Figure 3. Proportion of electrical and non-electrical burns in 1005 patients

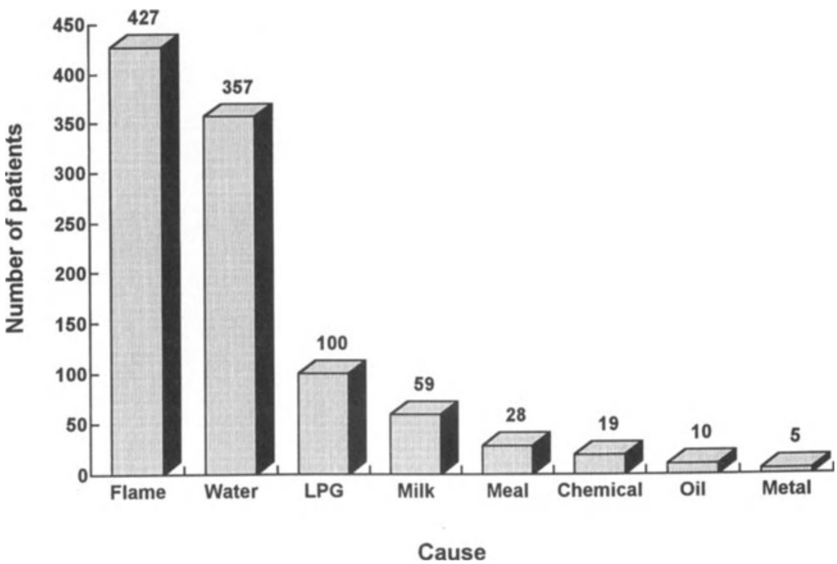


Figure 4. Causes of non-electrical burns

burns died. The mortality rate of patients with burns caused by hot milk was the highest, at 61.7%. The most frequent cause of death was sepsis in both groups. The most important complications in patients with electrical burns were amputations (25.0%) and acute renal failure (14.42%), whereas gastrointestinal complications were frequently encountered in patients with other types of burn.

DISCUSSION

Burns are still one of the most important problems threatening public health. In the present study, children were found to be most frequently subject to burns. This finding correlates with that of reports from other countries (El Danaf *et al.*, 1991; Lindblad and Terkelsen, 1990; Tejerina *et al.*, 1992; Elberg *et al.*, 1987; Clark and Lerner, 1978). Since the socioeconomic levels of the patients correspond more or less to the socioeconomic status of our country, socioeconomic status cannot be considered a strong risk factor in these series, in contrast to previous reports by other investigators (Loche *et al.*, 1990; Clark and Lerner, 1978).

The number of electrical burn injuries in our series was higher than that in other countries (El Danaf *et al.*, 1991; Lindblad and Terkelsen, 1990; Tejerina *et al.*, 1992). In the light of our previous studies, this may be attributed to the higher risk in our country of being injured by electricity (Haberal 1986; Haberal *et al.*, 1988, 1989). The rate may however be aggravated because our burn unit is one of the leading centres for electrical injuries. The distribution of burns due to other causes correlates with those of other countries (El Danaf *et al.*, 1991; Lindblad and Terkelsen, 1990; Tejerina *et al.*, 1992; Clark and Lerner, 1978). Most of the burns in the present study occurred at home. This finding concurs with that of several investigators from other countries (El Danaf *et al.*, 1991; Lindblad and Terkelsen, 1990; Clark and Lerner, 1978). Although the patients were treated by all modern treatment materials and methods, including emergency haemodialysis, the mortality rate for burns was very high compared with that of other studies (El Danaf *et al.*, 1991; Lindblad and Terkelsen, 1990; Tejerina *et al.*, 1992; Clark and Lerner, 1978). This may be attributed to the late admission of the patients to hospital, which delayed wound management and fluid and electrolyte treatment and led to the development of sepsis and acute renal failure.

The mortality rate of burns caused by hot milk was the highest of all in this series. This confirms our suggestion about the mortality rates, since milk proteins constitute a rich medium for bacterial growth, if not removed immediately. The mortality rate in electrical burn injuries was lower than that of other kinds of burns because of the relatively rapid admission to hospital of the patients.

This epidemiological study stresses how the importance of burns is underestimated by the authorities and physicians, who should be encouraged to take part in burn prevention and management. Educational programmes for burn prevention should be designed and carried out urgently. A special organization for the management of major burns should be established to decrease the mortality and morbidity rates in our country.

REFERENCES

Clark, W. R., Jr and Lerner, D. (1987). Two years hospitalized burned patients in Central New York. *J. Trauma*, **18**, 524

Elberg, J., Schorder, H., Glent-Masden, L. *et al.* (1987). Burns: epidemiology and effect of a prevention programme. *Burns*, **13**, 391

El Danaf, A., Alshlash, Filobbos, P., Rasmi, M. and Salem, S. (1991). Analysis of 105 patients admitted over a 2-year period to a modern burns unit in Saudi Arabia. *Burns*, **17**, 62

Haberal, M. (1986). Electrical burns: a five-year experience. *J. Trauma*, **26**, 103

Haberal, M. (1984). Early care of minor and moderate burns. In Davis, C. A. (ed.) *Burns: Emergency and Acute Care*. University of California: 29–38

Haberal, M., Oner, Z., Bayraktar, U. and Bilgin, N. (1987). The use of silver nitrate incorporated amniotic membrane as a temporary dressing. *Burns*, **13**, 159

Haberal, M., Oner, Z., Gulay, H. *et al.* (1988). Severe electrical injury and rehabilitation. *Ann. Medit. Burns Club*, **1**, 121

Haberal, M., Kaynaroglu, V., Oner, Z. *et al.* (1989). Epidemiology of electrical burns in our center. *Ann. Medit. Burns Club*, **2**, 14

Lindblad, B. E. and Terkelsen, C. J. (1990). Domestic burns in children. *Burns*, **16**, 254

Locke, J. A., McKay, R. and Burke, J. F. (1990). Socioeconomical factors and the incidence of hospitalized burn injuries in New England Counties, USA. *Burns*, **16**, 273

Tejerina, C., Reig, A., Codina, J., Safont, J., Baena, P. and Mirabet, V. (1992). An epidemiological analysis of burn patients hospitalized in Valencia, Spain during 1989. *Burns*, **18**, 15

31
Burns epidemiology in Syria: Al-Kindi Hospital, Aleppo

ANTOINE DAYOUB
General and Plastic Surgery, Faculty of Medicine, University of Aleppo Burns Section, Syria

---

A survey of burn patients and methods of treatment was performed at the Al-Kindi state hospital, Aleppo, Syria. The hospital has a capacity of 400 beds and has several divisions, of which the burns department is our particular concern.

The burns department at Al-Kindi Hospital consists of two operation rooms, one of which is clean and the other is 'dirty'. There are four plunges and the 16 rooms can hold 22 patients. This hospital admits all kinds of burn patients, both new and old are admitted. After acute treatment, they are transferred to the division of plastic surgery, where reconstruction operations are performed. In the Aleppo Main University Hospital, from early times until today, the topic of burns has always been very significant because it is one of the commonest causes of death and deformation. The treatment of burns begins in the Al-Kindi Hospital in this division. We cannot however deny that we still see, to a limited extent, some primitive methods of treating burns based on plants and chemical drugs made up by grocers, which may cause some confusion and deformation. Thankfully these harmful methods are becoming a thing of the past owing to the social progress that has taken place.

Over a two-year period between 1 July 1990 and 1 July 1992, 492 burns patients were admitted to the burns department at Al-Kindi Hospital for treatment by various advanced surgical and medical methods, including early surgical debridement, early burn cover, antibiotic prophylaxis and specialist topical treatment.

All burn patients admitted to the hospital underwent blood analysis, establishment of intravenous lines, analgesia, catheterization for urinary retention, debridement and incision and prophylaxis for tetanus and haemolytic streptococcal infections. Treatment was provided by administering liquids after calculating the burn area by the method of nines.

The amount of liquid was calculated according to *'Broock Base'* and liquids were administered in a solution of *Renferlaktan*.

The study covered 492 burn patients who were treated in the hospital and in an outside clinic annexed to the hospital if their burns were of first and superficial second degree, with an area of < 10%, and patients were > 5 years of age.

Table 1 shows that the proportion of burns in females is higher than that in males because of their kitchen tasks. Fifty-two per cent of burns were caused by gases: this rate is similar to the higher burn rate in females (52.8%); the burn rate is highest between 14 and 60 years of age, because this is the age of greatest activity in people.

Table 1. Number of patients and according to age and sex

Age (years)	*Number*	*Female*	*Male*
1–7	192	108	84
7–14	56	32	24
14–60	240	92	148
> 60	4	–	4
Total	492	232	260

Table 2, which concerns the causes of burns, shows that while most burns were caused by gas (52%), burns from hot water were responsible for 28.4%, and flaming gas burns caused by kerosene for 11.3%. Fourth most common were cooking oil burns (6.5%). Other burns were due to charcoal and wood (1.6%). There was a high percentage of burns from hot water in children between 1 and 7 years of age (74.2% of all ages). This percentage is so high because of children's lack of awareness, particularly in their early years, when containers full of tea or milk spill over them while they are playing. There is a high percentage of gas burns between 14 and 60 years of age (60%) because of the frequent use of gas with badly manufactured equipment such as kerosene cookers or rusty gas containers.

Table 2. Causes of burns according to age

Age (years)	*Gas*	*Fuel*	*Boiling water*	*Electric*	*Oil*	*Other causes*
1–7	60	–	104	–	24	4
7–14	36	–	8	–	8	4
14–60	156	56	28	–	–	–
>60	4	–	–	–	–	–
Total	256	56	140	–	32	8

Another cause of expanding burns is clothes made of flammable substances and which are much used in our country. These easily catch fire and cause a high percentage of burns.

Table 3 considers the relationship between age and burn area. The high percentage (43.8%) of burns in < 20% of body surface shows that in our country burns are generally very simple and less dangerous because there are no serious causes of burns.

Table 3. The percentage area of burns related to age

Age (years)	*< 20%*	*20–30%*	*30–40%*	*40–50%*	*> 50%*
1–7	84	52	20	20	16
7–14	24	16	12	4	–
14–60	100	24	72	16	28
>60	4	–	–	–	–
Total	212	92	104	40	44

Burns to 20–30% of body surface account for 8.6% of cases, while those affecting 30–40% of body surface account for 21.1%, only 8.1% of burns affect 40–50% of body surface, and those affecting 50% of body surface were very few (8.8%).

Table 4, which considers the relationship between age and burn degree, shows that third-degree burns were the least frequent of all, while second-degree burns were the most frequent.

Table 4. The degree of burns related to age

Age (years)	*1st*	*2nd*	*3rd*
1–7	4	184	20
7–14	28	56	4
14–60	64	232	40
> 60	–	4	–
Total	96	476	64

Table 5 indicates that the overall death rate was 14.6%, which is reasonable considering the abundant possibilities.

Table 5. Causes of death according to age

Age (years)	*Mortality*	*Unknown causes*	*Inhalation of gases*	*Septicaemia*	*Shock*	*Deterioration of health*
1–7	28	2	2	10	6	8
7–14	–	–	–	–	–	–
14–60	44	6	3	7	13	15
> 60	–	–	–	–	–	–
Total	72	8	5	17	19	23

Among the prime causes of death are, first, the patient's unhealthy condition (31.9%), second, shock (26.3%) and, third, septicaemia (23.6%).

Table 6.

Month	*Number*	*Bandages for inpatients*	*Bandages for outpatients*	*$AgNO_3$*	*General anaesthesia*	*Local anaesthesia*	*Without anaethesia*
Jan	349	245	75	11	2	6	10
Feb	446	352	62	–	2	9	21
Mar	381	306	52	–	3	5	15
Apr	337	276	48	–	4	6	3
May	465	368	56	13	6	2	20
Jun	374	297	41	18	2	4	12
Jul	352	270	42	17	3	4	16
Aug	415	331	59	–	5	5	15
Sep	388	306	61	–	3	5	13
Oct	523	396	104	–	2	5	16
Nov	428	336	78	–	–	5	9
Dec	496	387	91	–	4	4	10
Total	4954	3870	769	59	36	60	160

Our study suggests that burns still occupy an important position on the 'death list', and that burns caused in 'factories' were very slight, with most people being burned in domestic accidents.

It is also noteworthy that many patients were unable to come to Al-Kindi Hospital and therefore had their treatment at home, where most of them died, especially those with mortally dangerous burns (Table 6).

Our study also includes family burns, some of which caused disasters, for instance when a gas container burst, leading to a family catastrophe that killed eight members of one family: father, mother and six children.

In conclusion we can say that the death rate in our hospital was 14.6%, which is very low compared with the overall burns death rate, because most burn cases were dealt with away from hospital.

I look forward to the day when we reach a more advanced level by establishing an up-to-date modern Burn Unit connected with smaller subunits in the suburbs where a patient receives first aid and is then transferred to a larger burns centre in the city.

32

Comparison of epidemiological data and life prognosis in patients transferred from the Maghreb to France, and in all patients admitted to one Burns Centre in Paris

D. WASSERMANN, F. LEBRETON, M. SCHLOTTERER and A. CHAOUCH
Centre des Brûlés de l'Hôpital Cochin, Paris, France

French burns centres frequently receive patients from the countries of North Africa (the Maghreb). These patients are transferred from their country of origin because of the lack of facilities necessary for their treatment and they usually reach France after long delays due to administrative problems. The delayed initiation of appropriate therapy often means that the patients are in a critical condition when they eventually reach a French burns centre: most are in a state of major septic shock. It would therefore seem important in the long term to assess the medical validity of the practice of these costly transfers: the money spent might be better employed in developing more efficient facilities in North Africa.

We present here a statistical analysis performed at the Hôpital Cochin Burns Centre in Paris in which we compared patients coming from the Maghreb during the 5-year period 1987–91 with all patients admitted during the same period.

CHARACTERIZATION OF PATIENTS AND GRAVITY OF BURNS

Fifty-one of the 661 patients admitted during the period in question arrived from North Africa, i.e. just under 8%. Of these 51, 46 were from Algeria (90%), three from Tunisia (6%) and two from Morocco (4%). The Maghreb patients were younger on average than overall (age 31 years vs

42 years), had more extensive burns (total body surface area burned 40% vs 20%) and a higher proportion had third-degree burns (25% vs 7%). The mean number of burned surface units (BSU) was 114 compared with 42 in the total population (Figures 1 and 2).

EPIDEMIOLOGY

The type of accident causing the burn was similar in the two populations, domestic accidents being the most common cause in both Maghreb patients and the total population (nearly 70%), while about 20% were due to accidents at work. There was also little difference

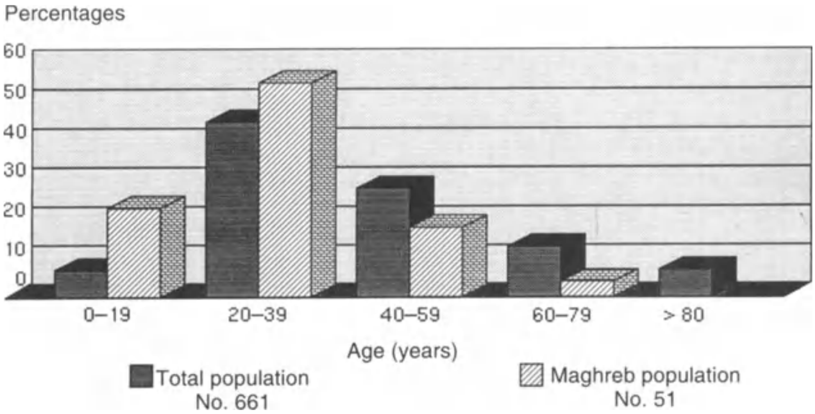


Figure 1. Distribution of patients by age

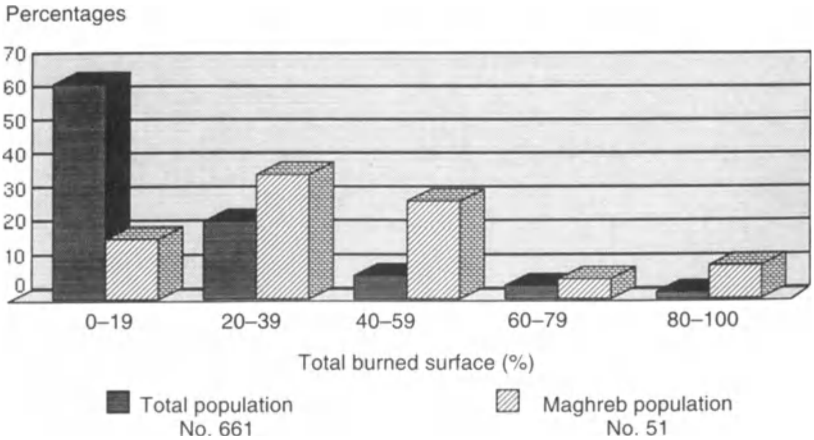


Figure 2. Distribution of patients by burned body surface area

between the two populations with regard to the causative agent. In both populations flame burns were responsible for about 50% of the lesions. There was a slightly higher frequency of burns due to gas explosion in the North African patients (30% of all burns) than in the total population (less than 15%). This difference is probably related to living conditions in Algeria, where most of the patients came from, and where the recent introduction of mains gas into the homes has increased this particular risk.

PROGNOSIS

Figure 3 shows percentage survival in the two populations as a function of total burned surface. There was little difference between the two except for a slightly lower mortality in Maghreb patients with burns affecting more than 80% body surface area; however the number of cases is small and the finding cannot be considered significant.

Analysis of survival as a function of BSU also showed minimal differences between the two populations (Figure 4). The only clear difference was among the most seriously burned patients, among whom survival was slightly better in the North African population. Interpretation of these data should, however, take in to consideration the age of the patients concerned; age is an extremely important factor in the prognosis of severely burned patients. Since patients from North Africa were younger than the general burned population, this necessarily improved their life prognosis.

Figure 5 shows the survival of the most seriously injured patients in the two populations, severity being expressed in terms of both burned surface and the number of BSU. Survival differed little, although there was an important difference as regards mean age. This therefore in fact

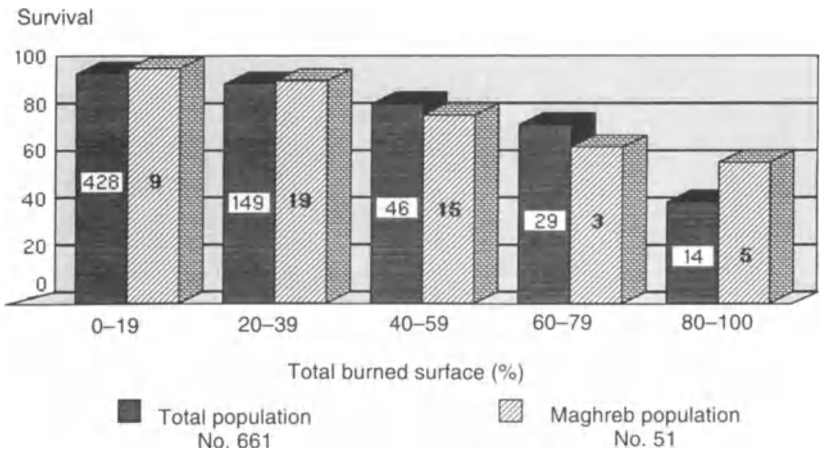


Figure 3. Percentage survival in the two populations as a function of burned body surface area

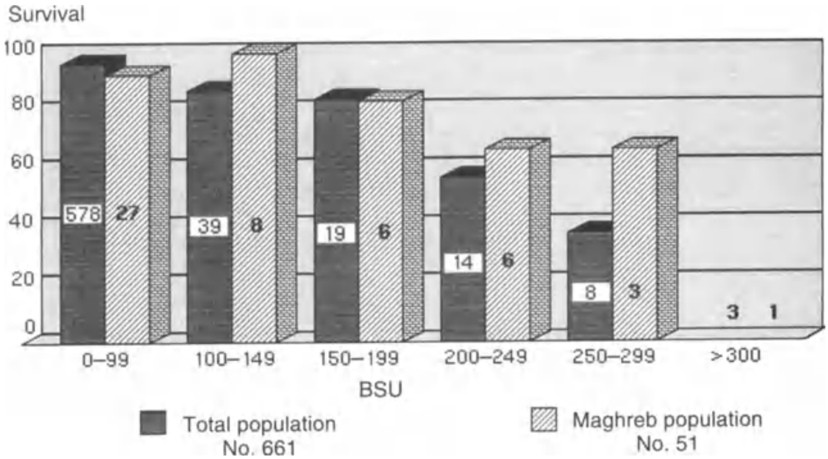


Figure 4. Percentage survival in the two populations as a function of BSU

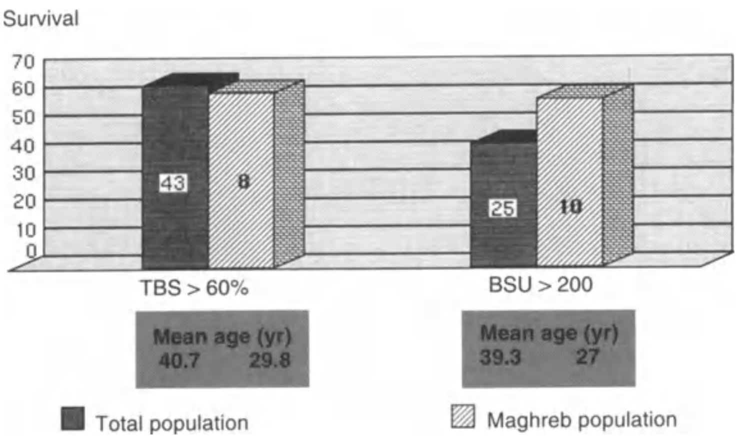


Figure 5. Comparison of the two populations with regard to survival and the mean age of the most seriously injured patients

indicates a worse prognosis in the Maghreb patients who, despite being younger, had the same mortality as the total population.

CONCLUSIONS

Comparison of the prognosis of patients admitted in the period 1987–91 after transfer from the Maghreb, in particular Algeria, with that of the total population admitted in the same period is complicated by the differences observed between the two populations. It would appear, however, that if we consider the younger mean age of the Maghreb population this group has an increased mortality rate. This aggravated risk is probably related to the considerable delays in the transfer of these patients from North Africa.

Figure 6 shows the distribution of the Maghreb population in relation to the delay in their transfer to France. It can be seen that although one-third of the patients arrived in our centre within the first 2 days after suffering the burn, one-third arrived after 3–7 days and another third more than 1 week after the injury.

These results argue in favour of a reorganization of the transfer to France of severely burned patients from North Africa and in particular Algeria. It is recommended that efforts should be made to limit the number of transfers and to improve local conditions for the treatment of such patients. Failing that, it is imperative that action is taken to reduce delays in transfer.

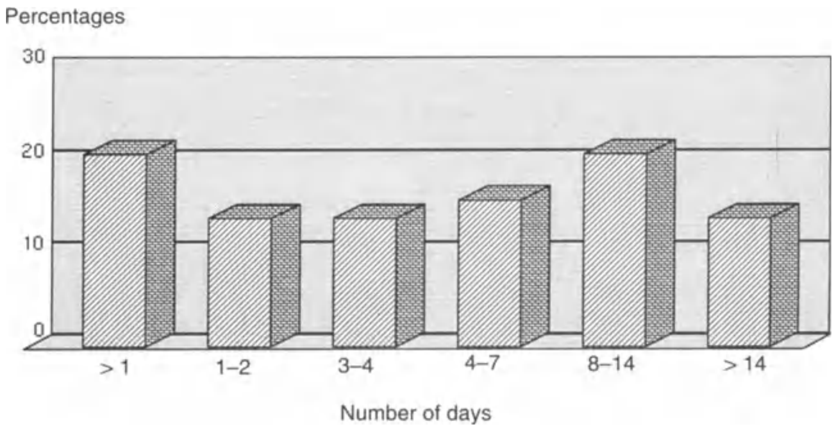


Figure 6. Distribution of Maghreb patients as a function of delays in transfer

33
Analysis of burned children in Libya; Tripoli burns and plastic surgery centre

M. M. ZAIDI, A. ABUSETTA, A. BROGOWSKI, P. L. AGRAWAL and M. R. FRANKA
Burns and Plastic Surgery Center, Tripoli, Libya

INTRODUCTION

Burns are the most devastating of injuries and the burn patient may suffer from complications for the rest of his life. In spite of recent developments in burn care, we still see high mortality rates and significant morbidity in terms of burn complication and functional, social and psychological impairment.

Burn injuries are a major problem in developing countries and indeed constitute a worldwide problem. The incidence of burns is increasing everywhere, and consequently the incidence of burns in children is also increasing.

Paediatric burns in Libya are a real problem, related to the wide use of LPG for cooking, house electricity, the use of chemicals in the home, the use of hot water geysers in bathrooms, large families with many children, the widespread social habit of preparing tea at ground level, and the increased standard of living.

Children are at high risk because of their natural curiosity, their mode of reaction, their impulsiveness and their lack of experience in the calculation of risk (Lindblad and Jerkelson, 1990). The care of small children is dependent upon others. They cannot take care of themselves. Burns in the home constitute the majority of burn injuries in children, scalding being the commonest cause. Scalds constitute 64.4% of burn injuries in children, followed by hot oil (14.8%).

Burns in children are a difficult medical and surgical problem, as children can receive deep burns even when exposed to high-temperature liquids for just a few seconds.

The purpose of our study is to identify the epidemiological features of burn injuries affecting children in our population which may be prevented by implementing preventive measures and by the education of parents. No study of paediatric burns has previously been reported from Tripoli.

MATERIAL AND METHODS

This article covers 250 burned children aged 0–14 years, divided into four groups, 0–1, 2–3, 4–6 and 7–14 years, admitted to our Burn and Plastic Surgery Center, which is the only specialized centre in Libya for treating burn injury victims. There are 225 beds for burns and plastic surgery, maxillofacial and hand surgery. The burn ICU has nine beds: three isolation rooms and two large rooms with three beds each. Each room contains an air-fluidized bed, a general bed, a bath set and Striker beds. There is one operating theatre for the ICU only and one dressing-room. All beds are equipped with proper monitoring facilities. The ward is completely isolated, with no visitors. The personnel in the ICU consists of one chief surgeon, one chief anaesthetist, four assistant surgeons and 29 specialized nurses. All medical care is given free of charge in Libya.

The criteria for admission to the ICU are extensive burns, inhalation injury, burns with complications and burns with other systemic problems.

The paediatric burn ward consists of two large rooms with 15 beds each and two separate rooms each with an air-fluidized bed.

In the period 1 January 1992 to 31 December 1992 250 burned children were admitted to the centre. Of these 250, 41 were admitted to the ICU and the rest to the Burn Department (Table 1).

All patients admitted were resuscitated if necessary according to the Evans formula, modified for each patient according to the clinical condition at the time of admission, patient response and age group.

Table 1. Age distribution of admitted patients in burns and plastic surgery centre in Tripoli, Libya, from 1 January 1992 to 31 December 1992

	0–6 yr.	*7–14 yr.*	*Total*
In Department	156	53	209
In ICU	27	14	41
Total	183	67	250

SUB-GROUP 0–6 years

	0–1 yr	*2–3 yr*	*4–6 yr*	*7–14 yr*	*Total*
In Department	25	89	42	53	209
ICU	3	16	8	14	41
Total	28	105	50	67	250

The local treatment of the burn wound depended on the area involved (open or closed method). The open method was used for face, scalp and perineum burns and the closed method for all other parts, with Flamazine dressing. Early bathing of burn patients is the norm in our centre.

Further care of the burn wound depended on the depth of the burn. Superficial partial-thickness burns were treated conservatively. Deep partial-thickness burns were treated by early surgical intervention. Out of the 250 patients, 106 were subjected to early surgical necrectomy. Tangential excision is our method of choice but we also perform fascial excision in deep third-degree flame burns, the wounds being covered with skin autograft or homograft from live donors or sheepskin graft. If the wounds are covered with homo- or sheepskin graft, it is followed by intermingled autopatch graft every 2–3 days until all homo- or sheepskin graft is removed.

Early nutritional support is the policy followed in our centre.

RESULTS

A study of the epidemiological data revealed that the incidence of burns in Libyan children is quite high, equal to 59.24% of all patients treated in our centre. The male to female ratio is 1.4:1 in the first and second age groups and almost the same in the other age groups.

In all age groups, burns due to scalding are followed by those caused by hot oil and flame. The causes of burn in the different age groups are shown in Table 2. Scalds were due to hot water or hot tea. Flame burn was mostly due to gas explosion, followed by petrol fire in older children. Almost all the accidents occurred in the home, especially in the kitchen (96.4%).

Paediatric burns are common in the winter months, from November to May in the Mediterranean climate. Most of the patients belonged to large families. Ninety-five per cent of the patients attended hospital within 3 h of their injury.

One hundred and seventy-one patients (68.4%) had less than 15% BSA burns; 61 patients (24.4%) had burns in 15–30% BSA; and 17 patients

Table 2. Causes of burns in different age groups

	Age (years)					
Causes of burn	*0–1*	*2–3*	*4–6*	*7–14*	*Total*	*%*
Scald	18	70	33	40	161	64.4
Hot oil	4	20	10	3	37	14.8
Fire	3	11	4	13	31	12.4
Electric	2	2	2	5	11	4.4
Contact	1	2	1	4	8	3.2
Others	0	0	0	2	2	0.8
Total	28	105	50	67	250	100.0

Table 3. Percentage of burn in different age groups

Percentage burn	Age (years) 0–1	2–3	4–6	7–14	Total	%
0–15	23	71	37	40	171	68.4
16–30	3	30	7	21	61	24.4
31–80	2	4	6	6	18	7.2
⩾80	–	–	–	–	–	–
Total	28	105	50	67	250	100.0

(6.8%) had 30–80% burns. We did not observe burns of more than 80% in any child during this period. The extent of injury in the different age groups is shown in Table 3.

Most of the scalds were caused by the spilling of hot tea or hot water while parents were preparing or drinking tea or when hot water was being carried. Some children were scalded by pulling over the hot water pot. Most of the burns due to flame were caused by gas explosion (20 patients), six patients were burned as a result of clothes catching fire and five patients were burned by petrol flames.

In our study, the most common burn site was the head and neck. Site distribution in the different age groups is shown in Table 4.

Morbidity and hospital stay in burned children were reduced drastically to one-half or one-third of the time in previous years when we used only conservative treatment in burn wounds and covered the burn wound when granulation tissue appeared.

We had no incidence of graft failure in early operated patients. We perform necrectomy under tourniquet and we also place grafts under tourniquet. No cases of post-operative bleeding requiring change of dressing were seen. Patients with small to moderate-size burns were discharged 10–13 days post-burn. The hospital stay of children with burns of different extent is shown in Table 5. The greater the burn extent, the longer the hospital stay.

Twenty-four patients died, corresponding to 9.6% of the burned children admitted. Table 6 shows mortality in different percentages and

Table 4. Site of burn distribution in different age groups

Site of burn	Age (years) 0–1	2–3	4–6	7–14	Total	%
Face and neck	4	15	7	12	38	15.2
Upper limbs	5	11	7	9	32	12.8
Anterior trunk	3	8	8	8	27	10.8
Posterior trunk	2	7	4	4	17	6.8
Buttocks	4	18	1	2	25	10.0
Lower limbs	4	20	10	11	45	18.0
More than one site	3	16	7	11	37	14.8
All sites	3	10	6	10	29	11.6
Total	28	105	50	67	250	100.0

Table 5. Period of hospital stay (days) in relation to percentage of burn

Percentage burn	*1–10*	*11–20*	*20–30*	*31–45*	*> 45*
0–15	81	71	5	14	–
16–30	10	12	25	13	1
31–80	–	4	6	3	4

Table 6. Mortality rate in relation to TBSA and different age group burned children in the burns and plastic surgery centre in Tripoli, Libya, between 1 January and 31 December 1992

Percentage burn	*Age (years)*						*Total*	%
	0–1		*2–3*		*4–6*	*7–14*		
	Scald	*Flame*	*Scald*	*Flame*	*Flame*	*Flame*		
0–15	–	1	–	–	–	–	1	0.4
16–30	–	1	2	4	–	–	7	2.8
31–80	–	4	–	4	2	6	16	6.4
⩾81	–	–	–	–	–	–	–	–
Total	–	6	2	8	2	6	24	–
%	25		41.66		8.33	25	–	–

Percentage of mortality of admitted children in burns and plastic surgery centre = 9.6%.

burn causes. The relationship between BSA and burn cause shows that the deaths were most common in flame burn patients in whom burns were very deep, involving a large surface area, and there was associated inhalation injury. Twenty-two of the 24 deaths followed flame burn. No patient died in the first 48 h post-burn. Two patients died on day 5 post-burn and the other deaths were in the second to third week post-burn. The main causes of mortality were antibiotic resistance, *Pseudomonas* infection and septicaemia, followed by bronchopneumonia and gastrointestinal haemorrhage.

Post-burn complications such as contractures, hypertrophic scarring and keloids have decreased owing to early physiotherapy and the use of pressure garments and neck collars, but the rate is still high.

In many children long-term follow-up is not possible in Libya.

DISCUSSION

Of the 520 patients admitted in the period considered 250 were children, which corresponds to 48% of all admissions and 59.24% of all patients treated in our emergency department. This is consistent with other reports (Bang *et al.*, 1992). This high burn incidence in children forces us to investigate the causes, patterns and modes of burns in order to institute preventive measures to reduce their frequency.

In our series, in all age groups, scalding was the main cause of burns, in contrast to findings in other studies (Iskrant, 1967; Smith, 1969;

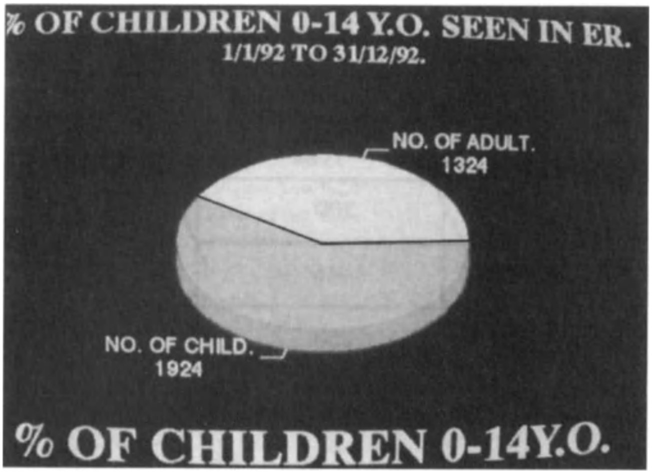


Figure 1. Total number of children in relation to adults seen in Burn Emergency

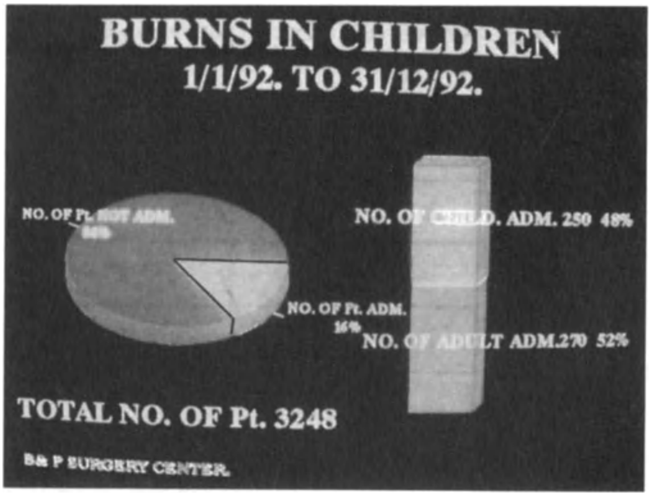


Figure 2. Percentage of children among patients admitted to Burn and Plastic Surgery Center

Mackay *et al.*, 1979), where scalding is the main cause of burns in younger age groups and flame in older age groups. The high incidence of scalds in children is due to their high activity, longer stay at home and inability to protect themselves, which is consistent with other reports (Akhtor and Gang, 1981; Jamal *et al.*, 1990).

Most children suffered burns in the home (96%), particularly in the kitchen (76%). This is consistent with the findings of Davies (1990), who

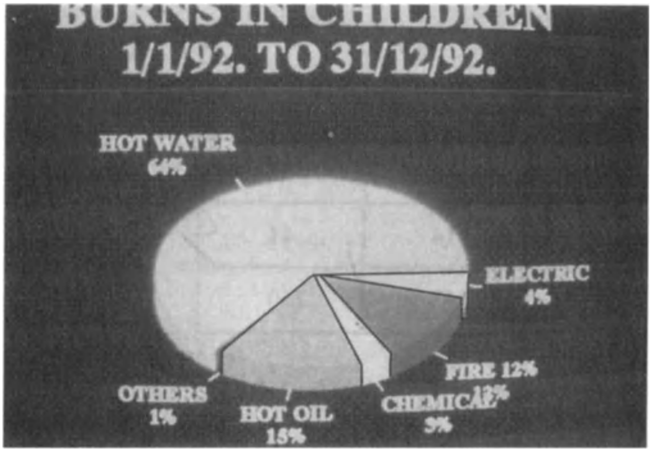


Figure 3. Causes of burn

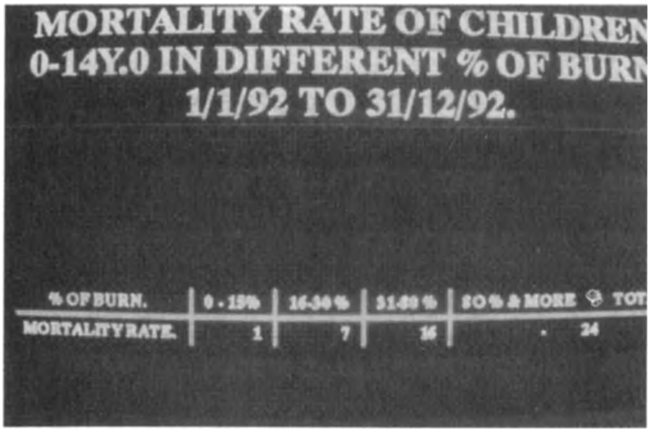


Figure 4. Table of mortality rate

found that 93% of all burns in children aged under 6 years, occurred in the home, but contrasts with the findings of Lindblad and Jerkelson (1990).

The sex ratio in this study corresponds to that reported by Davies (1990), Learmonth (1979) and Gorem *et al.* (1988). It appears that very active and inquisitive boys under 5 years of age are responsible for the predominant male incidence.

The general pattern of burns in relation to the various age groups is almost the same in Libya as in western studies and in India (Muir *et al.*,

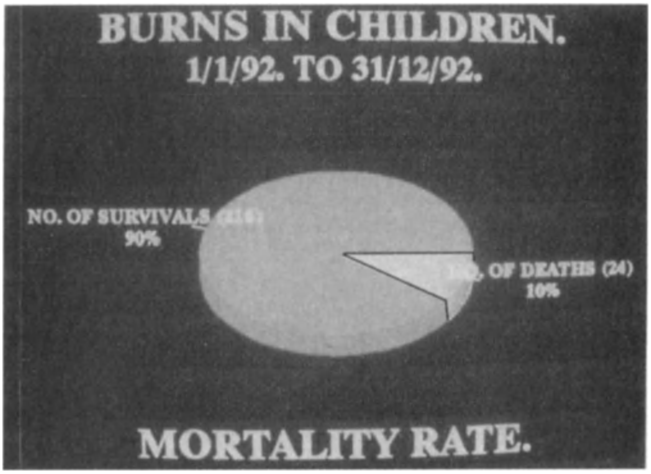


Figure 5. Mortality rate

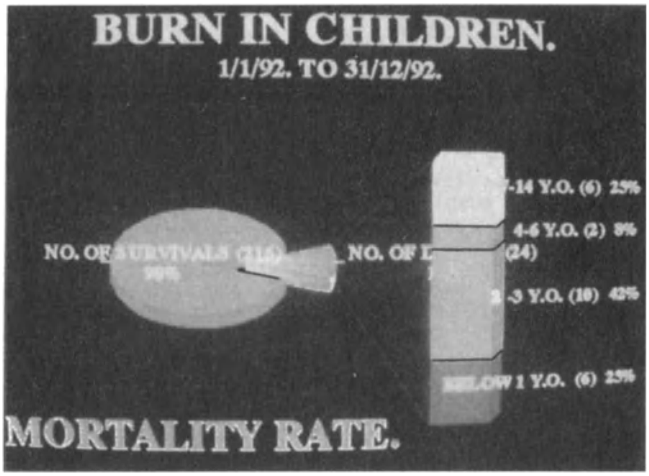


Figure 6. Mortality rate, age distribution

1987; Gupta *et al.*, 1992). Children below one year of age are relatively immobile and receive burns from hot liquids being spilled on them.

The overall mortality in our study was 9.6%, which is lower than that reported by Mabogunje *et al.* (1987) (13%) and Gupta *et al.* (1992) (19.7%) but higher than Jamal *et al.* (1990) (4.3%) and Bang *et al.* (1992) (3%). The decrease in mortality and morbidity is not related to a decrease in incidence but is due to recent advances in burn care.

The above study shows clearly that most burns were due to parental carelessness and negligence. An intensive campaign to make parents aware of the dangers of floor-level tea preparing and of allowing children to help or play around the kitchen or cooking areas and to play with matches is necessary to minimize the incidence of burns in children. Parents must not ask children to carry dangerous hot liquids (milk, tea or water). This study reveals that we should provide education for parents, especially housewives, in order to save children from devastating injuries. At present we have no organization to promote this campaign and burn care units must therefore start the work of prevention. This will go a long way towards reducing the incidence of burns.

BIBLIOGRAPHY

Akhtor, M., Gang, R. K. (1981). Epidemiology of burns in Benghazi, Libya. *Burns*, **7**, 351
Bang, R. L. *et al.* (1992). An analysis of childhood burns in Kuwait. *Burns*, **18**, 224
Davies, J. W. L. (1990). The problem of burns in India. *Burns*, **16** (Suppl), 54–515
Gorem *et al.* (1988). Burn injury in children. *Ind. Prac.*, (1988). 847
Gupta, M., *et al.* (1992). Pediatric burns in Jaipur, India: an epidemiological study. *Burns*, **18**, 63
Iskrant, A. P. (1967). Statistics and epidemiology of burns. *Bull. N. Y. Acad. Med.*, **43**, 636
Jamal, Y. S. *et al.* (1990). Pediatric burn injuries in the Jeddah area of Saudi Arabia. *Burns*, **16**, 36
Learmonth, A. M. (1979). *J. Ind. Med. Assoc.*, **73**, 43
Lindblad, B. E., Jerkelson, C. J. (1990). Domestic burns among children. *Burns*, **16**, 254
Mabogunje, O. A. *et al.* (1987). Childhood burns in Zaria, Nigeria. *Burns*, **13**, 298
Mackay *et al.* (1979). A comparison of age specific burn injury rates in five Massachusetts Communities. *Am. J. Public Health*, **69**, 1146
Muir I. F. K. *et al* (1987). The scope of the burns problem. In: *Burns and their management*, 3rd ed. Oxford: Butterworth Heinemann
Smith, E. L. (1969). The epidemiology of burns. The cause and control of burns in children. *Paediatrics*, **44**, 821

34
Epidemiology of outpatient burns as a public health problem

N. UÇAR and M. HABERAL
Turkish Transplantation and Burn Foundation Hospital Ankara, Turkey

INTRODUCTION

The majority of burned persons can be treated as outpatients (McDouglas and Slade, 1978; Shuck, 1978; Haberal, 1984; Haberal *et al.*, 1987). Outpatient burn care should ideally be given in specialized burn units, since even minor burns, if neglected, may sometimes cause severe contractures and scars, particularly in the face and hands. Hypertrophic scars and keloids are also not uncommon following burns, especially in children. These very unfavourable late complications of burns can be minimized only by a team approach. In our centre, burns are managed in close collaboration with the Department of General Surgery and the Department of Plastic Surgery. Experienced nurses and physical therapists also belong to this team.

PATIENTS AND METHODS

In our centre, the patients are managed according to a special treatment protocol. In emergency cases, premedication is administered for relief of pain and anxiety, particularly in children. A combination of meperidine HC (100 mg), chlorpromazine (25 mg) and antihistamine (100 mg) is our choice of premedication (Haberal, 1984; Haberal *et al.*, 1987). In minor burns tricloryl is given. In the 30-minute wait while sedation is achieved, a cool, moist, clean towel is placed on the wound, if it has not been covered previously. Burn wounds are cleansed using povidone iodine and isotonic saline solution. Silver sulphadiazine or nitrofurazone embedded gauze is applied topically. Finally, the wound is covered with a bulky dressing which is changed three or four times a week. Data collected on outpatients from 1 January 1989 to 31 July 1992 were analysed retrospectively.

RESULTS

Between 1 January and 31 July 1992, 461 patients were treated on an out-patient basis in the burn unit of the Turkish Organ Transplantation and Burns Foundation Hospital. Of these, 180 (39.1%) were ≤ 10 years old, 83 (18.0%) in the second decade, 68 (14.8%) in the third decade, 59 (12.2%) in the fourth decade, 32 (6.9%) in the fifth decade, 17 (3.7%) in the sixth decade and 21 (4.6%) were over 60 years of age (Figure 1).

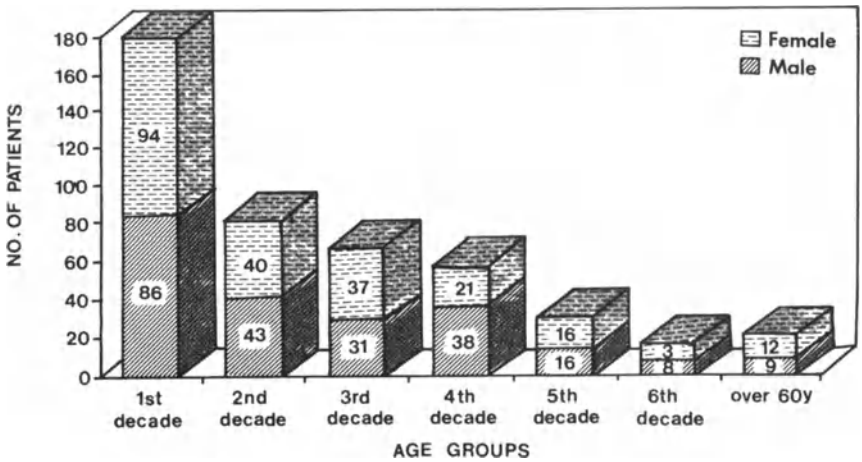


Figure 1. Distribution of patients according to age and sex

Patients ≤ 20 years of age were also evaluated separately, since burns in children are of particular importance. One hundred and twenty-nine patients (28.0%) were ≤ 4 years of age, 51 (11.1%) between 5 and 9 years old, 41 (8.9%) between 10 and 14 years old, and 42 (9.1%) between 15 and 19 years old (Figure 2).

Although there was a variety of causes, the majority of burns were caused by scalding or flame. Three hundred and forty-two burns (74.2%) were caused by hot liquids, 46 (10.0%) by flame, 21 (4.5%) by steam, including scalds due to explosion of canned goods and pressure cookers, 15 (3.3%) by electricity, 13 (2.8%) by hot metal, and 24 (5.2%) by other thermal agents (Figure 3). Most of the burns in children were due to scalding. Burns caused by flame were observed more often in those aged 30–49 than in the other decades. Burns due to domestic and occupational accidents (electricity, explosion of pressure cooker, hot tools, carburettor, LPG, etc.) were mostly seen in young adults.

Three hundred and sixty-eight (79.8%) of the patients had burns involving less than 5% of their body; 64 (13.9%) and 29 (6.3%) had burns to 6–10% and more than 11% of the total body surface respectively.

Second-degree superficial burns occurred in 92 (20.0%) patients, second-degree deep burns in 360 (78.1%) and third-degree burns in 9 (1.9%).

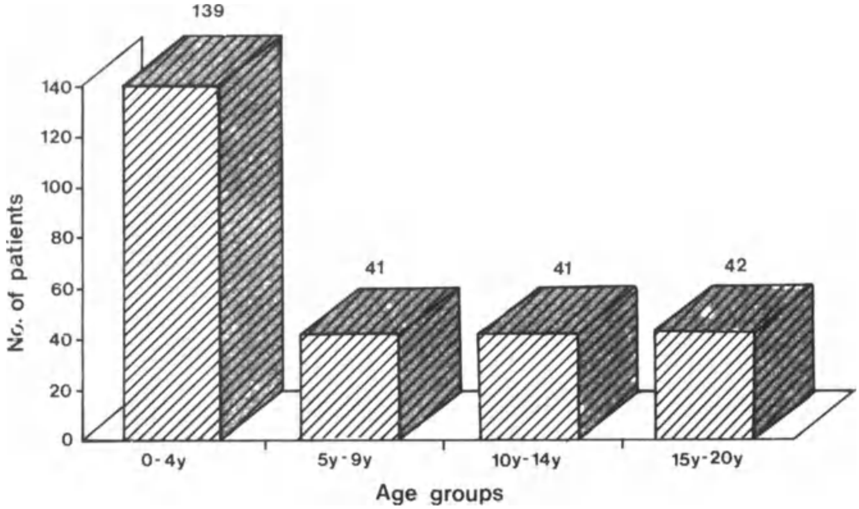


Figure 2. Distribution of patients in the first and second decades according to age

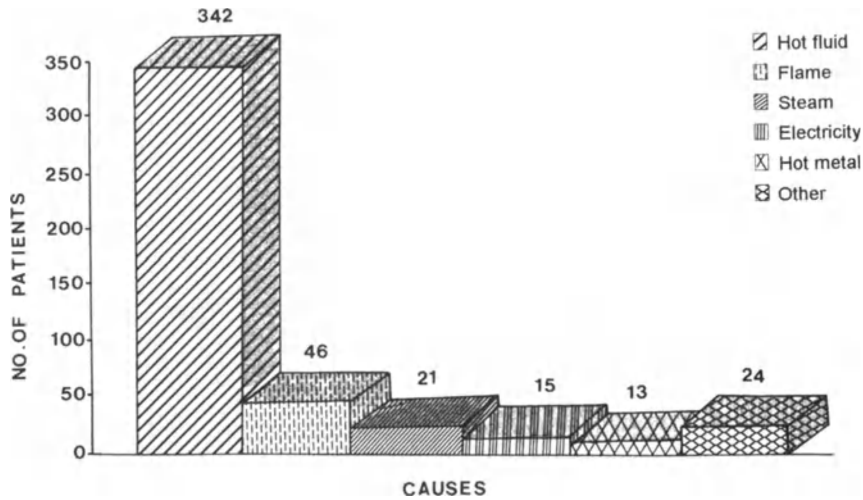


Figure 3. Distribution of patients according to cause

DISCUSSION

Burns continue to threaten public health in Turkey. Even though they are usually minor, they occasionally cause physical and psychological disorders in individuals and may lead to a reduction in their productive capacity. One of the reasons why an improvement in burn prevention could not be achieved in our country is the lack of reliable data on burns treated in different centres in Turkey. Since epidemiological studies on burns are rarely performed, the importance of burns in public health cannot be sufficiently stressed. Only by means of epidemiological studies will it be possible to establish the causes of burns and the most involved groups in the community. Then, on the basis of these data, effective measures can be taken.

The distribution of burns according to cause and the age of the patient, as also the seasonal incidence of burns, were consistent with data obtained from studies performed in another Turkish burn centre (Haberal, 1985; Haberal *et al.*, 1987, 1988, 1989).

In this study we have shown yet again the high number of children with burns. This can be attributed to insufficient parental supervision and education as regards burn prevention. Thorough questioning shows that the majority of scaldings are caused by hot water poured from teapots which have been placed carelessly on the table or floor. Burns due to occupational accidents mainly involved young people, and were due to inattentiveness and lack of knowledge about burn prevention.

No physician involved in burn treatment should neglect the epidemiological aspect of burns. Burn prevention must be promoted at least as much as AIDS education. Compared with AIDS, burns cause many more deaths, while the measures taken for burn prevention are less than one hundredth of those taken for AIDS. Worldwide health-care programmes for burn prevention should be scheduled and performed immediately. Health-care officials and physicians should educate the people through every available means in the news media.

Prevention is easier and cheaper and gives better results than burn treatment.

REFERENCES

Haberal, M. (1984). Early care of minor and moderate burns. In: *Burns: Emergency and Acute Care*. Davis, CA: University of California, 29–38

Haberal, M. (1985). Electrical burns: A five year experience. 1985 Evans Lecture. *J. Trauma*, **26**, 103–109

Haberal, M., Oner, Z., Bayraktar, U. and Bilgin, N. (1987). Epidemiology of adults' and children's burns in a Turkish burn centre. *Burns*, **13**, 136–140

Haberal, M., Oner, Z., Bayraktar, U. and Bilgin N. (1988). Analysis of 745 hospitalized burn patients. *Ann. Medit. Burns Club*, **1**, 44–45

Haberal, M., Kaynaroglu, V., Oner, Z., *et al.*, (1989). Epidemiology of electrical burns in our centre. *Ann. Medit. Burns Club*, **2**, 14–16

McDouglas, S. and Slade, W. (1978). Comprehensive manuals of surgical specialties. In: *Manual of Burns*. Berlin: Springer-Verlag, 3

Shuck J. M. (1978). Outpatient management of the burned patient. *Surg. Clin. N. Am.*, **58**, 1102

Section V

Intensive care

35
Computer support in fluid resuscitation for burn patients

A. BENIGNO, S. GULLO, R. BRANCATO and M. MASELLIS
Divisione di Chirurgia Plastica e Terapia delle Ustioni, Ospedale Civico, Palermo, Italy

INTRODUCTION

In the belief that information technology can offer burns specialists valuable support in their daily work, we have produced a software program for fluid resuscitation in burn patients. The computer clearly cannot replace the physician in diagnostic and therapeutic decisions, but it can give information and forewarning in emergency conditions and provide immediate support for the decisions taken.

The module that we present considers resuscitation therapy in the first 24 h in a burn patient not suffering from previous pathologies or any complications. The module is part of a wider project for the clinical and therapeutic monitoring of burn disease in all its complexity and therefore also for patients suffering from previous or concomitant pathologies.

The program was produced using the therapeutic protocols followed at the Department of Plastic Surgery and Burns Therapy in Palermo (Italy). The parameters used were established on the basis of experience acquired during many years of activity.

THE PROGRAM

The program is in four sections:

1. Input of patient's personal details and anamnesis. Assessment of expected therapy.
2. Print-out of predicted therapy in first 24 h with laboratory test timetable.
3. Input of patient's clinical data and laboratory test results in first 24 h.
4. Modification / update of patient data.

Section 1 of the program begins with the input of data listed in Table 1. When the data have been inserted, the following values are calculated automatically: time interval between trauma and admission to the Burns Centre; predicted quantity of infusion fluids; hourly infusion rate; and the Roi index.

The volume of fluid is calculated on the basis of the formula used in the Burns Department:

$$\frac{\text{BSA} \times \text{body weight} \times 2.5}{24\ \text{h}}$$

The fluid is calculated as equal percentages (50%) of Ringer's lactate and plasma protein solution administered alternately during the 24 h. In the case of patients admitted without having received any fluid resuscitation and after a time interval of 3 h the volume calculated is increased by 30%.

Table 1. Patient data

Personal and physical data
Date and time of burn
Date and time of admission
Percentage body surface area (BSA) burned
Cause and manner of trauma
Previous pathologies and / or associated traumas
Lesions in the respiratory tract
Burns in the face and / or perineum
Fluids infused before admission

Section 2, after the data input phase, consists of the print-out of a therapy sheet to be attached to the clinical file, indicating the quantity and type of infusion solutions plus the blood chemistry tests to be performed, together with time schedules and supportive medical therapy.

The clinical data input section includes data listed in Table 2. The modification/update section makes it possible to modify any incorrect data and to add data available only after discharge, as for example data concerning final recovery.

Table 2. Clinical data

Diuresis
Haematocrit
Arterial pressure
Temperature
Weight
Laboratory tests

ANALYSIS OF THE PROGRAM

Computer management of the patient provides an hour-to-hour assessment of diuresis and of blood gas analysis data, with indications for any necessary corrections. Every 3 h an overall evaluation is made of the various parameters, and an opinion is formulated as to the accuracy of the predicted quality and hourly quantity of infusion fluids and to any modifications of pH that may be necessary.

Any therapeutic procedures performed by the physician that are different from those processed by the computer will be automatically accepted by the program; a record will remain in the data base for future reference.

When pH is lower than 7.37 it is recommended that bicarbonates should be infused, according to the formula:

$$(B.\ E. \times \text{body weight})\ /\ 3$$

Any significant modifications of $P_{CO_2} > 50$ mm Hg and < 30 mm Hg are reported.

On the assumption that in burn patients not suffering from previous and/or concomitant pathologies the volume of urine output is one of the most reliable parameters for the monitoring of fluid therapy, we regard an hourly diuresis ranging between 0.5 and 1.0 ml/kg as normal.

The urine balance is calculated every 3 h, i.e. on the basis of the diuresis of the previous 3 h. In cases of excessive diuresis there should be a 30% reduction in the amount of fluid remaining to be infused, and an increase of 30% in cases of insufficient diuresis (Figure 1).

If mean diuresis in the previous 3 h is greater than the expected range but there is a trend in the third hour towards reduction, or if mean diuresis is lower than the range but the trend in the third hour increases, the overall balance is postponed for 1 h in order to have a more accurate calculation of the parameters. In this case the assessment is calculated on the basis of mean diuresis in the last 2 h (Figure 2).

Calculation of the overall balance is also postponed when the final laboratory tests indicate plasma hyperosmolarity or hypoglycaemia,

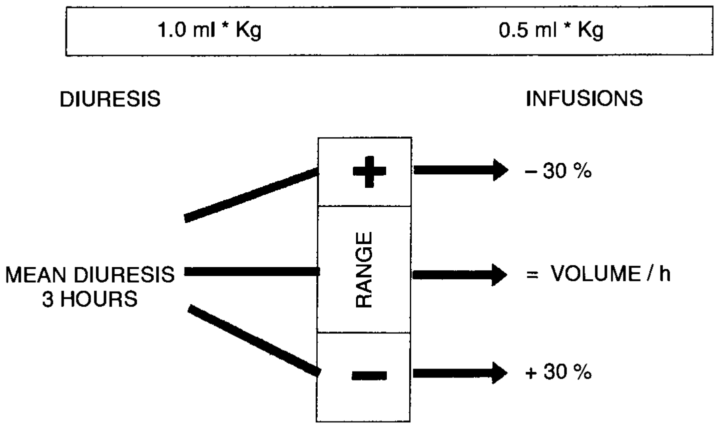


Figure 1. Algorithm followed in formulation of recommended treatment

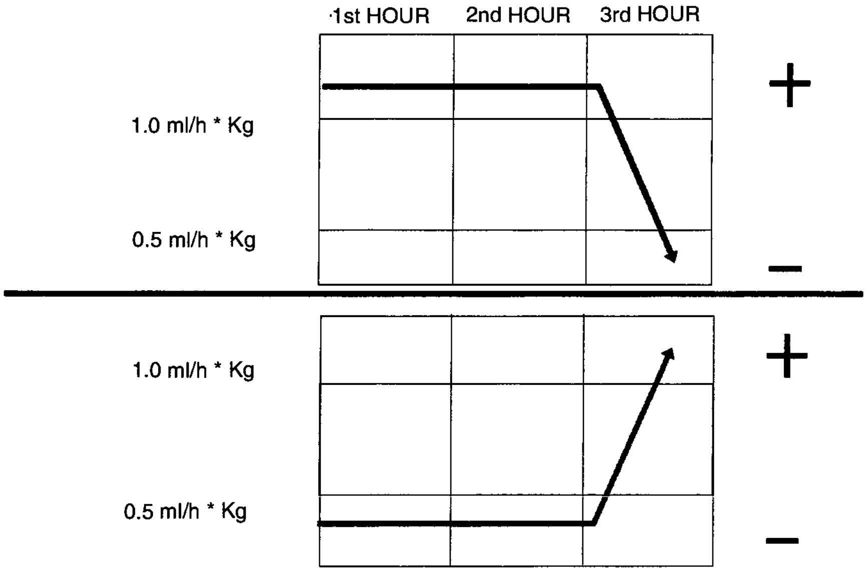


Figure 2. Cases in which the prescribed treatment is temporarily suspended or postponed to the next hour

without any other alterations of blood chemistry, but in the presence of a diuresis that is greater than or equal to the normal range.

In this case the prescribed treatment is suspended for the next 2 h and, if hyperglycaemia is adequately corrected, the assessment is made on the basis of diuresis in the hour when glycaemia returns to acceptable values (Figure 3).

If it proves impossible to correct the patient's glycaemia values, the patient is automatically excluded from the protocol. Patients with persistent hyperglycaemia as described above and those with diuresis less than the normal range who present hyperglycaemia and/or hyperosmolarity even without other modifications are also excluded (Figure 4), as are those with altered parameters as shown in Table 3, patients with oliguria or anuria for > 5 h and patients in whom the computer program is not observed at the prescribed times.

Table 3

increase in BUN > 70 mg/dl
increase in natraemia > 150 mEq/l
increase in plasma osmolarity > 310 mosm/l
increase in urine osmolarity > 1000 mosm/l
reduction in plasma osmolarity < 270 mosm/l
reduction in urine osmolarity < 150 mosm/l
reduction of Po_2 below 65 mm Hg

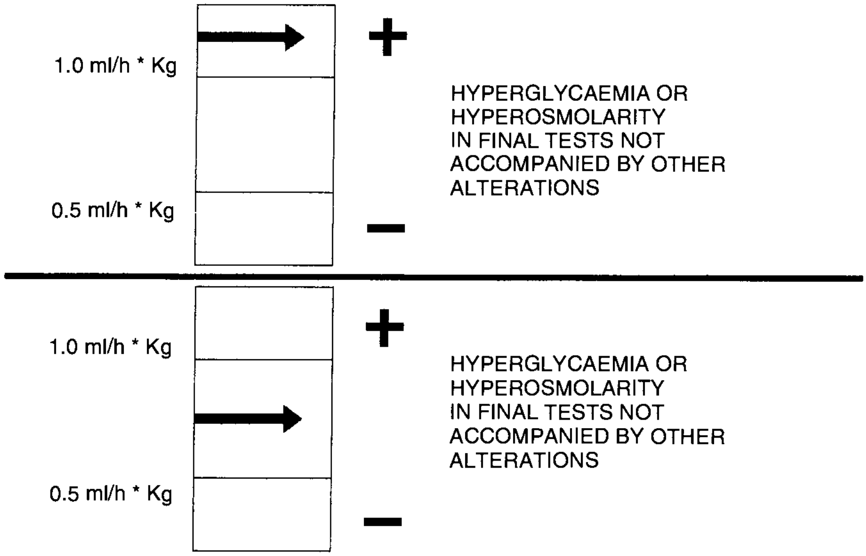


Figure 3. Cases in which the recommended treatment is temporarily suspended or postponed to the next hour

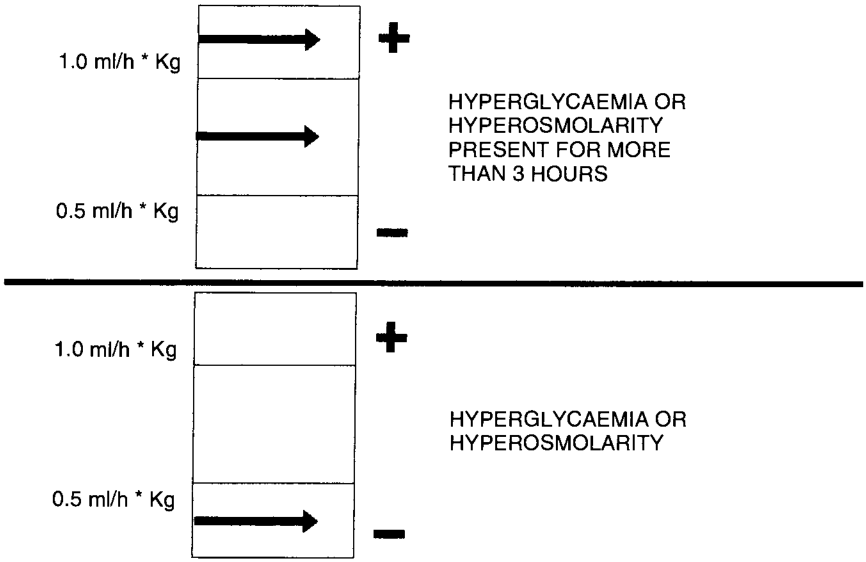


Figure 4. Cases in which the patient cannot be followed up by the program

CONCLUSIONS

The program is intended to be a useful and practical instrument in the physician's daily work. It represents the first step in a more ambitious plan aimed at the production of a protocol based on multiple and multidisciplinary experiences, the reliability of which will be checked and improved by periodic retrospective revisions of the input data.

BIBLIOGRAPHY

Arturson, G. (1988). Computer simulation of fluid resuscitation in thermal injury. *Burns*, **14**, 257–268

Arturson, G. *et al.* (1984). Potential use of computer simulation in treatment of burns with special regard to oedema formation. *Scand. J. Plast. Reconstr. Surg.*, **18**, 39–48

Arturson, G. *et al.* (1989). Computer simulation of fluid resuscitation in burns. *J. Burn Care Rehab.*, **10**, **4**

Demling, R. H. (1985). Burns. *N. Engl. J. Med.*, **313**, 1389–1398

Demling, R. H. (1987). Fluid replacement in burned patients. *Surg. Clin. N. Am.*, **67**, 15–29

Planas, M. *et al.* (1982). Characterization of acute renal failure in the burned patient. *Arch. Intern. Med.*, **142**, 2087–2091

Schiavon, M. *et al.* (1988). A study of renal damage in seriously burned patients. *Burns*, **14**, 107–114

Settle, J. (1972). Urine output following severe burns, *Burns*, **1**, 23–42

36
The life-saving potential of anaesthesiology in burned patients; classical approaches and new perspectives

J. POKORNY
Prague Rescue Service, Chair of Emergency and Disaster Medicine, Postgraduate Medical Institute, Prague, Czecho Republic

---

Burn and fire disasters, in spite of enormous technical progress, continue to be a real danger even in our days. They may take the form of a natural disaster, e.g. a volcanic eruption or a thunderbolt, or they may be man-made. They cause considerable material losses and mass burn casualties.

Severe burn injury stresses the victims enormously with pain and shock and is life-threatening, first immediately after the accident and later on, during stressful and long treatment. The care of a severely burned patient starts on the site of the accident immediately after the injury, with first aid measures. It continues with prehospital immediate medical care, followed by hospital care, ideally in a burn centre. Specialized care for burn patients is provided by the burn specialist in close cooperation with an anaesthesiologist and other medical professionals, such as internists, clinical biochemists and radiologists.

Thermal injury induces immensely variable pathological changes. The patient's fate is determined, above all, by the extent of the burned body surface, the depth and localization of the burns, and the rapidity of effective first aid. During the emergency period the burn patient requires immediate and skilled first aid, prehospital immediate care from adequately trained medical personnel (physicians, nurses), and specialized hospital care.

The specialty of anaesthesiology and intensive care plays a significant role in the care of burn patients from the moment of injury until completion of reconstructive surgical interventions. In prehospital immediate care anaesthesiology provides effective analgesia and, in cases of respiratory or circulatory failure, life-saving interventions (cardiopulmonary cerebral resuscitation). The anaesthesiologist's skill may be decisive in the care of patients injured by inhalation of hot vapour or gas, toxic fumes or ingestion of corrosives. In less serious cases of respiratory insufficiency the anaesthesiologist initiates and controls inhalational oxygen therapy. As a member of the Emergency Medical Service (EMS) car squad the anaesthesiologist is the best qualified person to start resuscitation of the victim. He has the clinical skill to perform the primary triage of burn patients and to initiate life-saving measures such as the opening and securing of the airways, control of lung ventilation with ventilatory support, if necessary, and also, by inserting the intravenous life-line, he initiates and controls antishock therapy. In cases of cardiac arrest, the anaesthesiologist starts basic life support (BLS) or takes over therapy from first-aid workers and continues with advanced life support (ALS).

Prehospital emergency care includes the following life-saving and therapeutic methods used and developed by anaesthesiologists:

- opening and securing the airway;
- checking of lung ventilation and oxygenation, control of artificial ventilation and inhalational oxygen therapy;
- access into the blood circulation and initiation of aggressive antishock infusion therapy;
- cardiopulmonary cerebral resuscitation;
- pain-relieving analgesia: ketamine 0.3–0.5 mg/kg, meperidine 0.5–1.0 mg/kg, fentanyl 0.005–0.01 mg/kg, morphine 0.7–1.0 mg/kg.

In mass burn casualties, an experienced anaesthesiologist may be authorized to perform the primary triage of victims.

The most extensive task that anaesthesiologists have to master, however, is the specialized hospital care of severely burned patients, which is extremely demanding and complex and is provided by a team of experts cooperating with a burn surgeon. The anaesthesiologist is irreplaceable in planning and performing analgesia and anaesthesia in the very frequently repeated dressing changes and in surgery. He is responsible for the relief from the immense suffering in severely burned patients not only during their surgical treatments but also in between.

The anaesthesiological care of severely burned patients has specific requirements to be respected.

1. During the emergency period, shock may last 24–48 h. Shock treatment and the patient's general state must be taken into account when anaesthesia is vitally indicated.
2. During the emergency period life-threatening complications may arise. Their prevention and therapy may require continuous monitoring of breathing, early tracheal intubation, assisted or augmented artificial lung ventilation or corticosteroids (locally as well as parenterally).

3. Owing to the requirements of surgical treatment, anaesthesia has to be given for many weeks in short intervals for painful dressing-changes, necrectomies, plastic reconstruction of burned surfaces and their covering. These surgical operations are stressful, performed on patients in a catabolic state, and they limit significantly his nutritional regime. Repeated anaesthesias overload the metabolic mechanisms and infection and haemorrhage may complicate treatment.
4. The tolerance to anaesthetics in an individual weakened by the burn injury may develop into resistance or hypersensitivity. One attending anaesthesiologist who knows the patient best should thus control care throughout treatment.
5. The burn injury causes considerable and long-lasting pain which is multiplied by the necessary surgical treatment. The anaesthesiologist must therefore see and monitor the patient in periods between therapeutic interventions in order to adapt analgesia to the needs of the patient.
6. Many seriously burned patients after the emergency period develop malnutrition because of a failure to satisfy the increased need of nutrients through parenteral nutrition.
7. In spite of maximal efforts to maintain an aseptic regime, infection may occur and the patient may develop chronic sepsis.

The severely burned patient is subjected to enormous stress, much more severe than that after planned surgical operations, for a long period after injury. Survival requires complex and complicated therapy. This can best be realized in specialized departments and burn centres, where anaesthesiologists participate in the intensive or resuscitative care, as well as providing anaesthesiological care.

I will now describe some results of research undertaken in Czechoslovakia over the last 32 years, results which will in my opinion contribute significantly to the treatment of severely burned patients in coming years. The first of our research topics was local and general electroanaesthesia. The team, headed initially by J. Počta and since 1969 by Jan Pokorný (anaesthesiologists) and by M. Lébl (technician), constructed for the experimental period and later for clinical trials a series of four different apparatuses for electroanaesthesia and developed a method for clinically applicable general electroanaesthesia. Electrical impulses, the main anaesthetic agent, are fully non-toxic and without any after-effects. The most important aspect is that there are no demands on the patient's excretory mechanism. The present method comprises routine premedication, followed by intravenous induction using minimal doses of some ultra-short acting hypnotic such as diazepam, flunitrazepam, fentanyl or thiopentone. Initiating with drugs prevents the excitatory manifestations of induction with electrical impulses only. After endotracheal intubation anaesthesia is maintained by defined electrical impulses applied to the brain through electrodes fixed on the frontal and occipital regions of the head. Anaesthesia lasts as long as the time of release of electrical impulses; it is therefore fully controllable and adjustable to any time needed for the intervention. After termination of electroanaesthesia the patient awakes immediately and a very beneficial long-lasting state of analgesia follows. Combined general electroanaesthesia (CGE) appears to be a good perspective for severely burned patients because the amount of drugs applied is insignificant so that there is no accumulation of drugs in the severely stressed patient and consequently repeated application is possible without any undesirable side-effects. In Czechoslovakia, CGE was tested successfully in more than 600 surgical operations of many kinds although not in severely burned patients. Nevertheless, the excellent results achieved in patients with serious complicating diseases allow us to recommend the technique. The apparatus is small and compact, and simple to operate, offering the well-proven, best combination of electrical impulses. The search for this combination has been the topic of our long-lasting experimental and clinical research (Figures 1 and 2).

The second method for improving the care of severely burned patients with really positive potentials is the result of 12 years' research headed by O. Brychta (technician and physicist) and V. Zábrodský (anaesthesiologist) on high frequency jet ventilation (HFJV) of the lungs. This artificial ventilation mode has been studied all over the world as an alternative to the conventional mode for the last 15 years. In the USA. M. Klain, H. Keszler and J. Smith are investigating HFJV in parallel and since 1980 they have cooperated with us, as regards its clinical application. Brychta is the designer of the apparatus and the theoretical physi-

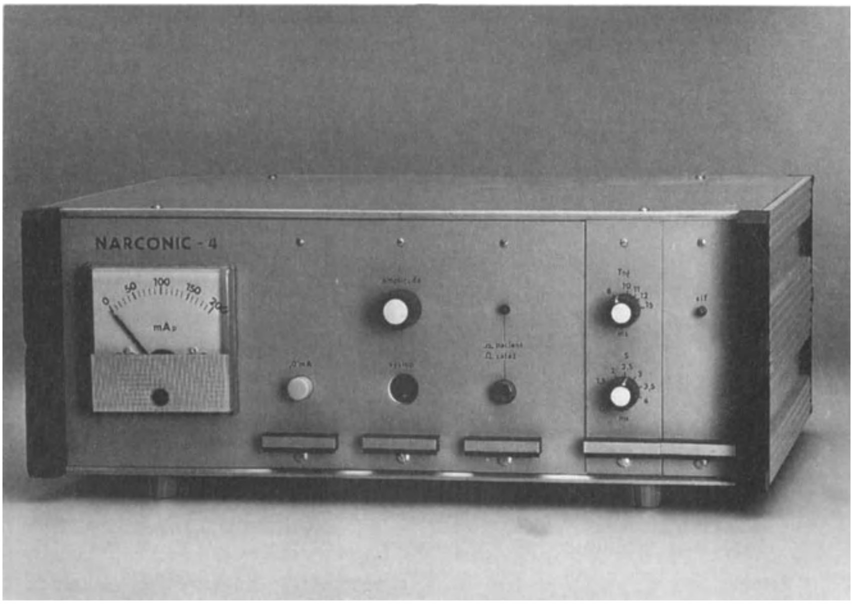


Figure 1. Czechoslovak apparatus for general electroanaesthesia

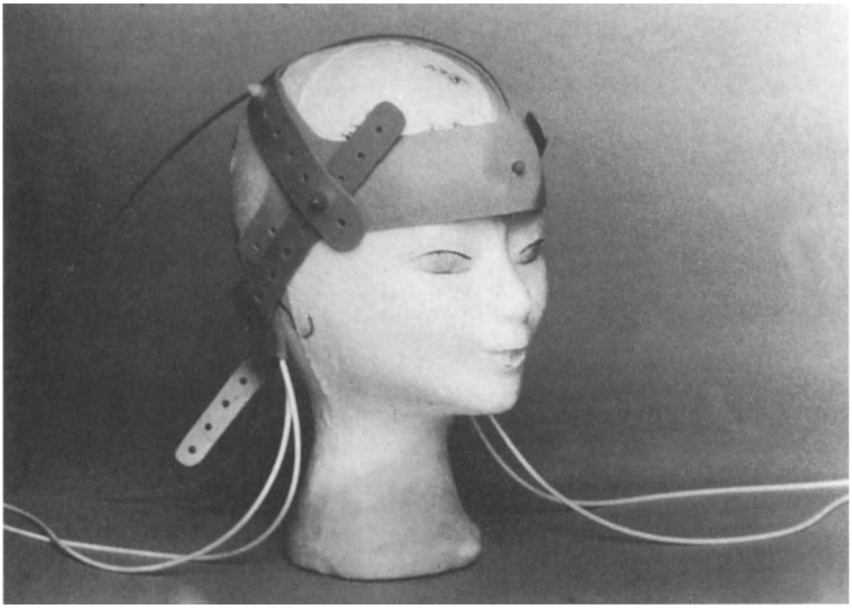


Figure 2. Fixation of frontal and occipital electrodes for general electroanaesthesia

cist. He has elaborated the theoretical basis for understanding the mechanism of HFJV. This ventilatory mode integrates the present conventional artificial lung ventilation as it is effective in patients in whom the conventional mode fails. Its application to the patient's airway does not require a sealed tracheal tube – a catheter over the bifurcation of the trachea or a needle introduced into the trachea through the cricothyroid membrane is sufficient. By the expulsion effect this method protects the patient from the aspiration of foreign contents into the lower airway. Thanks to the same expulsion effect aeration of the lungs may be restored and maintained. We call this effect 'programmable lung drainage'. These properties of the method are of utmost importance for persons affected by inhalation burn injury. Brychta has solved a very urgent problem of HFJV, i.e. how to protect the patient from barotrauma due to possible penetration of high driving pressure into the airway. Brychta constructed a sensor for continous monitoring of tracheal pressure over the bifurcation with a feed-back to the ventilator which automatically switches off the driving pressure from the patient whenever tracheal pressure rises above an acceptable level. He has also invented and constructed the 'multi-jet generator', a device enabling the attachment of the high frequency jet ventilator to patients of all bodymass and age categories, from the newborn to the heaviest of adults. The principle of expulsion is based on the regulation of the inspiratory–expiratory time relation during HFJV. The operator may 'tune' the machine according to impulsion, if he wishes to transport therapeutic aerosols into the lower airway as far as the respiratory bronchioles, or to expulsion, if it is necessary to expel from the peripheral airway secretions, tissue detritus or aspired foreign content. In severely burned patients, particularly children, we were able to solve these problems, which may be of utmost importance. The high frequency jet ventilator (Figures 3–6) has proved to be a desirable supplement to therapeutic facilities in a burns centre. HFJV in severely burned patients may dramatically improve the following conditions:

- Adult respiratory distress syndrome (ARDS);
- Ventilatory insufficiency due to stiff thorax after burn injury to the thorax wall;
- Inhalation burn injury;
- Excessive secretions and tissue detritus in the lower airway.

The third contribution to the care of severely burned patients is the access into the blood circulation for infusion therapy, blood transfusion and the administration of drugs including anaesthetics through the spongy bone. The method of intraspongiose (intraosseous) administration was developed, clinically elaborated and proposed as early as 1943 by the Czech surgeon V. Drašnar, who has received international

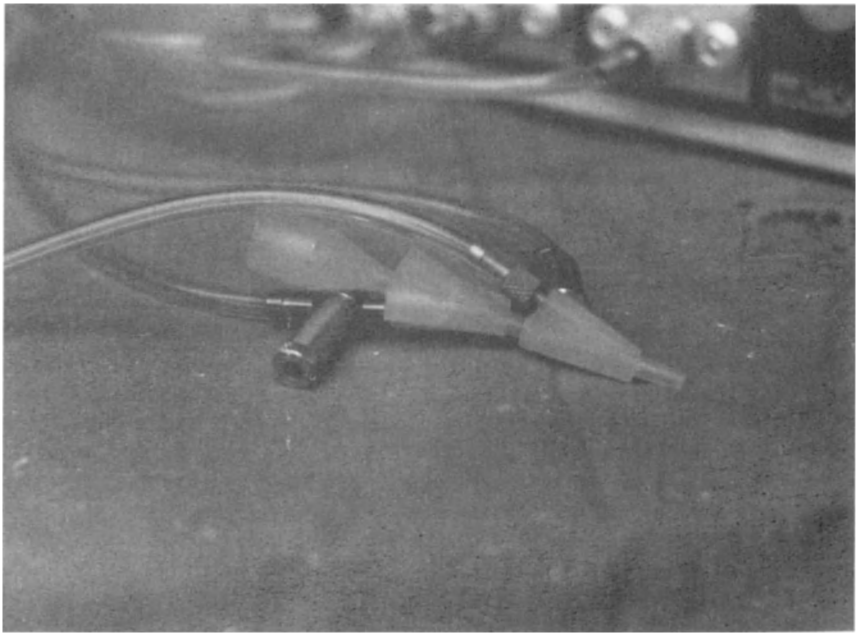


Figure 3. Multi-jet generator by O. Brychta; part of the Czechoslovak high frequency jet ventilator

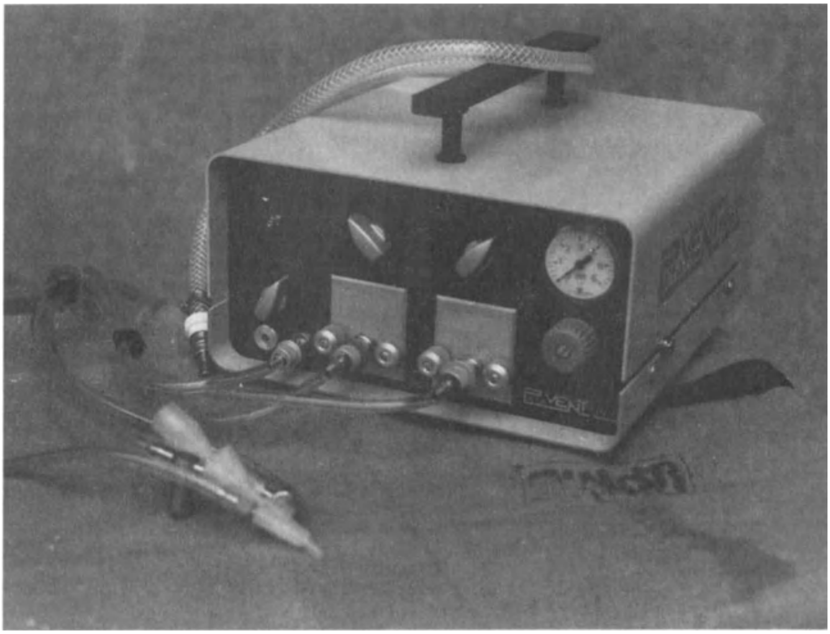


Figure 4. Czechoslovak high frequency jet ventilator. Portable type for the Emergency Medical Service

Figure 5. Czechoslovak high frequency jet ventilator – clinical type

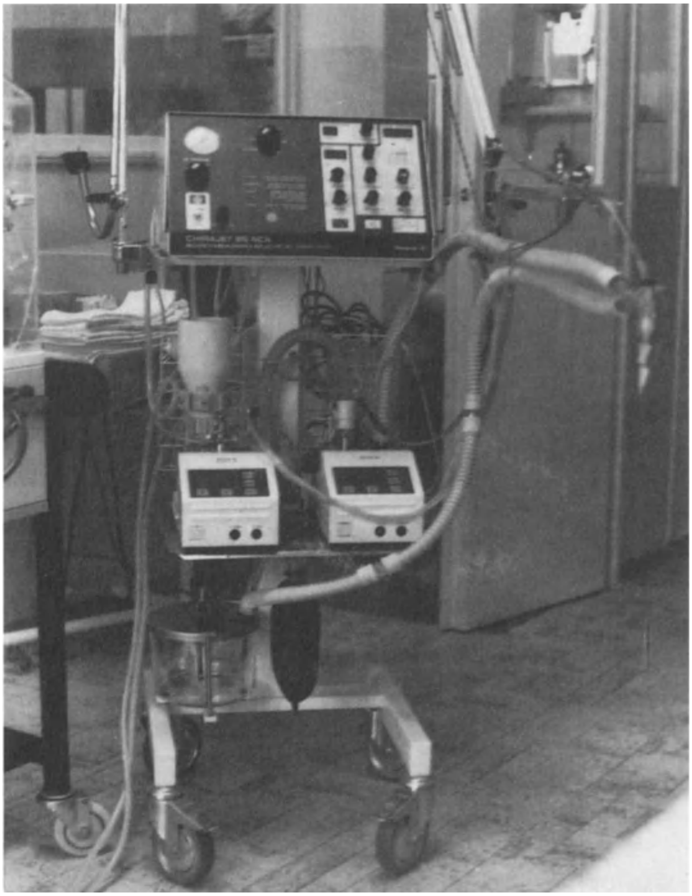


Figure 6. Czechoslovak high frequency jet ventilator – clinical type with low-pressure and high-pressure humidifiers

acknowledgement as an inventor in the French and Swiss literature. He designed the appropriate needle, manufactured since 1958 by the Czechoslovak producer PREMA (Figure 7). The method provides easy and rapid access into the blood circulation in burned patients in whom the skin surfaces covering the veins normally used for veni-puncture and catheterization are injured. An immediate initiation of fluid therapy is thus possible on the site of accident and in the emergency period. The technique of bone puncture is simple and suitable for disaster medicine. It was popular in the 1950s, but later abandoned. At the Pan European Conference on Emergency and Disaster Medicine in Budapest in 1992 the Italian paediatrician Ghirga recommended this still neglected method for children in emergency. He uses an updated model of the needle for the puncture.

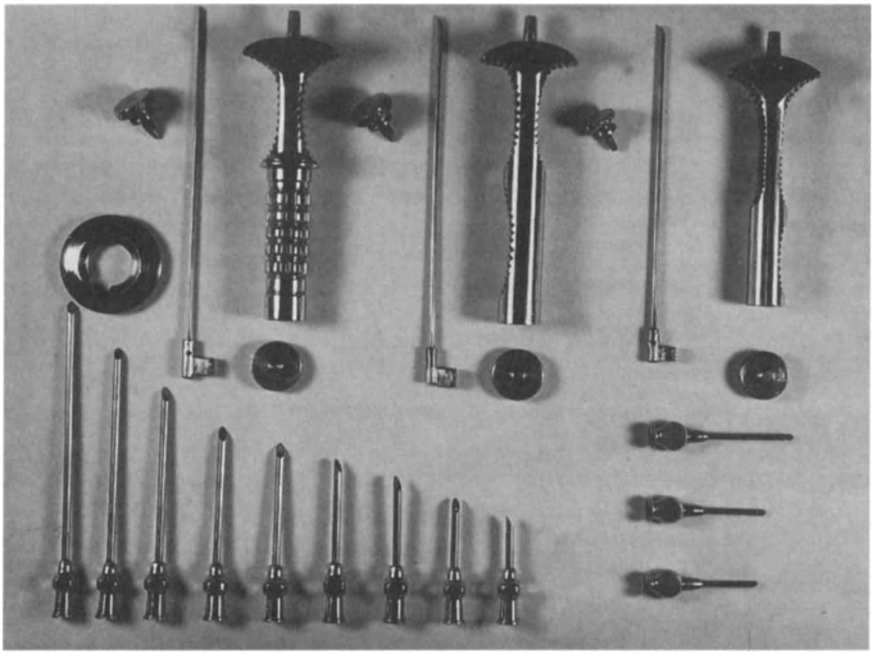


Figure 7. Set of needles with handles for intraspongiose (intra-osseous) administration of fluids

The care of severely burned patients is highly demanding, even that of a single case. In mass burn casualties various measures may serve to lower mortality and to save as many lives as possible. These measures include:

- good organization of rescue operations;
- good preparedness of the rescuers;
- early and effective first aid;
- correct triage of victims;
- best medical care available.

There are, of course, great differences in the possibilities of life-saving which depend directly on the number of victims and the capacities of the medical service in the territory affected. If the number of victims is calculated in tens the life-saving chances are much higher than in an extensive catastrophe with hundreds or even thousands of burned patients.

In 1983 WHO officially informed governments in a special report that in a nuclear war no medical system in any country would be able to provide effective aid to the casualties. Some 60–80% of all the injured are expected to be burned. The present détente in international relations and the reduction of the risk of a nuclear war are therefore warmly welcome. Nevertheless, even in peacetime, mass burn casualties are to be expected – as the Mediterranean Burns Club systematically and realistically warns.

BIBLIOGRAPHY

Brychta, O. Theory of HFJV Mechanics and its Verification. Presented at 4th International Conference on Fetal and Neonatal Physiological Measurement, May 12–15, 1991, Noordwijkerhout, Netherlands. Erasmus University Rotterdam Abstract. p. 292

Brychta, O., Zábrodský, V., Pokorný, J. (1985). Expulsion effect of high frequency jet ventilation. *Eur. J. Anaesthesia*, **2**

Freitag, B. (1987). *Ausgewählte Arzneimittel in der Anaesthesie und Intensivtherapie*. Berlin: VEB Verlag Volk und Gesundheit

Kaye, W., Bircher, N. G. (1989). *Cardiopulmonary Resuscitation*. New York: Churchill Livingstone

Koenig, H., Drašnar, V. (1943). Die intrasternale und intrailiacale Dauertropfinfusion. *Zbl. Chir.*, **70**, 980–987

Königová, R. (1978). *Rozsáhlé popáleninové trauma (Extensive Burn Trauma)*. Praha: Avicenum

Manni, C., Magalini, S. I. (1985). *Emergency and Disaster Medicine*. Berlin: Springer-Verlag

Pokorný J., Lébl M. (1988). Metodika kombinované celkové elektro-anestézie (Method of the Combined General Electroanaesthesia). *Rozhl. Chir*, **67**, 83–93

Shapiro, B. A., Harrison, R. A., Trout, C. A. (1979). *Clinical Application of Respiratory Care*. Chicago: Year Book Medical Publishers

37
Efficacy of haptoglobin in haemolysis and prevention of acute renal disorders following severe burn injury

MUNEO OHTA and HIROAKI TERADA
Osaka Prefectural Senri Critical Care Medical Center, Osaka, Japan

INTRODUCTION

In Japan recent interest in burn injury has focused on the survival rate, and the pathophysiology of severely burned patients. The main causes of death in severely burned patients are sepsis and acute organ failure, while acute renal failure secondary to haemoglobinuria also occurs as a cause of death in early stages.

In patients with severe burn injury, the direct thermal destruction of circulating erythrocytes and their indirect damage due to vascular bed injury may often cause intense haemoglobinuria immediately after the burn injury. For this reason the detrimental effects of haemoglobinuria on renal function should be monitored because of the risks involved.

An injectable solution of haptoglobin, consisting of α-globulin fractions, has been marketed for 6 years by The Green Cross Corporation in Japan. It is administered in order to prevent acute renal failure due to haemoglobinuria.

Free haemoglobin is metabolized as shown in Figure 1. This indicates the significance of haptoglobin: free haemoglobin is metabolized to be the haptoglobin–haemoglobin complex in the liver. However, when the amount of free haemoglobin in the serum exceeds the metabolic capacity, owing to the exhaustion of haptoglobin, haemoglobinuria occurs and the haeme, part of the decomposed haemoglobin, may cause direct damage to the lower nephron, producing renal failure. This mechanism of the development of a haemoglobinuria also suggests the significance of the administration of exogenous haptoglobin solution in severely burned patients with haemoglobinuria (Funikoshi *et al.*, 1976; Yoshioka *et al.*, 1985, Aikawa *et al.*, 1984).

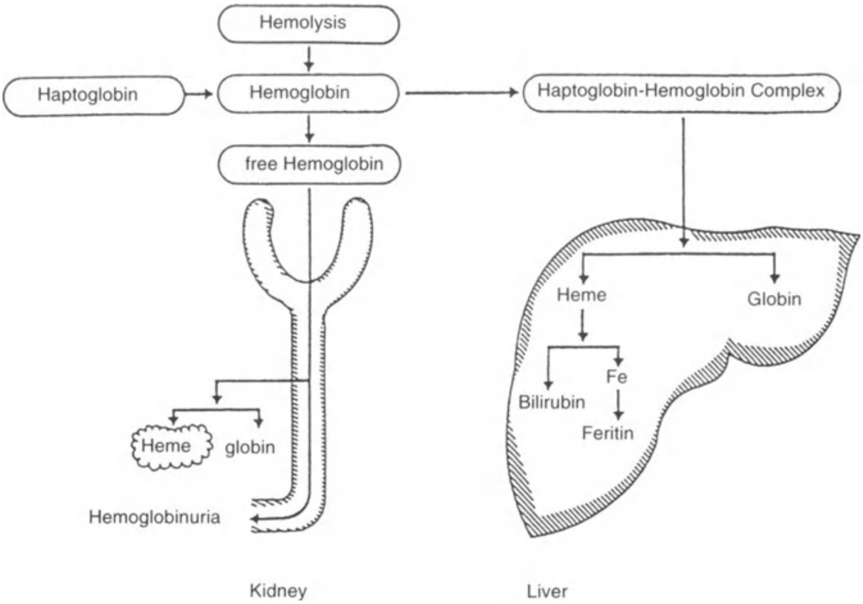


Figure 1. Metabolism of haemoglobin

The efficacy of exogenous haptoglobin administration to prevent renal disorders due to haemoglobinuria in severely burned patients was evaluated in two series of clinically controlled studies.

METHODS AND RESULTS

The first study was performed to determine the clinical efficacy of resolving haemoglobinuria. Forty-four patients with haemoglobinuria were divided into two groups on the basis of whether they received haptoglobin or not (Table 1). The control group of 19 patients received only serum while the treated group received haptoglobin in quantities from 200 to 500 ml (285.7 ± 112.5 ml) within the first few hours after burn injury. No significant difference in background was noticed between the two groups.

Table 1. Patient backgrounds (study 1)

	n	*Age (years)*	*TBSA burned (%)*	*Burn index*
Control group	25	51.0 ± 20.4	53.7 ± 29.6	45.1 ± 30.5
Haptoglobin group	19	47.5 ± 20.2	48.0 ± 29.1	38.1 ± 27.6

Values are given as mean ± s.d.

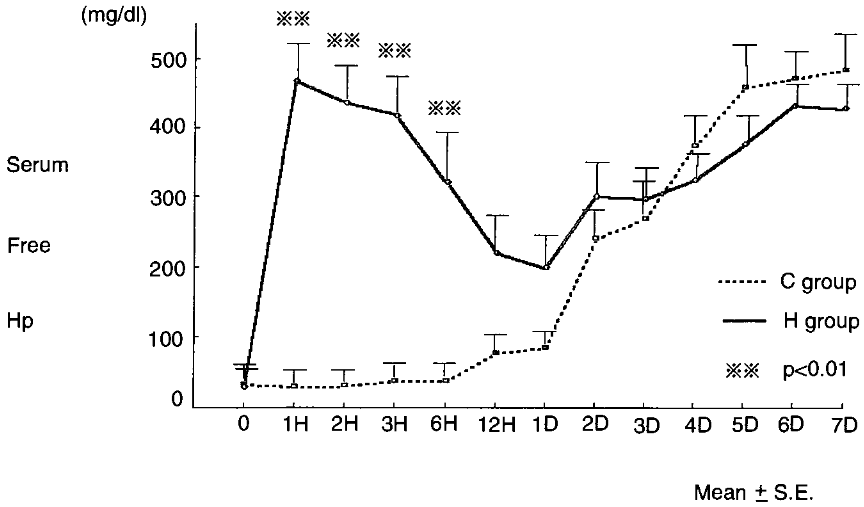


Figure 2. Changes in serum haptoglobin (study 1)

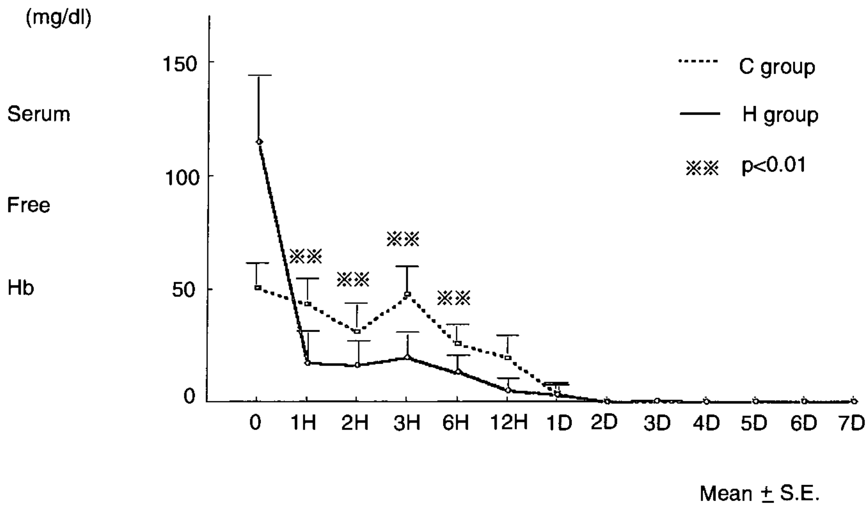


Figure 3. Changes in serum haemoglobin (study 1)

Free haptoglobin concentration in serum was certainly elevated in the treated group (Figure 2) and the free haemoglobin level in serum (Figure 3) and urine (Figure 4) was reduced to the expected level in these patients. Deaths due to acute renal failure are shown in Table 2. Deaths in patients 2 and 4 were due to sepsis. Patient 1 showed an increase in urine volume, in spite of a fatal burn with 96% burned surface area. Patient 3 also had renal failure, but this was undoubtedly due to delay in

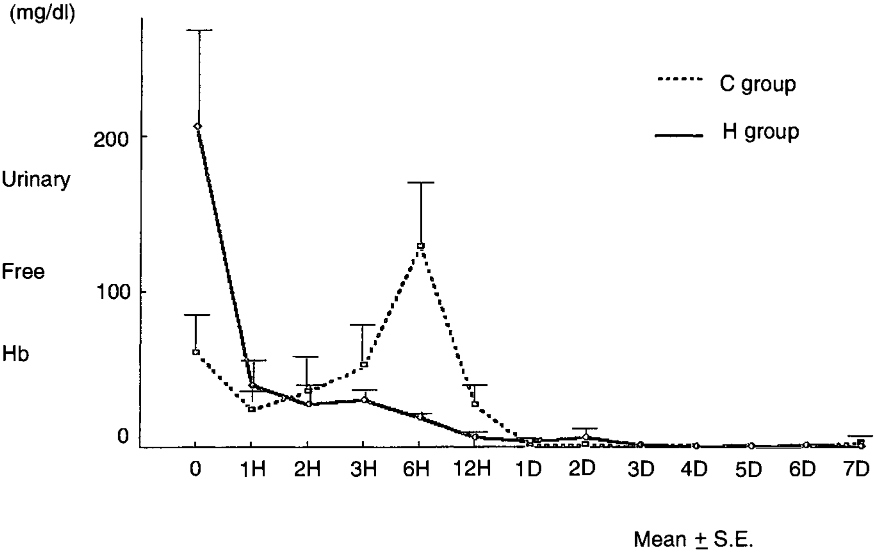


Figure 4. Changes in urinary haemoglobin (study 1)

the administration of haptoglobin. There were therefore no deaths due to renal failure in the early stage after administration of appropriate doses of haptoglobin. In contrast, five control patients (26%) died of acute renal failure.

The second study was designed to evaluate renal function on the basis of seven parameters by comparing two groups divided as above (seven in the haptoglobin group and eight controls). Again, there was no significant difference in background between the two groups (Table 3).

The sequential changes in daily urine volume during the first week postburn are shown in Figure 5. This shows that urine volume tended to be greater in the treated group than in controls, although the difference between the two was not significant. One control patient manifested oliguric renal failure, with less than 400 ml of daily urine volume during the follow-up period.

Changes in blood urea nitrogen (BUN) are shown in Figure 6. BUN in the treated patients remained roughly within normal levels during follow-up, in contrast to the serial increase in the controls with a

Table 3. Patient backgrounds (study 2)

	n	*Age (years)*	*TBSA burned (%)*	*Burn Index*
Control group	8	31.9 ± 10.9	78.8 ± 15.0	70.3 ± 18.7
Haptoglobin group	7	31.9 ± 11.7	38.9 ± 15.1	62.7 ± 15.1

Values are given as mean ± s.d.

Table 2. Patients developing acute renal failure (study 1)

Group	*No.*	*Sex (age)*	*B.I.*	*Cause of death (date of death)*	*Remarks*
Haptoglobin	1	Female (48)	96.0	Burn shock (2 days later)	Oliguric renal failure from burn shock Urine volume increased by haptoglobin administration
	2	Male (57)	19.3	Sepsis (9 days later)	Oliguric renal failure from sepsis (7 days later)
	3	Male (71)	40.5	Multiple organ failure (7 days later)	Renal failure → multiple organ failure Late administration of haptoglobin (48 h after injury)
	4	Male (46)	88.0	Sepsis (11 days later)	Oliguric renal failure from sepsis (7 days later)
Control	1	Male (54)	81.5	Burn shock (2 days later)	Oliguric renal failure from burn shock (1 day later)
	2	Male (64)	95.0	Acute renal failure (9 days later)	Non-oliguric renal failure (5 days later) Sepsis (–)
	3	Female (51)	46.5	Multiple organ failure (36 days later)	Non-oliguric renal failure (7 days later) Sepsis (–) Numerous casts were identified by necropsy
	4	Male (24)	42.5	Sepsis (7 days later)	Oliguric renal failure from sepsis (5 days later)
	5	Male (30)	54.8	Chronic renal failure (20 days later)	Chronic renal failure → Aggravation just after injury

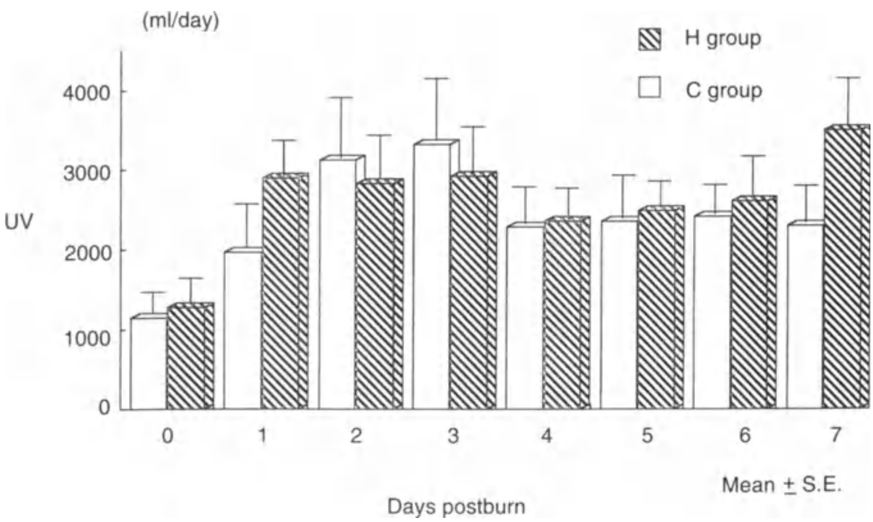


Figure 5. Changes in urine volume (study 2)

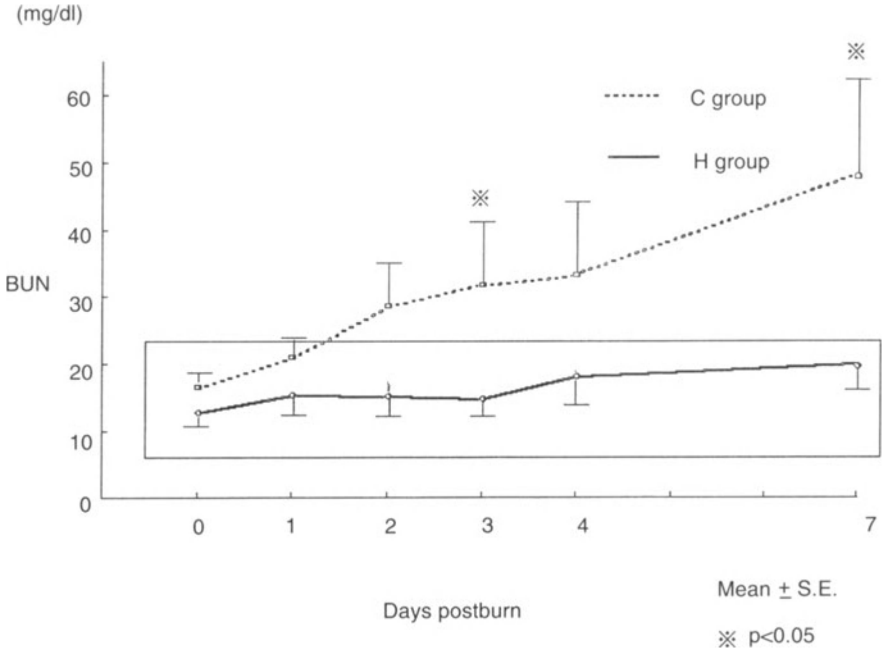


Figure 6. Changes in blood urea nitrogen (study 2)

significant intergroup difference on days 3 and 7. Two of the eight patients in the control group developed azotaemia with a BUN of 60 mg/dl or over, resulting in oliguric renal failure in one patient and non-oliguric renal failure in the other.

Changes in serum creatinine are shown in Figure 7. Patients treated with haptoglobin showed variations with normal levels throughout the follow-up period, while the controls showed a serial increase in this parameter, similar to that seen in BUN, indicating a significant intergroup difference on day 1 ($p < 1$) and on days 2 and 3 ($p < 0.5$).

Figure 8 shows the changes in creatinine clearance. The haptoglobin treated group showed near normal variations during the follow-up period, while the controls registered a mean value as low as 32.0 ± 7.7 ml/min on day 1, with trends towards gradual improvement until day 4, with another decrease on day 7. A significant intergroup difference existed on day 1 ($p < 0.1$) and on days 2 and 3 ($p < 0.5$).

Changes in free water clearance are shown in Figure 9. During the follow-up period, five of the eight control patients and one of the seven patients receiving haptoglobin had a value over 0.5 ml/min.

The last parameter concerns changes in the excreted fraction of filtered sodium (Figure 10). In the early phase patients received infusion of lactated Ringer's solution or hypertonic lactated Ringer's solution. A progressive aggravation was noted in two control patients while two

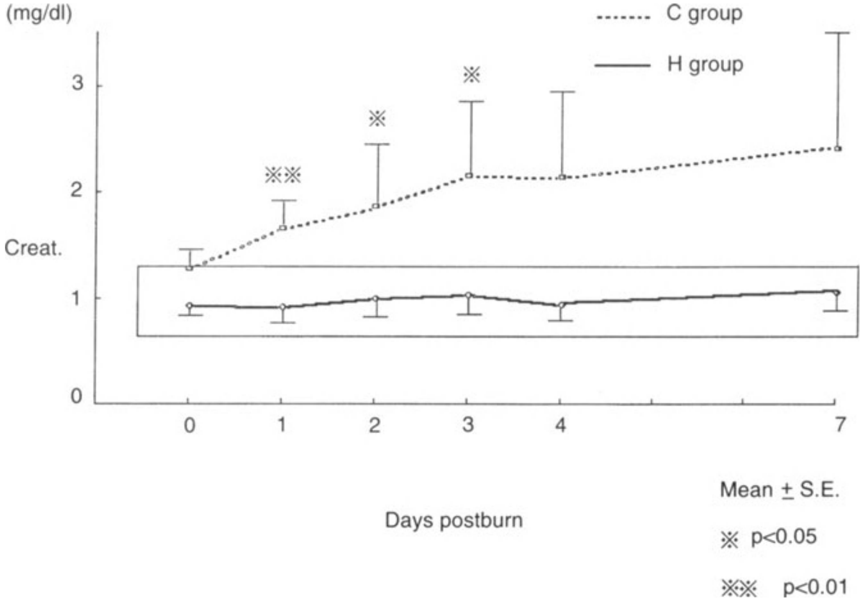


Figure 7. Changes in serum creatinine (study 2)

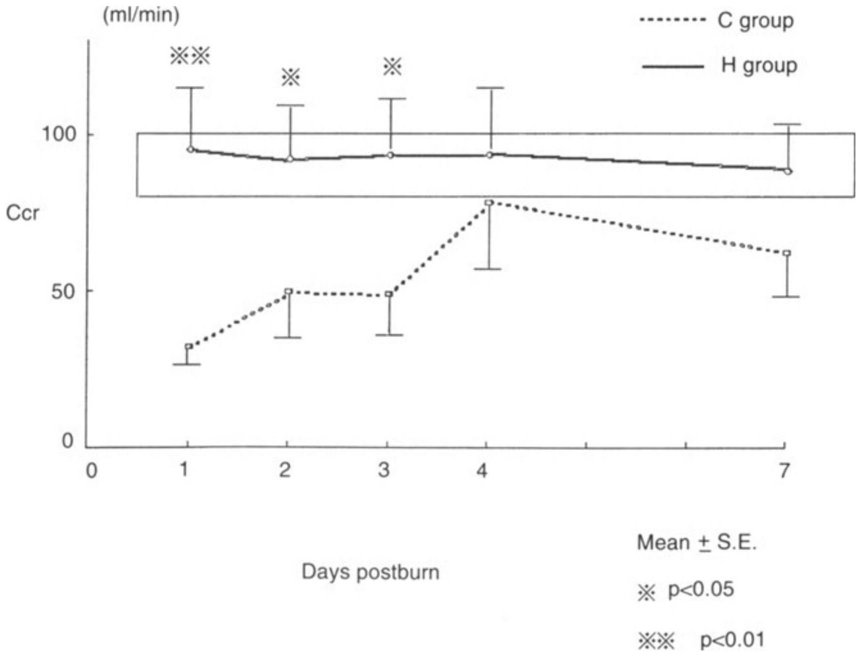


Figure 8. Changes in creatinine clearance (study 2)

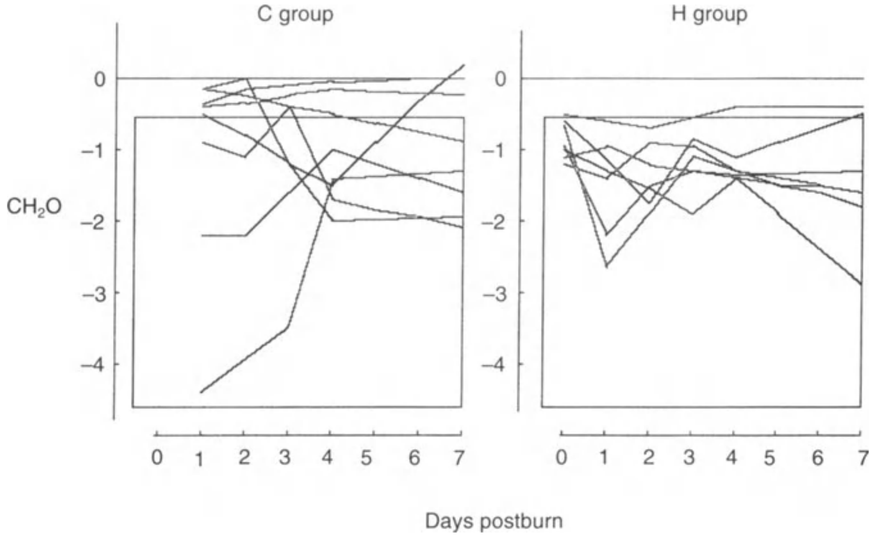


Figure 9. Changes in free water clearance

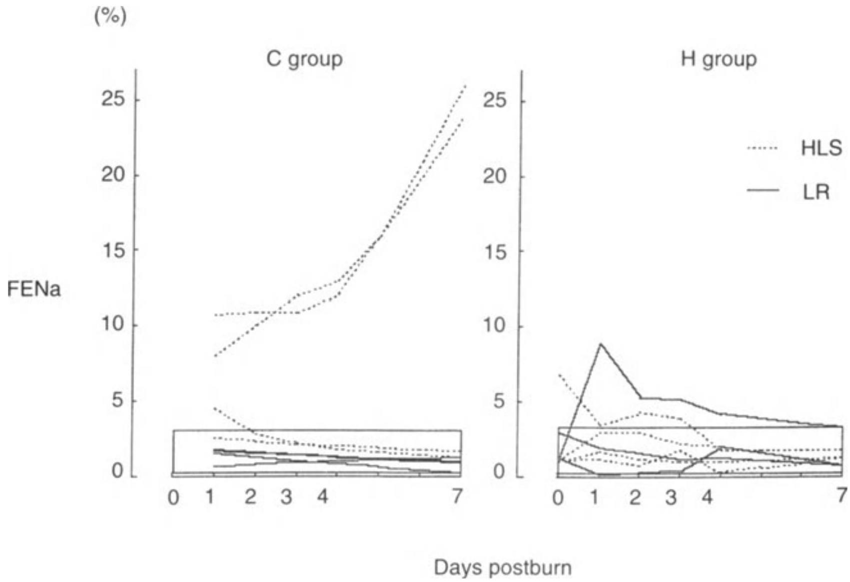


Figure 10. Changes in fractional excretion of sodium

patients in the treated group who had a high value in the early days postburn tended to improve during follow-up.

In addition to the above results, two of the eight control patients developed acute renal failure during the follow-up period, while there were no such cases in the treated group. The two renal failure patients were classified as one oliguric and one non-oliguric renal failures.

CONCLUSION

The efficacy of exogenous haptoglobin solution in the treatment of haemolysis and the prevention of acute renal disorders following severe burn injury was evaluated by two clinically controlled studies. Haptoglobin produces rapid resolution of haemoglobinuria and prevented acute renal failure, if it is administered in the early stage at the appropriate dose.

Consequently, exogenous haptoglobin administration is recommended as an effective prophylactic procedure against the development of acute renal failure in severely burned patients with haemoglobinuria.

REFERENCES

Aikawa, N., Ishibiki, K., Okusawa, S *et al. (1984).* Use of haptoglobin to prevent renal damage due to hemolysis in extensive third-degree burns. *J. Burn Care Rehab.*, **5**, 20–4

Funakoshi, S., Oomura, T., Oshiro, T. and Hong SD. (1976). Haptoglobin: its isolation and clinical significance. In *Trace components of plasma: Isolation and clinical significance.* New York: Alan R. Liss, 397–410

Yoshioka, T., Sugimoto, T., Ukai, T. and Oshiro, T. (1985). Haptoglobin therapy for possible prevention of renal failure following thermal injury: A clinical study. *J. Trauma*, **25**, 281–7

38
Effective method of extracorporeal detoxification in severe burns

E. E. YARUGSKI, A. A. SAIDOV and V. A. CAREV
Republican Burns Centre, Tashkent, Uzbekistan

INTRODUCTION

The traditional methods of treating burns usually have limited therapeutic effect in patients with severe burns because of the inability of the kidneys to eliminate toxic metabolites. Haemoperfusion with activated carbon is more effective, but these sorbents precipitate on their surface plasma proteins, immunoglobulins, hormones and enzymes, with a consequent unfavourable effect on the patient's immunity.

Interesting results were obtained following connection of a patient's circulation to pig spleen, an organ that determines the detoxificating potential of an animal and has immunomodulative function, synthesizes antibodies and immunoglobulins and also has phagocytosis and filtrative functions. This procedure was named biohaemosorbtion, or extracorporeal connection to pig spleen (ECPS).

Experimental connection to a homologous spleen was performed by Fine *et al.* in 1968. The blood from a dog's femoral artery was perfused through the donor spleen and returned via the femoral vein. This procedure increased the survival of animals in shock to 90%. Seventeen years later, Schumacov and Tsypin applied ECPS to two patients with peritonitis. This application confirmed the experimental findings of high detoxification ability of the pig spleen and stimulation of the phagocytic activity of the patient's leucocytes.

MATERIALS AND METHODS

ECPS was used to treat burned patients in the Republic Burns Centre from 1987. The procedure was undertaken in 315 patients with burns of third and fourth degree covering 25–95% BSA, with an age range of 1–60. The number of patients with critical trauma was 81, and supercritical, 234. Indications for the procedure were severe toxaemia with pneumonia, myocarditis, hepatitis, intestinal stasis, brain intoxication, suppuration of wounds and sepsis.

After removing pig spleen under sterile conditions it was canulated via the arteries and veins and lavage was performed with isotonic NaCl solution up to 1000 ml containing heparin (10 000 units). Before the procedure the patients received I.V. heparin, 300–500 units/kg. Perfusion was performed on a veno-venous connection for 25–60 min at a speed of 20–40 ml/min using a roller pump.

RESULTS

After 1–3 ECPS we saw a positive effect of the process: hyperthermia was decreased, activity was increased, sleep and appetite improved, breathlessness and intestinal stasis improved and the wounds began to heal. There was a positive effect in 92% of patients, with improved breathing in 78% and improved intestinal function in 83%.

A positive effect on biochemical parameters was also seen. The level of plasma protein increased from 51 ± 0.2 to 62 ± 0.3 g/l after ECPS ($p < 0.01$). Albumin level remained almost the same (46.7 ± 1.6 vs. 47.4 ± 5.6%; $p < 0.01$), but concentrations of low molecular weight fraction of globulins considerably increased (α_1-globulins rose from 7.6 ± 1.9 to 9.9 + 1.9, α_2-globulins from 11.1 ± 1.2 to 12.1 ± 1.3 and β-globulins from 10.1 ± 2.1 to 15.5 ± 1.2; $p < 0.01$).

The level of large dispersed globulins decreased from 23.6 ± 2.1 to 15.1 ± 2.3 ($p < 0.01$). The improved protein profile can be explained by a decrease in the toxic and proteolytic properties of plasma and, probably, improved protein synthesis by the liver after ECPS. Unlike haemosorption, there is no increase in hypoproteinaemia after ECPS since only toxic metabolites are precipitated in the pig spleen. There were also changes in cellular and humoral immunity. Burns may be considered as an illness associated with secondary immunodeficiency, when specific and non-specific defences are reduced. This is one of the main causes of the animal's inability to fight generalized infection. Alterations in immunity in burned patients are shown in Table 1, which shows that

Table 1. Changes in immunological parameters after ECPS in burn patients

Indices	*Normal*	*Before ECPS*	*After ECPS*	*Day 3*	*Day 7*	*Day 14*	*1 month*
Phagocytic activity of leucocytes	57.1 ± 2.1	26 ± 3.2	39.5 ± 2.6	52.2 ± 3.0	54.9 ± 2.7	46 ± 4.1	30.4 ± 1.2
Phagocytic index	7.7 ± 0.7	3.4 ± 0.5	5.6 ± 0.6	9.2 ± 0.9	7.8 ± 1.0	6.0 ± 0.8	5.4 ± 1.0
Plasma lyzozyme titre	48.0 ± 2.4	16.0 ± 2.6	72 ± 10.4	128 ± 15.7	128 ± 7.9	64 ± 4.2	32 ± 5.9

Table 2.

Indices		*Before ECPS*	*After ECPS*	*Normal*	p
Number of leucocytes (g/l)		6.0 ± 0.4	7.7 ± 0.6	6.5 ± 0.5	< 0.05
Number of lymphocytes	(%)	16.4 ± 1.2	26.9 ± 1.8	28.4 ± 0.7	< 0.05
	(abs)	1062 ± 115	1790 ± 93	1846 ± 111	
T-lymphocytes	(%)	51 ± 1.3	62.6 ± 1.3	65.8 ± 2.2	<0.05
	(abs)	549 ± 63	1136 ± 39	1215 ± 41	<0.05
T-helpers	(%)	9.6 ± 1.0	12.4 ±1.1	18.1 ±1.0	<0.05
	(abs)	102 ± 12	222 ± 23	334 ±20	
T-suppressors	(%)	6.6 ± 0.3	13.1 ± 0.9	11.4 ± 1.0	<0.05
	(abs)	70 ± 11	235 ± 19	270 ± 29	
B-lymphocytes	(%)	14.9 ± 1.1	17.8 ± 1.5	19.5 ± 1.5	<0.05
	(abs)	139 ± 20	314 ± 21	360 ± 28	
B-cells	(%)	11 ± 1.4	20.1 ± 1.7	20 ± 0.4	<0.05
B-cells	(abs)	12.8 ± 1.6	20.9 ± 1.7	22.8 ± 0.3	<0.05

before ECPS burned patients had decreased non-specific defence indices, expressed by a decrease in leucocyte phagocytic activity (LPA) from the normal 57.1 ± 2.1 to 26 ± 2.6%. Twenty-four hours after ECPS this index increases to 39.5 ± 2.6%, returning almost to normal at 3–7 days (correspondingly 52.2 ± 3.0% and 54.9 ± 2.7%). After 14 days the LPA decreases to 46 ± 4.1 and after a month it returns almost to normal.

The phagocytic index (PI) decreases from 7.7 ± 0.7 in controls to 3.4 ± 0.5 in severely burned patients. The PI increases 24 h after ECPS to 5.5 ± 0.6 and 9.2 ± 0.9 in 3 days, that is higher than the normal level. After 7 days the PI begins to decrease and after a month it reaches 5.4 ± 1.0.

The blood lysozyme content (BLC) after ECPS increases to 400% of normal, reaching 800% at day 3–7. On the 14th day the BLC decreases to 50% and after a month it is 32 ± 5.9%. The blood complement activity showed no significant change.

All burned patients had depressed cellular immunity, expressed by reduced levels of T-helper, T-suppressor and B-cells. Humoral immunity improved (Table 3). Severe burns were associated with an increased level of IgA and IgG and decreased IgM. After ECPS the increase in IgA and IgG continued while IgM content was considerably changed. In 81 patients with critical trauma, 72 had positive results, while 126 of 234 patients with supercritical trauma improved.

Table 3. Changes in humoral immunity indices after ECPS

Indices	*Normal*	*Before ECPS*	*After ECPS*	p
IgA	1.8 ± 0.08	1.4 ± 0.1	1.6 ± 0.1	<0.05
IgG	11.7 ± 0.2	12.0 ± 1.2	16.3 ± 0.003	<0.05
IgM	1.5 ± 0.3	1.1 ± 0.009	1.2 ± 0.1	<0.05

BIBLIOGRAPHY

Cupper, S., Green D. R. (1984) Immunoregulation after thermal injury: sequential appearance of 1-I,L-1,T-suppressor inducer cells and L-2 T-suppressor affector cells following thermal trauma in mice. *J. Immunol.*, **133**, 3047–3053

Fine, J. (1964). Septic shock. *JAMA*, **182**, 427–432

Zidcov, C. P., Medvedev, Y. A. *et al.* (1986). Extracorporeal connection of pig spleen in treating suppurative surgical diseases. *Vest. Chir.*, **11**, 86–91

Fine, J., Palmerio, C., Rutenburg, S. (1968). New developments in therapy of refractory traumatic shock. *Arch. Surg.*, **96**, 163–175

Schumacov, V. I., Tsypin, A. B., Safarov, S. F. (1985). Extracorporeal connection of pig spleen for detoxication of organism. *Chirurgia*, 4, 110–114

Section VI

Immunology in burns

39
Value of immune status analysis in the assessment of burn patients

A. ALEKSEEV
Vishnevsky Institute of Surgery, Moscow, Russia

Parallel to an increase in the infectious processes, secondary immune insufficiency develops in patients with extensive burns: defects develop in T- and B-lymphocyte function, immunoglobulins, neutrophil phagocytosis and in other non-specific defence factors. Disruption of the body's defence mechanisms creates conditions for generalized infection.

Non-specific defence and humoral immunity were analysed in a complex clinical and laboratory study of 110 patients with 25–80% burns.

In the majority of cases, alterations in the parameters studied corresponded with severity of the trauma and the degree of sepsis. The most characteristic sign of burn sepsis was disruption of the immune system caused by alterations in the tissue enzyme system and by mobilization of compensatory defence mechanisms.

In relation to this, for objective description of the degree of toxaemia, it is reasonable to determine the levels of antigen-specific circulating immune complexes in the blood of severely burned patients. Their formation is directed at the neutralization of the antigens of various origin, including bacteria.

Levels of caeruloplasmin, IgG and IgE in the blood reflects, on the contrary, the compensatory disintoxication mechanism of immune defence.

Objective evidence of major burn sepsis and the critical state of the humoral defence mechanisms is provided by an increase in the number of circulating immune complexes in severely burned patients, as shown by the dynamic test. This is particularly marked before the 20th day and on days 41–60 post-trauma. Further evidence is provided by the decrease in the caeruloplasmin level, within terms parallel to the process described above. They are prognostic and early diagnostic criteria of burn sepsis.

In the further course of the treatment of burn patients, including active antisepsis and immune correction, we observed a decrease in the immune complex level. As clinical signs of bacteria began to disappear we observed an increase in the caeruloplasmin level.

Early diagnostic criteria of generalized infection include a decrease in IgG level and a considerable increase in IgE. These serum immunoglobulins are antitoxic and antimicrobial factors of the humoral defence mechanism. IgE, in particular, is capable of binding antigens at the level of the barrier tissue, mainly in the liver. Changes in IgE level depend on metabolic intensity and the functional loading of the immune system.

Dynamic tests showed a decrease in IgG level until day 41–60 post trauma, which corresponded to the appearance of the clinical signs of generalized infection. At the same time, in patients with burn sepsis, after the period of relatively low IgE levels we observed a sharp increase in serum IgE, which was considerably greater than in severely burned patients in the control group. The content of IgM levels in the serum of severely burned patients showed that the humoral defence mechanism was activated early, while the IgM level shows that the local immunity of IgM during the first 20 days post-trauma decreases in patients with sepsis and extensive full-thickness burns of more than 40% TBSA. 'Delayed' activation of the immune defence system in this group of burn patients is a prognostic criterion of sepsis or of its development.

Increase in IgA levels reflects development of local immune activity and is a diagnostic sign of generalized infection.

We cannot rule out that this is one of the main reasons for the rejection reaction in sepsis and in particular a cause of lysis of autogenous skin grafts. The development of burn sepsis is preceded by a decrease in antibody formation and by prolonged suppression of the cellular immunity, particularly the T lymphocytes.

Much attention has been paid of late to analysing the functions of polymorphonuclear leukocytes. According to many scientists neutrophil leukocytes constitute the first line of defence against infection. Absorption of bacteria by the leukocytes is accompanied by a respiratory burst, characterized by an increase in oxygen consumption with superoxide ion formation. This increase is associated with the phagocytic activity of the leukocytes.

The analysis performed showed that a decrease in superoxide production by leukocytes can serve as an objective laboratory criterion for early diagnosis and prognosis of sepsis and for assessment of the adequacy of treatment. A progressive decrease in superoxide production, beginning on day 10 post-trauma, shown by dynamic observation, is an unfavourable prognostic sign for the development of sepsis and requires directed prophylaxis. A decrease in the absolute level of superoxide production below normal can serve as an early diagnostic criterion for generalized infection and, as a rule, it coincides with the clinical signs of sepsis.

Complex analysis and assessment of the immune status of burn patients has made it possible to determine some important diagnostic and prognostic signs of sepsis and to perform early prophylaxis and successful treatment based on intensive antibacterial and immune therapy, correction of homeostasis and reconstruction of skin integrity soon after the trauma.

40
Immunobacteriological monitoring of burn patients: a proposed protocol

N. D'ARPA, B. NAPOLI and M. MASELLIS
Ospedale Civico, Palermo, Italy

INTRODUCTION

Septicaemia is the most common cause of death in burn patients. This problem is a result of the altered relationship between infecting agents and the immune system. Successful management of burn patients requires bacteriological control to restrict the risk of infection, and the immune response must be monitored to allow early therapeutic intervention.

BACTERIAL MONITORING PROTOCOL

Bacteria in an extensively burned patient have three possible origins:

1. Endogenous. These bacteria have survived the heat of the burn because they were wedged in the infundibula of the glands or in hair follicles, from where they have multiplied and spread into the overlying lesion. They may also originate from the anogenital and oropharyngeal areas and from healthy skin.
2. Environmental. These bacteria are present in the ward, and colonize the burned areas following admission of the patient.
3. Cross-infection. These bacteria are transmitted from one patient to another in various ways.

At the Palermo Burns Centre the bacteriological monitoring and control of the burn patient is carried out as follows. First, on admission, patients are depilated in the pubic and axillary regions, and if their general condition is good enough they are also showered in a balneotherapy bath, using antiseptics. A biopsy is then obtained from two sites where the burns are deepest, and swabs are taken from more superficially burned areas as well as from the anogenital area, the nasal orifices and at some sites in healthy skin.

The extent of the burn areas is indicated on an outline of a human form, using different colours or different marking for the different burn depths. The biopsy and swab areas are also indicated. Bacteriological findings from the microbiology laboratory are added later at the foot of the page. Further pages are added over time to produce a complete picture of the bacteriological situation. The patient is placed in a bed with sterile sheets.

Local treatment comprises therapy with packs of appropriate antibiotic solution, selected according to antibiogram indications, or, if chemical escharectomy is indicated, with applications of antibiotic salicylate Vaseline. The frequency of medication depends on the development of the burn areas. Skin swabs are taken every 3 days and biopsies every 7 days. Patients are showered twice a week using disinfectant and antiseptic solutions. General prophylactic antibiotic treatment is initiated on day 5 or 6 following the burn. The choice of antibiotic depends on the microbiological findings of previous days. Haemoculture is performed in the presence of clinical indications (e.g. altered consciousness, tendency to abdominal distension, persistence of high temperature for several days) or laboratory indications (e.g. marked leucocytosis or leucopenia, persistent hypoglycaemia), which are possible precursors of septic shock.

The venous catheter used for fluid therapy is removed on average every 3 days if located in a small or medium-sized vessel. It is removed immediately at any sign of pain, skin hyperaemia or episodes of hyperpyrexia, which are possible precursors of phlebitis. A culture test is always performed on the catheter tip.

Environmental bacteriological monitoring and control

The Intensive Care Unit in the Palermo Burns Centre has its own autonomous air-conditioning system. Sterile air is delivered to every room and the humidity and temperature levels can be regulated to create an ideal microclimate. When a patient is discharged from the ICU the room is sterilized. Bacteriological research and assessment of the environmental microbe charge are performed frequently, using:

1. Petri culture dishes (diameter 10 cm) placed in every room for 1 h, 1 m above the floor and 1 m from every obstacle (Fischer's 1 times 1 times 1 system);
2. An RCS-Biotest sampler which quantifies the bacterial load per volume of air in the room. The rooms are carefully cleaned twice a day using appropriate disinfectants. When the room is momentarily empty because the patient is in the operating theatre or undergoing balneotherapy, the room is sanitized by iodine vapour and ultraviolet germicide lamps.

Cross-infection monitoring and control

The medical and paramedical staff are periodically monitored by culture of nasal and pharyngeal swabs and by microbiological tests on gloves before and after contact with the patient and items surrounding the patient.

Acute patients are kept in isolation, one per room. All staff rigorously observe antisepsis standards (e.g. use of sterile cap, mask, coat and gloves) every time they come into contact with the patient. The wards are organized so that staff have at their disposal all material necessary for the care of the patient. Stainless steel cupboards contain disposable coats, gloves, linen, dressing material, infusion pumps, drip-feed accessories, etc.

Every room has a fully equipped medication trolley with all instruments necessary for medication and minor surgical operations. The disposable containers for waste material to be incinerated and for items such as linen to be washed are meticulously sealed before being removed from the room.

Every room has its own adjacent toilet with a pedal-operated wash-basin, W.C. and an automatic device for washing and disinfecting items used for collecting the patient's biological products.

IMMUNOLOGICAL MONITORING PROTOCOL

Alterations in the immune system after extensive burns principally involve the T cell system, and to a lesser extent the B cell system. The T cells are reduced in number and show reduced non-specific responses to mitogens, diminished reactivity to cytotoxicity tests, and a massive release of lymphokines. Neutrophils and macrophages show functional anomalies that appear to be correlated with increased susceptibility to serious infections, such as those due to *Staphylococcus aureus*.

There are also alterations in complement and in the endothelial reticular system, the cells of which are affected by the drastic reduction in fibronectin.

IMMUNOLOGICAL CONTROL PROTOCOL

Serological tests are generally performed on days 1, 4, 8, 12, 20 and 30 post-burn in patients with > 40% BSA burns and on days 1, 5, 10 and 20 post-burn in patients with < 40% BSA burns. The following are tested: leucocyte distribution, serum protein electrophoresis, fibronectin, complement factors, T lymphocytes and T lymphocyte subpopulations (T4–T8, NK), T4/T8 ratio, B lymphocytes, IgA/IgE/IgG/IgM and cortisol. A skin test is performed on days 4 and 20.

CONCLUSION

It is not always possible to prevent sepsis developing in burnt patients, and once it does develop it may be fatal. The use of measures that reduce and verify the action of factors favouring and inhibiting the evolution of the disease is the objective of the protocols described.

It is clear that the equilibrium between factors that favour and inhibit infection is also related to other aspects of the disease, such as the patient's general condition, the type of intensive care, etc. Our research must be directed at developing instruments and techniques capable of reducing the risk of infection and increasing the immune defences.

The monitoring of the immunological response in particular may also be used as a prognostic index that will make it possible to identify conditions requiring specific therapies (immunomodulants, fresh plasma, etc.) and to improve possible strategies that take into account the immunosuppressive effect of certain therapies.

BIBLIOGRAPHY

Alexander, J. W., Ogle, C. K., Stinnett, J. D. *et al.* (1978). A sequential prospective analysis of immunologic abnormalities and infection following severe thermal injury. *Ann. Surg.*, **188**, 809–816

D'Arpa, N., Lio, D., Cucchiara, P. and Vitale, R. (1987). Modificazioni delle subpopolazioni linfocitarie in pazienti ustionati. *Riv. Ital. Chir. Plastica*, **2**, 295–299

D'Arpa, N., Lio, D., Masellis, M., Caprera V. and Vitale, R. (1988). Modificazioni dell'immunità umorale specifica in ustionati con esteso interessamentro della superficie corporea. *Chir. Plast. Ricost. Estet.*, 319–322

Frame, J. D., Kangesu, L. and Malik, W. M. (1992). Changing flora in burn and trauma units: experience in the United Kingdom. *J. Burn Care Rehab.*, **2** (Suppl.), 276–280

Gordon, M. D. (1987). Monitoring burn wounds for infection. *J. Burn Care Rehab.*, **6**, 568–572

Hoyt, D. B., Ozkan, A. N. and Ninneman, J. L. (1987). Immunologic monitoring of infection risk in trauma patients: research question and an approach to the problem. *J. Burn Care Rehab.*, **6**, 549–553

Lio, D., Vitale, R., Masellis, M., D'Arpa, N. and Cucchiara, P. (1986). Presenza nel siero di pazienti ustionati di fattori inhibitori della produzione di IL-2 e della blastizzazione. *Atti del 35 Congr. Naz. della Soc. It. di Ch. Plastica* (Monduzzi, Bologna)

Loose, L. D. and Turinsky, J. (1979). Macrophage dysfunction after burn injury. *Infect. Immun.*, **26**, 157–162

Ninneman, J. L. (1987). Trauma sepsi and the immune response. *J. Burn Care Rehab.*, **6**, 462–468

Shelby, J. (1987). Transfusion-induced immunosuppression. *J. Burn Care Rehab.*, **6**, 546–548.

Smith, D. J. and Thomson, P. D. Changing flora in burn and trauma units: historical perspective – experience in the United States

Winkelstein, A. (1984). What are the immunological alterations induced by burn injury? *J. Trauma*, suppl. **9**, 72–81

41
The expression of HLA-DR, IL-2R, ICAM-1 and TNF alpha molecules as possible prognostic elements of hypertrophic scarring in burns

G. MAGLIACANI*, M. STELLA*, C. CASTAGNOLI** and P. RICHIARDI**
*Centro Grandi Ustionati, CTO, Turin, Italy
**Dipartimento di Genetica, Università di Torino, Turin, Italy

INTRODUCTION

Patients suffering from hypertrophic scarring secondary to extensive burns have to expect modifications in their social and working life, together with lengthy physiotherapeutic and surgical procedures, in a background of uncertainty as regards the long-term evolution of the scars and the quality of the final result. It is thus important to study the little known aetiopathogenic factors involved, in order to propose new therapeutic approaches in burn scars.

Clinical observations of burn scar evolution have found that the hypertrophy begins 1–3 months after closure of the lesions, regressing over a time period ranging from a few months to a number of years. For this reason it has become customary to regard temporary hypertrophies (i.e. regressing within 6 months) as borderline phenomena of scar pathology, while clinical and laboratory criteria have been used in an attempt to predict the kinetics of regression of hypertrophies lasting > 6 months (which are considered persistent) (Muir, 1990).

A retrospective survey of cases admitted to our centre did not reveal any clinical criteria predicting the evolution of scars (Castagnoli *et al.* 1990). Many researchers attribute an important aetiological role to immunological factors, associating the presence of scar hypertrophy with alleles of the major histocompatibility complex class II antigens, an increase of circulating immunoglobulins, Langerhans cells and autoantibodies (Castagnoli *et al.*, 1990; Cracco *et al.*, 1992; Stella *et al.*, 1989).

One particularly interesting characteristic of the hypertrophic scar is round-cell infiltration, which is typical of certain inflammatory dermatoses associated with anomalous expression of cell activation molecules on non-lymphoid keratinocytes and cells (Table 1). It was therefore decided to characterize cell infiltrates and to analyse the expression of class II histocompatibility leukocyte antigen (HLA) molecules, the interleukin-2 receptor (IL-2R), the intercellular adhesion molecule ICAM-1 and tumour necrosis factor alpha (TNF) (Table 2), using immunohistochemical methods in biopsies of hypertrophic scars.

Table 1. Dermatological pathologies characterized by leukocyte infiltrates and the anomalous expression of HLA-DR, ICAM-1 and IL-2R molecules on keratinocytes

Pathology	HLA-DR	ICAM-1	IL-2R
Lichen planus	+	+	not dem.
Atopic dermatitis	–	+	not dem.
Psoriasis	–/+	+	+
GVHD	+	+	not dem.
T cell lymphoma	+	+	not dem.
Allergic dermatitis	+	+	not dem.
Mycosis fungoides	+	+	not dem.
Pemphigus vulgaris	–	+	not dem.
Bullous pemphigoid	–	+	not dem.
Tuberculin reaction	+	+	not dem.

Key: not dem. = not demonstrated; GVHD = graft-versus-host disease

Table 2. Activation markers analysed

HLA-DR	Antigen of major histocompatibility complex class II (histocompatibility leukocyte antigen) *Function* Presentation of antigen *Expression* Activated B and T lymphocytes, monocytes, endothelia
IL-2R	Interleukin 2 receptor *Function* Immune response activation *Expression* Activated B and T lymphocytes
ICAM-1	Intercellular adhesion molecule 1 *Function* Bond with the leukocyte integrin LFA-1 which permits the installation of lymphoid cells infiltrating the tissues *Expression* Leukocytes, dendritic cells, endothelia
TNF-alpha	Tumour necrosis factor α *Function* Dose-dependent activator of collagenase, collagen and fibroblast proliferation *Expression* Activated T lymphocytes and macrophages

PATIENTS AND METHODS

Fourteen patients (eight female, six male) with hypertrophic scars secondary to extensive burns (10–40% BSA) were selected. These patients, followed up for >1 year after closure of their lesions and treated with continuous pressure therapy, presented prominent, erythematous and often painful scars with varying degrees of contraction, clinically considered to be active lesions with no signs of regression.

During corrective surgery a number of 5 mm biopsies were removed, immersed in OCT, frozen in cold isopentane (–70°C) and cut with a cryostat into 5 μm sections. Serial sections were fixed in acetone for 10 min and reacted with monoclonal antibodies (Table 3) at optimal dilution for 45 min; after three washings incubation was performed with anti-rat rabbit Ig for 45 min. After further washing incubation was performed with peroxidase-antiperoxidase for 60 min and then with the substrate AEC (indirect immunoperoxidase method).

Table 3. Monoclonal antibodies

Antibodies	*Specificity*	*Ig class*	*Distribution*
Hot 214	HLA-DR, DP	G1	macrophages, act. T, endothelia, B
Anti-CD25	IL-2R p55	G1	act. T, macrophages
Anti-p75	IL-2R p75	G1	act. T, macrophages
SV 48	ICAM-1	?	endothelia, T
SV 49	ICAM-1	?	endothelia, T
Anti-TNF alpha	TNF alpha	G1	act. T, macrophages
OKT6	CD1	G1	Langerhans cells
Anti-Leu14	CD22	G2b	B lymphocytes
Anti-Leu4+5b	CD3+CD2	G1	T lymphocytes
Anti-LeuM5	CD11c	G2b	macrophages

A quantitative analysis was made by counting the marked cells in two or three serial cells, considering the epidermis, papillary dermis and reticular dermis as separate compartments.

As controls, seven biopsies were taken from normotrophic scars and six were obtained from the healthy skin of patients undergoing plastic surgery. These biopsies were processed as described above.

RESULTS

Characterization of the infiltrates

The hypertrophic scar samples always contained a much higher number of infiltrating cells than normotrophic scar or healthy skin samples. These infiltrating cells included Langerhans cells (CD1), macrophages (CD11), T lymphocytes (CD3 + CD2), and a few natural killer (NK) cells (CD56 + CD57). B lymphocytes were not observed. Seventy percent of the T cells were activated (IL-2R$^+$, HLA-DR$^+$) in hypertrophic scars compared with 40% in normotrophic scars and 10% in healthy skin.

Expression of HLA-DR, IL-2R, ICAM-1 and TNF alpha

HLA-DR, IL-2R and ICAM-1 molecules were expressed anomalously on keratinocytes in nearly all the samples of hypertrophic scars. IL-2R and the HLA-DR molecules were also expressed on fibroblasts in the same sections (Table 4). Keratinocytes and fibroblasts from control samples (normotrophic scars and healthy skin) were negative for these molecules. The anti-TNF alpha antibody reacted positively with only 8% of the infiltrating activated macrophages and T lymphocytes, compared with 34.5% of macrophages in normotrophic scars (Figure 1). Keratinocytes and fibroblasts were never positive with anti-TNF alpha antibody.

Table 4. Expression of HLA-DR, ICAM-1 and IL-2R molecules in non-haematopoietic cells in hypertrophic scars and controls

Tissue	*Cell type*	*DR*	*IL-2R*	*(p55 p 75)*	*ICAM-1*
Hypertrophic	Keratinocytes	+		+ foci	+ foci
scars	Endothelia	+		–	+
(No = 14)	Fibroblasts				
Normotrophic	Keratinocytes	–/+	–/+		– scars
endothelia	+ –			+	
(No = 7)	Fibroblasts	–		–	–Healthy
Skin keratinocytes	–	–		–	
Endothelia	+ –			+	
(No = 6)	Fibroblasts	–		–	–

DISCUSSION

The above findings support the hypothesis that hypertrophic scars are in an immunologically activated state and that an altered cell response plays a pathogenically important role in this process.

We found on the one hand, an abundance of activated T lymphocytes in the dense infiltrates and, on the other, anomalous expression of certain molecules on the surface of keratinocytes and fibroblasts, which is another characteristic of cell activation. The activation of the keratinocytes can be attributed to the presence of the infiltrates, which secrete lymphokines.

It is not certain that the aberrant expression of HLA-DR, IL-2R and ICAM-1 on these cell types implies their transformation into elements possessing specific immunological functions such as the presentation of antigens to cells of the immune system; it also has to be remembered that ICAM-1 molecules are considered to be necessary for the development and maintenance of the immune response.

An interesting finding comes from the analysis of TNF alpha-positive cells, the production of which according to some reports is reduced in certain autoimmune diseases (Jacob *et al.*, 1988, 1990). In our study, although activated infiltrating cells were present in great numbers, the

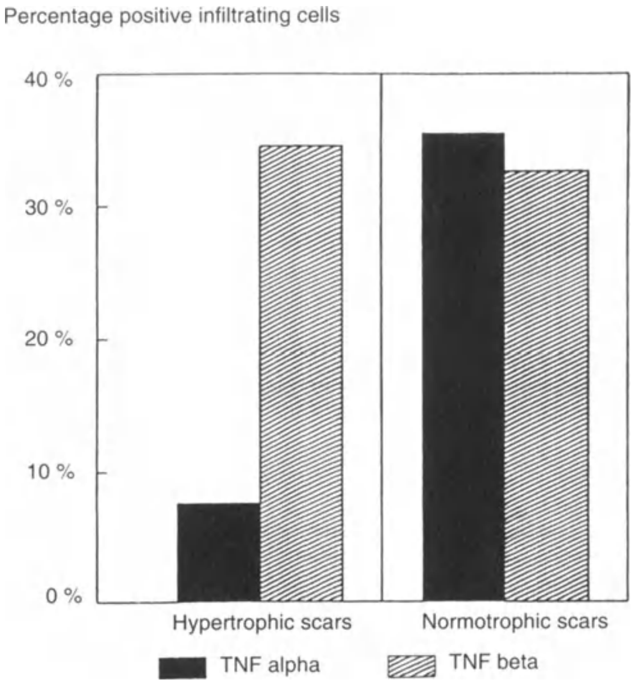


Figure 1. Percentage of cells capable of producing TNF alpha and beta in hyper- and normotrophic scars

percentage of positive cells was low in hypertrophic scars and high in normotrophic scars.

Recently published research attributes to this cytokine an important role in the control of fibroblast proliferation (Kovacs, 1991), with a dose-dependent effect: at low concentrations TNF alpha activates proliferation, while at high concentrations it inhibits proliferation. TNF alpha also plays a fundamental role in regulation of the production of collagen and collagenase, and therefore is extremely important in the modelling of the architecture of the dermis (Duncan and Berman, 1989).

Our results show that TNF alpha may be critical for normal healing, and that hypertrophic scarring may be a consequence of its low tissue production.

In conclusion, this chapter illustrates a series of immunohistochemically demonstrable alterations that are characteristic of hypertrophic scars. A follow-up study is now in progress to further analyse these findings in order to provide precise prognostic elements regarding the evolution of pathological scarring.

ACKNOWLEDGEMENT

This work was supported by a grant from the Piedmont Foundation for Burns Studies and Research.

BIBLIOGRAPHY

Castagnoli, C., Peruccio, D., Stella, M., Magliacani, M., Mazzola, G., Amoroso, A. and Richiardi, P. (1990). The HLA-DR beta 16 allogenotype constitutes a risk factor for hypertrophic scarring. *Hum. Immunol.*, **29**, 229–232

Castagnoli, C., Stella, M., Peruccio, D., Richiardi, P. and Magliacani, G. (1990). HLA susceptibility factors in hypertrophic scarring. *Proceedings of the 8th International Congress on Burn Injuries, New Delhi, India*

Cracco, C., Stella, M., Teich-Alasia, S. and Filogamo, G. (1992). Comparative study of Langerhans cells in normal and pathological human scars. II. Hypertrophic scars. *Eur. J. Histochem.*, **36**, 53–65

Duncan, M. R. and Berman, B. (1989). Differential regulation of collagen, glycosaminoglycan, fibronectin, and collagenase activity production in cultured human adult dermal fibroblasts by interleukin 1-alpha and beta and TNF alpha and beta. *J. Invest. Dermatol.*, **92**, 699

Jacob, C. O. and McDevitt, H. O. (1988) TNF alpha in murine autoimmune lupus nephritis. *Nature (Lond.)*, **331**, 356

Jacob, C. O., Fronek, Z., Lewis, G. D., Koo, M., Hansen, J. A. and McDevitt, H. O. (1990). Heritable major histocompatibility complex class II-associated differences in production of tumor necrosis factor alpha: relevance to genetic predisposition to systemic lupus erythematosus. *Proc. Natl Acad. Sci. USA*, **87**, 1233

Kovacs, E. (1991). Fibrogenic cytokines: the role of immune mediators in the development of scar tissue. *Immunol. Today*, **12**, 17

Muir, I. F. K. (1990). On the nature of keloids and hypertrophic scars. *Br. J. Plast. Surg.*, **43**, 61–69

Stella, M., Castagnoli, C., Magliacani, G. and Richiardi P. (1989). Fisiopatologia della cicatrice ipertrofica (revisione bibliografica). *Riv. Ital. Chir. Plast.*, **21**, 199

42

Prediction in burns outcome: a new prognostic index

V. STAVROPOULOU, J. DASKALAKIS and J. IOANNOVICH
Centre of Plastic Surgery and Microsurgery
General State Hospital of Athens, Greece

INTRODUCTION

The importance of prognostic indices for burns consists not only in their prediction of the outcome in an individual patient but also in the distribution of patients in comparable groups of severity for therapeutic and research purposes. Although prediction of the outcome in an individual patient is the first and most pressing question of the patient's family, the quantitative measurement of the patient's illness using these indices is of great importance for the burn centre to decide its therapeutic policy, to evaluate new therapy and the quality of patient care, and to estimate the cost of its services.

The more accurate an index, the more useful it is for this latter purpose. For this reason several burn indices, based on different statistical methods, are today compiled and computerized, in an effort to be more accurate in prediction. Nevertheless the most accurate prognosis in a burn centre is achieved using one of the known indices, adapted to its particular needs and conditions, or by producing a new index that is continuously updated.

MATERIALS AND METHODS

Three hundred and forty-two patients admitted to the burn centre of the General State Hospital of Athens during the period from July 1989 to July 1992, suffering from thermal burns (electrical and chemical burns were excluded) were studied. One hundred and forty patients were females (41%) and 202 were males (59%). The distribution of patients by age and extent of burn is shown in Tables 1 and 2.

Three hundred and thirteen patients (92.1%) did not present with inhalation burn, although 52 patients had suspicious symptoms and

Table 1. Age distribution of patients

Age (years)	*No.*	%
< 15	10	2.9
16–20	14	4.1
21–30	72	21.1
31–40	58	17.0
41–50	64	18.7
51–60	49	14.3
> 61	75	21.9

Table 2. Patient distribution by extent of burn

% TBSA[a]	*No.*	%
<10	168	49.1
11–30	109	31.9
31–50	33	9.6
>51	32	9.4

[a] TBSA, total body surface area

their respiratory system was thoroughly examined. Eight per cent of our patients had an inhalation burn, confirmed by clinical symptoms and abnormal blood gases. Eight required a respirator.

Mortality according to burn extent is given in Table 3. In our sample, for the determination of the survival rate, we applied the usual burn indices (Fisher–Bull, Baux, BUS–UDB, Stern, ABSI, Bowser, Roi, Clark), as well as the APACHE II severity index, which in fact is used in the ICU for non-burn patients suffering from simple or multiple organ

Table 3. Patient mortality related to extent of burn

% TBSA	*No. deaths*	%
<10	5	3.0
11–30	15	13.8
31–50	7	21.2
>51	23	71.9
Total	50	14.6

Table 4. Prognostic indices used

Fisher–Bull	(1954, mod. 1971)
Baux	(Baux, 1961)
BUS–UDB	(Sachs and Watson, 1969)
Stern	(Stern and Waisbren, 1978)
ABSI	(Tobiasen *et al.*, 1982)
Bowser	(Bowser *et al.*, 1982)
Roi	(Roi *et al.*, 1983)
APACHE II	(Knaus *et al.*, 1985)
Clark	(Clark *et al.*, 1986)

Table 5. Author's hit rates (%)

	Stern		*ABSI*		*Bowser*		*Clark*	
	alive	*dead*	*alive*	*dead*	*alive*	*dead*	*alive*	*dead*
Author's sample	98.7	75.2	97.5	78.4	95.8	79	94	74
Our sample	97.8	69.4	95.2	65.3	97.5	68.1	97.5	57.8

system failure (MOSF) (Table 4). While some of these indices are empirical, others are based on statistical methods such as logistic regression, probit analysis and discriminant analysis. The parameters taken into account in the indices we used in our sample are shown in Table 5. Clearly the burn indices include mainly empirical parameters, but APACHE II also includes precise clinical and laboratory measurements.

We used these indices as reported by their authors, according to their instructions and restrictions.

- For the Fisher–Bull index the mortality probability chart was used, as modified in 1971.
- For the Baux index inhalation burns were excluded.
- For the BUS index we predicted mortality from the authors' survival table in their original paper, taking into account the age of the patient.
- For the Stern index patients < 20 years old were excluded and the probability of survival was derived from the author's survival curve.
- For the Roi index the total burn model was used without considering perineum involvement, because of the lack of data.
- For the Clark index the symptom score was used and not blood carboxyhaemoglobin concentration.
- For the APACHE II index, after calculation of the *z*-score, we tried to find the probability of death using in the final equation the constants of multiple trauma, infection and sepsis.

RESULTS AND DISCUSSION

The calculated hit rates of the indices (Figure 1) were generally raised. Most had a high hit rate for survivors, but an inferior rate for non-survivors, except in the Baux index, which seems to be more accurate in predicting death. The most unreliable of them all, especially for predicting death, was APACHE II, which underestimated the severity of burn injury even when calculated with the most unfavourable constant of sepsis. There are probably two explanations for this. On the one hand it neglects the extent and the depth of the burn, which are significant determinants of mortality. On the other hand, like all ICU indices, it is

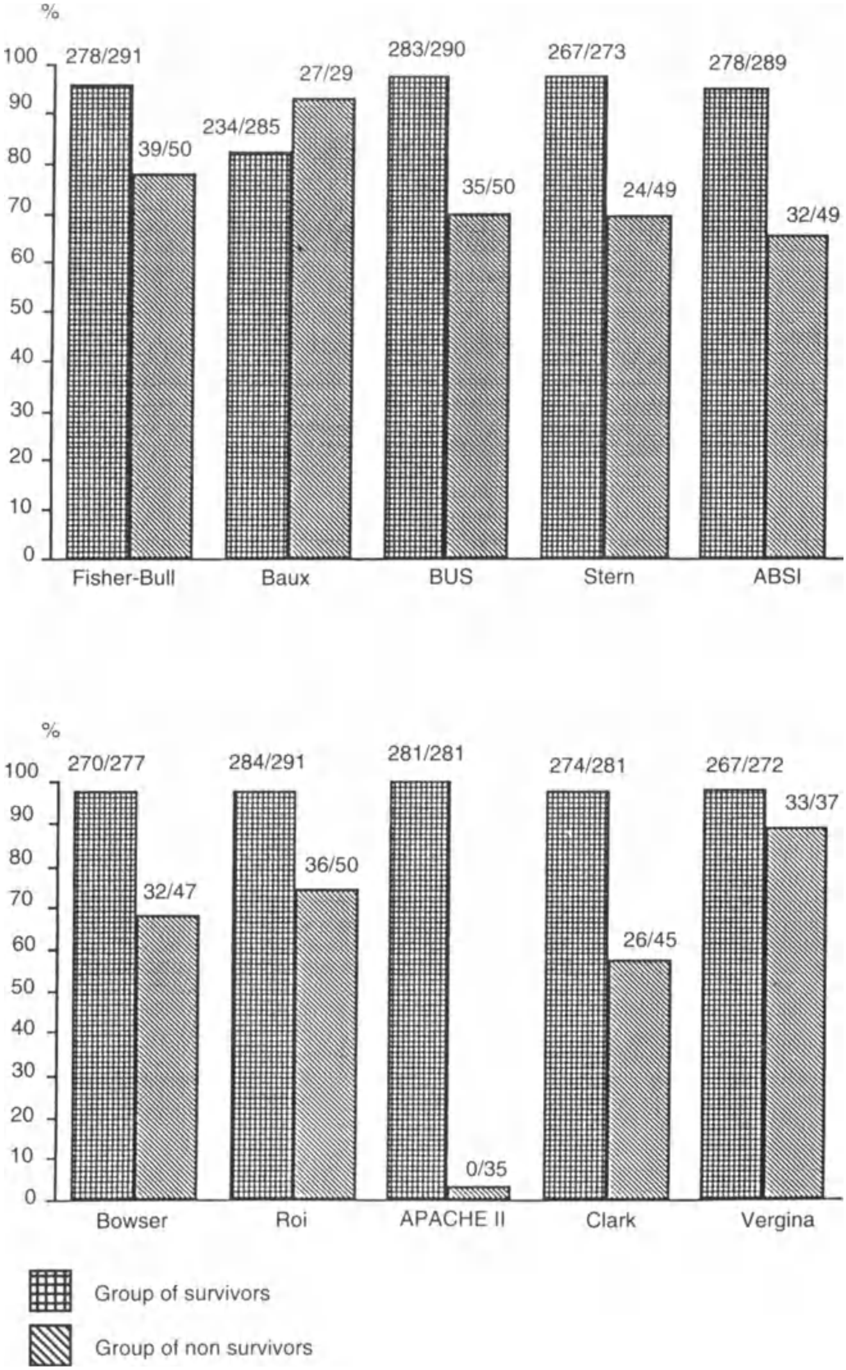


Figure 1. Hit rates of different indices

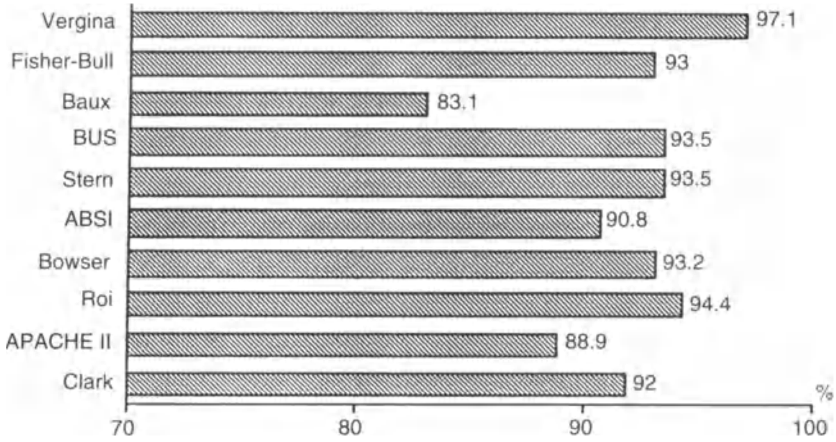


Figure 2. Overall hit rates

reliable in predicting the outcome of critically ill patients, but not the outcome of patients with long-lasting diseases. The overall hit rates of Baux and APACHE II indices were under 90% (Figure 2). All the other indices had hit rates ranging from 90.8% to 94.4%. The hit rates given by the authors in their samples are considerably higher in predicting non-survivors than our hit rates, when the same indices were applied to our

Table 6. Variables used in different indices

Variables	*Bull*	*Baux*	*BUS*	*Stern*	*ABSI*	*Bowser*	*Roi*	*Clark*	*APACHE II*	*Vergina*
Age	+	+	–	+	+	+	+	+	+	+
TBSA	+	+	+	+	+	+	+	+	–	+
Full thickness burn	–	–	+	–	+	+	+	–	–	+
Inhalation burn	–	–	–	–	+	+	–	–	–	+
Sex	–	–	–	–	+	–	+	–	–	–
Clothes ignition	–	–	–	–	–	+	–	–	–	+
Perineum involv.	–	–	–	–	–	–	+	–	–	–
Admission (d)	–	–	–	–	–	–	+	–	–	–
Temperature	–	–	–	–	–	–	–	–	+	+
Arterial pressure	–	–	–	–	–	–	–	–	+	+
Heart rate	–	–	–	–	–	–	–	–	+	–
Respiratory rate	–	–	–	–	–	–	–	–	+	+
Po_2	–	–	–	–	–	–	–	–	+	+
pH	–	–	–	–	–	–	–	–	+	+
K^+	–	–	–	–	–	–	–	–	+	+
Na^+	–	–	–	–	–	–	–	–	+	+
Creatinine	–	–	–	–	–	–	–	–	+	–
Ht	–	–	–	–	–	–	–	–	+	+
WBC	–	–	–	–	–	–	–	–	+	+
GCS	–	–	–	–	–	–	–	–	+	–
Chronic illness	–	–	–	–	–	–	–	–	+	–

sample (Table 6). This phenomenon may be explained by the fact that the indices were applied to different samples and in centres with different treatment standards. We agree with other researchers that every burn centre must adapt an index to its conditions and update it continuously. We believe that the most accurate prognosis in a burn centre is achieved by using prospectively an index that was produced there retrospectively.

A new prognostic index (Vergina)

For the reasons discussed above, we produced a new prognostic index (Vergina). To determine mortality we used in the final equation the variables previously reported to be statistically significant for the outcome of the patient (Table 7). These variables can be classified into three groups. The first includes general factors common to all burn indices. The other groups include variables which are affected by the pathophysiology of the burn and indicate the degree of haemoconcentration and the condition of respiratory and renal function on admission (Table 8). Any delay in the initiation of treatment influences these conditions as well as the outcome in the patient. A combination of all these variables was used in a predictive model, using discriminant analysis, and we developed an equation to discriminate between survivors and non-survivors. Discriminant analysis has already been used by researchers such as McCoy *et al.* (1968), Bowser (1989) and it has the following advantages:

1. It is multifactorial and therefore allows the incorporation of several predictive variables in a probability model.
2. It is more accurate in the prediction of death (hit rate ranges 86–90%). This accuracy enables us to evaluate a new therapy, quickly detecting small differences in the mortality, as proposed by Moores (1975), Feller and Clark.
3. When using discriminant analysis fewer cases are required to obtain accurate predictions (Clark *et al.*, 1978).

Table 7. Variables of Vergina index

A	TBSA Full thickness burn Clothes ignition Age Temperature	General factors
B	Inhalation burn Respiratory rate	Indicators of respiratory function
	PO_2 pH	Indicators of renal function
	K^+, Na^+	
C	Ht WBC Arterial pressure	Indicators of haemoconcentration

Table 8.

Variables	*Coefficients*
TBSA	−0.01748805
Full thickness burn	0.07273792
Clothes ignition	0.4307554
Age	0.03374205
Temperature	0.4294271
Inhalation burn	0.3057051
Respiratory rate	−0.036137
PO_2	−0.02906271
pH	3.376499
K^+	−0.3345974
Na^+	−0.02858629
Ht	−0.0115716
WBC	0.00002831902
Arterial pressure	0.007064892

Table 9.

z = Constant + $Co_1.V_1 + Co_2V_2 + \ldots$; (Co = Coefficient, V = Variable, Constant = −4.708813)
$z > 0$: Death
$z < 0$: Survival

A score is derived from the multifactorial equation shown in Table 9, which includes the 14 significant variables, appropriate coefficients and a constant. Once the z-score is calculated, reference to the survival curve

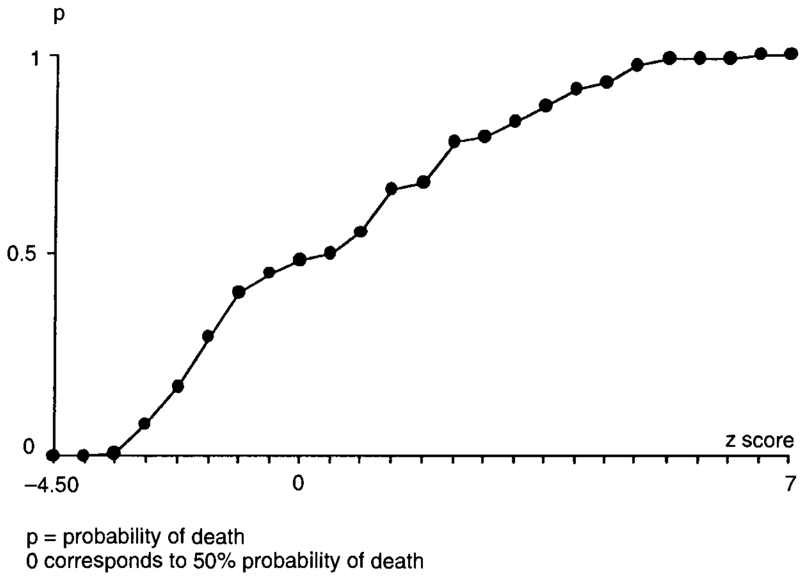


Figure 3. Survival curve

Table 10. Hit rate

		Predicted alive		Predicted dead	
Survived	272	267	(98.2%)	5	(1.8%)
Died	37	4	(10.8%)	33	(89.2%)

(Figure 3) predicts the mortality. Our results are shown in Table 10. The overall correct classification was 97.1% (Figure 2). The accuracy of the Vergina index is obvious from its high overall hit rate, but it is also important to emphasize its reliability for the prediction of death (hit rate 89.2%, the highest of all the proposed burn indices; see Figure 1). The Vergina index can be continuously or occasionally updated.

CONCLUSIONS

The usual burn indices are sufficiently reliable but the Vergina index is more accurate in the prediction of mortality in burn patients, because it considers objectively and in detail the patient's general condition at the time of admission. The predictive accuracy of APACHE II index in burns is poor.

REFERENCES

Bootman, L., Wertheimer, A., Zaske, D., Strate, R., Solem, L. (1979). Using discriminant function analysis to estimate the impact of a therapeutic intervention in burn care. *Burns,* **6**, 149–55

Bowser, B. H., Caldwell, F. T., Baher, J. A., Wall, R. C. (1982). Statistical methods to predict morbidity and mortality: self assessment techniques for burn units. *Burns,* **9**, 318–26

Bull, J. P. (1971). Revised analysis of mortality due to burns. *Lancet,* **2**, 1133

Clark, G., Volenec, F., Mani, M. *et al.* (1978). Predicting the survival of burned patients using discriminant function analysis. *Burns,* **4**, 81

Clark, J. C., Reid, H. W., Gilmour, Campbell D. (1986). Mortality probability in victims of fire trauma: revised equation to include inhalation injury. *Br. Med. J.* **292**, 1303

Knaus, W., Draper, E., Douglas, W. (1985). APACHE II: A severity of disease classification system. *Crit. Care Med.,* **13**, 818–29

Roi, L., Flora, J., Davis, T., Wolfe, R. (1983). Two new burn severity indices. *J. Trauma,* **23**, 1023–9

Sachs, A., Watson, J. (1969). Four years' experience at a specialised burns centre. *Lancet,* **718**

Stern, M., Waisbren, B. (1978). Comparison of methods of predicting burn mortality. *Burns,* **6**, 119–23

Tobiasen, J., Hiebert, J., Edlich, R. (1982). Prediction of burn mortality. *Surg. Gynecol. Obstet.,* **154**, 711–14

Section VII
Complications of burns

43
What is hazardous in fire smoke?

J. W. L. DAVIES
International Society for Burn Injuries, Glasgow, Scotland, UK

Most people are familiar with the situation where an elderly, infirm or intoxicated person falls asleep or otherwise becomes unconscious in an arm-chair while smoking a cigarette. The falling cigarette or a non-extinguished match then ignites the fabric covering the chair and subsequently the chair itself.

To investigate what then happens a mock structure of a room (3 m × 3 m × 3 m) containing such a covered chair was constructed and instrumented to measure the temporal changes which occur in the room after the chair has been set alight. The measurements included temperature, smoke production, which progressively obscures visibility, and the chemical constituents in the air. The amount of air which can enter the room is controlled by a door which can be left open or progressively closed.

In one series of experiments a polystyrene chair was padded with polyurethane foam and covered with a cotton fabric. The door of the room was left wide open allowing the free access of air. The pattern of changes in oxygen concentration in air, smoke density and heat flux for the first 15 min after ignition of the fire are shown in Figure 1. The heat flux at the doorway was high, peaking at about 6 kW/m^2 (0.6 W/cm^2). The air temperature at the doorway rose rapidly during the first 5 min after ignition, peaking at just over 500°C (Figure 2). This peak temperature, and the average temperature 4–5 min after ignition, were above the heat tenability level of about 350°C; at this temperature radiant air produces almost instantaneous full skin thickness burns. The density of the smoke leaving the room rapidly increased, such that by only 2 min after ignition the obscurity limit (0.5 m^{-1}) had exceeded the tenability limit. By 4 min the smoke density had increased to seven times above the limit, and this peaked at over 10 times the limit by about 6 min. The smoke tenability limit is composed of two factors: the content of carbon particles having a respirable fraction ranging between 0.1 and 10 μm and the content of chemicals which irritate mucous membranes (see below).

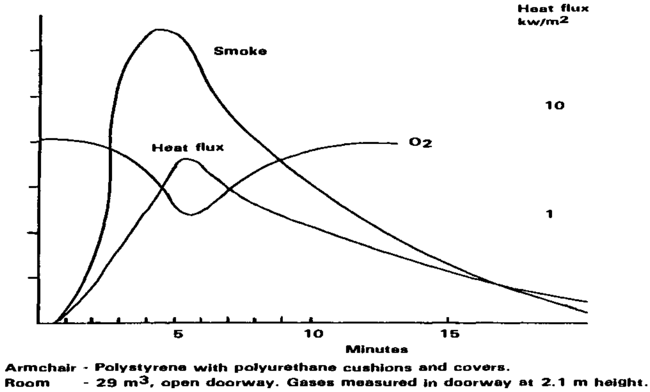


Figure 1. Smoke, heat and gases during single chair room burn. Data provided by Dr D. A. Purser (1988) in a personal communication

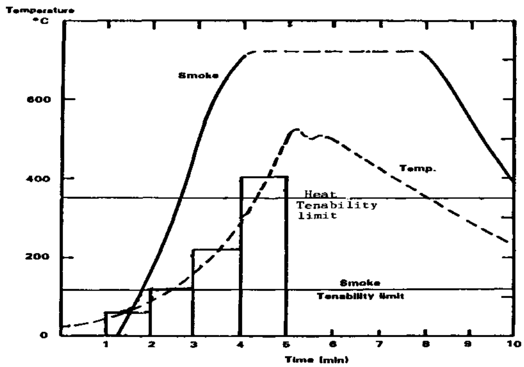


Figure 2. Physical. Data provided by Dr D. A. Purser (1988) in a personal communication

The air content of gases just inside the room during the first 10 min after ignition are shown in Figure 3. The changes peaked at between 5 and 6 min. The oxygen content decreased to about 12.5%, the CO_2 content increased to about 8%, the CO content peaked at about 0.65% and the HCN content reached almost 0.02%. These four changes in concentration all have a narcotic effect. The biological effects of these changes, which are concentration dependent, are shown in Table 1.

In another series of experiments in a mock room structure, about 200 kg of mixed household structural and furnishing materials were ignited in conditions where the supply of air to the room was strictly controllable. When the air supply was restricted the oxygen content in the room air fell to about 10%, the production of CO reached 8% and

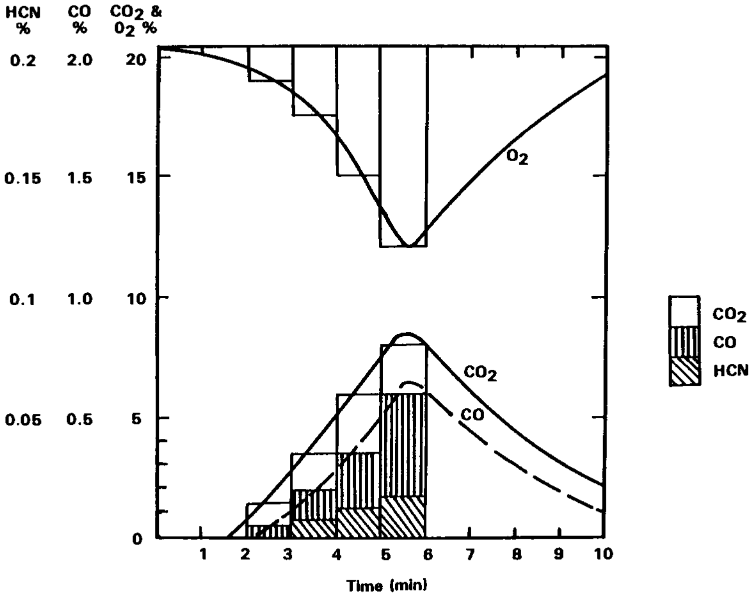


Figure 3. Narcotic gases during early stages of a single armchair burn. Data provided by Dr D. A. Purser (1988) in a personal communication

that of carbon monoxide reached 1.5% (Figure 4). The biological effects of these gas contents can be determined from Figures 4–6. The ambient temperature (Table 2) at the location of the partly open door which restricted the air supply rose to 1165°C by the end of the second minute after ignition and then stabilized at between 875 and 839°C over the subsequent 4 min. The quantity of combustion products, calculated from the smoke content, emanating from the room increased continually to 1560 m^3/min during the sixth and seventh minutes after ignition of the fire.

When the air supply to the room was completely cut off (Figure 5) the burning fire reduced the oxygen content in the air to less than 2%, the CO_2 content reached 17% and the CO content reached 3%. Reference to Figures 4–6 shows that each of these factors alone would cause unconsciousness within seconds and death within a very few minutes.

The availability of oxygen controls how a fire will burn: with a scarce supply of oxygen a fire will smoulder, with an ample supply of oxygen there will be a flaming fire. Comparatively speaking, a smouldering fire has a relatively low burning temperature (400–700°C) whereas a flaming fire can reach over 1000°C. The effects of combustion of a wide variety of polymeric materials at differing temperatures are shown in Figure 6, from which it can be seen that smouldering fires produce chemically complex decomposition products whereas higher temperature fires convert the complex products into simpler compounds.

Table 1. Changes in air gases and their effects. (Information modified from *Fire Safety Journal*, 1984, 7, pp. 271, 283)

Parameter	*Effect*
Oxygen level (%)	
21	Normal concentration in air
12–15	Shortness of breath, headache, dizziness, quickened pulse, fatigue on exertion, loss of muscular coordination for skilled movements
10–12	Nausea and vomiting, exertion impossible, paralysis of motion
6–8	Collapse and unconsciousness, but rapid treatment can prevent death
≤ 6	Death in 6–8 min
2–3	Death in 45 s
Hydrogen cyanide level (%)	
0.004–005	Tolerate for 30–60 min without difficulty
0.011–0.013	Death after 30–60 min
0.018	Death after 10 min
0.028	Immediate death
Carbon dioxide level (%)	
0.025–0.035	Normal concentration in air
2.5	Ventilation increased by 100%
5.0	Symptoms of poisoning after 30 min: headache, dizziness, sweating
12.0	Immediate unconsciouness; death in minutes
Carbon monoxide level (%)	
0.04	Nausea after 1–2 h; collapse after 2 h; death after 3–4 h
0.10	Difficulty in movement, death after 2 h
0.20	Death after 45 min
0.30	Death after 30 min
0.50	Rapid collapse, unconsciouness, death within a few minutes

Table 2. Temperatures and estimates of mean flow of combustion products during test I

	Time interval (min)						
	0–1	*1–2*	*2–3*	*3–4*	*4–5*	*5–6*	*6–7*
Mean estimated flow (m^3/min)	55	415	1015	1385	1505	1555	1560
Temperature °C (end of interval)	143	1165	875	865	853	839	–

When household materials made of wood, cotton, silk, rubber etc., and man-made plastic materials (which are also frequently used in industry and transport equipment such as cars, trains, aeroplanes and ships) burn in a confined space there is not only a depletion of oxygen,

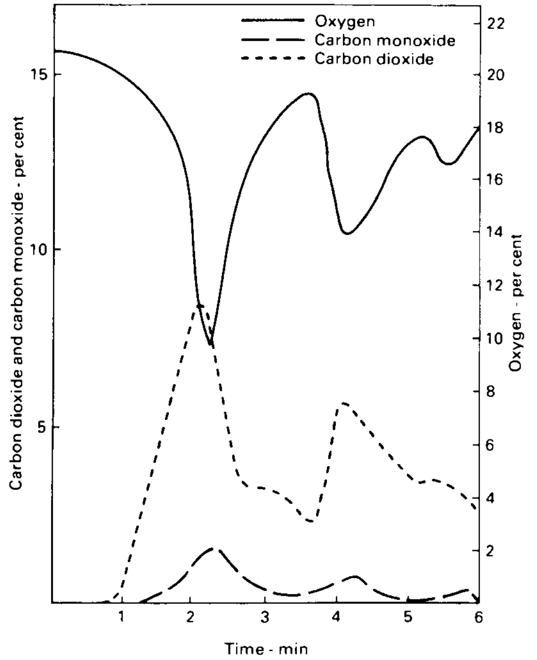


Figure 4. Concentrations of oxygen, carbon monoxide and carbon dioxide at room exit. Figure previously published in *Fire Safety Journal* (1984) 7, 278

very high temperatures, large volumes of smoke which obscures vision, and high levels of carbon monoxide and carbon dioxide but also the production (often in copious quantities) of the compounds listed in Table 3. The combustion of cellulose, polypropylene and acrylic materials produces acrolein (allyl aldehyde; Table 4), a compound which is intensely irritant to mucous membranes in minute quantities. Another highly irritant compound is hydrogen chloride (Table 4) which in the presence of water produces an acid solution which at concentrations of between 0.1 and 0.2% induces dangerous lung oedema.

Many of the decomposition products shown in Table 3 irritate the bronchopulmonary tract, the most dangerous compounds being formaldehyde, acetaldehyde, acrolein, ammonia, isocyanates, hydrogen chloride, phosgene, chlorine, hydrogen fluoride and octafluoroisobutylene. The latter is evolved from non-stick (Teflon) surfaces when they decompose at temperatures > 200°C. One of the more dangerous characteristics of these bronchopulmonary irritant compounds is that they induce hyperventilation, which increases the inhalation not only of air but also of all the narcotic and irritant chemicals found in fire smoke. The most troublesome chemicals in smoke and their generally accepted toxic levels are given in Table 5.

Three other groups of chemicals found in fire smoke are likely to be highly toxic: the complex compounds found in smouldering fires (at

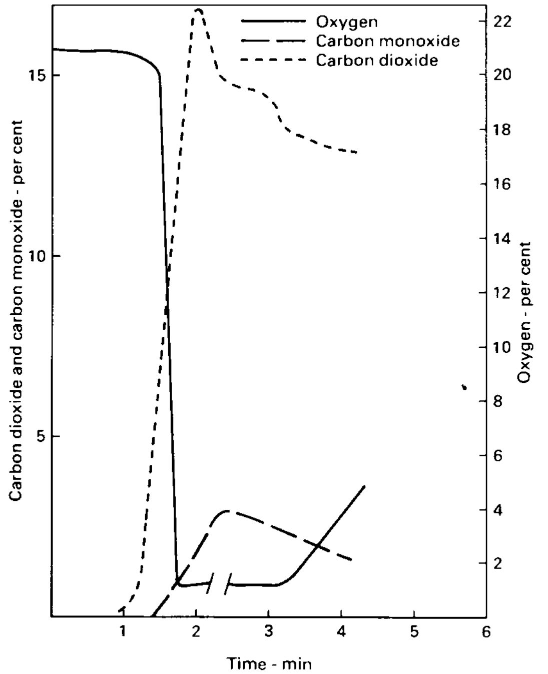


Figure 5. Concentrations of oxygen, carbon monoxide and carbon dioxide close to fire in closed room. Data previously published in *Fire Safety Journal* (1984) 7, 278

combustion temperatures below 700°C, Figure 6), a series of chemical elements, and the super-active free radicals.

Complex molecules

Gas chromatographic/mass spectrometer analyses of fire smoke have shown the presence of a multitude of compounds (Figure 7), at least 24 of which are of relatively low mol. wt (containing 2–10 carbon atoms). These have been condensed into six groups (Table 6). These compounds persist in smoke because the atmospheric oxygen content is so low that their oxidation or conversion to simpler compounds cannot take place. A not inconsiderable number of these complex molecules have been found in the blood of fire fatalities (Figure 8), the presumption being made that the person inhaled sufficient smoke prior to death for these compounds to have crossed the tissue/cellular barrier between the inhaled air and the blood stream. Only about half of the peaks observed in Figure 8 have so far been identified.

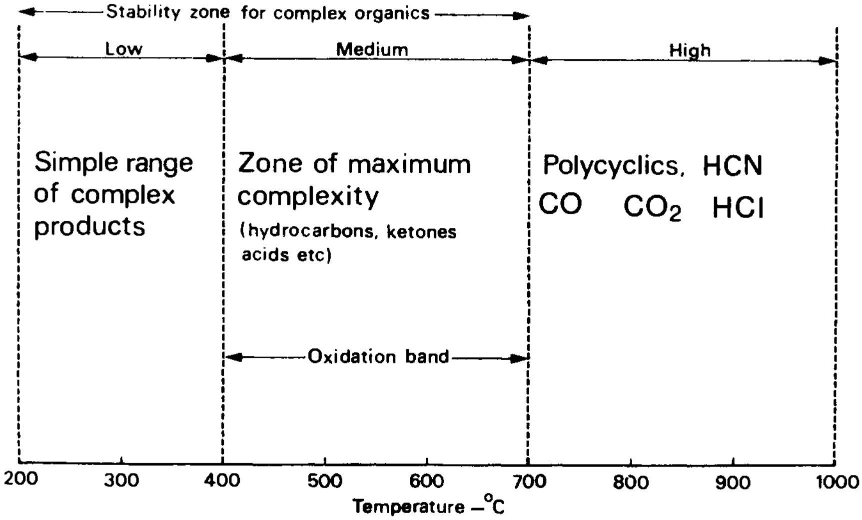


Figure 6. Important temperature zones during thermal decomposition of various polymers. Figure contained in UK Fire Research Station report, *Basic Aspects of Combustion Toxicology*

Chemical elements

Neutron activation analyses have shown a wide range of chemical elements in the tracheas of fire fatalities (Willetts *et al.*, 1982). Compared with the findings in non-fire fatalities, such individuals show increased concentrations of antimony, bromine, cadmium, chromium, cobalt, gold, iron, lead and zinc. The toxicological ramifications of these findings have not yet been determined.

Hyper-reactive free radicals

The smoke derived from burning plant materials [wood, cotton, plant leaves (including tobacco) etc.] contains highly reactive free radicals in both the particulate and gas phases (Church and Pryor, 1985). The particulate materials are retained by a glass fibre filter with a pore size of 0.1 μm whereas the gas phase passes straight through the filter.

The principal free radical in the particulate matter is the relatively stable quinone–hydroquinone complex, which is an active redox system capable of reducing molecular oxygen to superoxide, then to hydrogen peroxide and finally to the hydroxyl radical. The gas phase contains small oxygen- and carbon-centred radicals that are much more reactive than the particulate phase free radicals. Apparently these gas phase free radicals, which can be detected by electron spin resonance spectroscopy, are not produced directly in the fire but result from the oxidation of

Table 3. Some of the toxic compounds in smoke

Material	*Location*	*Decomposition products*
Cellulose	Wood, Paper, Cotton Jute	Aldehydes, Acrolein
Wool, Silk	Clothing, Fabrics Blankets, Furniture	Hydrogen cyanide, Ammonia Hydrogen sulphide
Rubber	Tyres	Hydrogen sulphide Sulphur dioxide
Polyvinyl chloride	Upholstery Wire and pipe covers Wall, floor and Furniture fabrics	Hydrogen chloride Phosgene, Chlorine
Polyurethane	Insulation and Upholstery filling	Hydrogen cyanide, Ammonia Isocyanates, Acrylonitriles
Polyesters	Clothing and other fabrics	Hydrogen chloride
Polypropylene	Upholstery Carpeting	Acrolein
Poly acrylonitrile	Various plastics in the home and at work	Hydrogen cyanide
Polyamide (Nylon)	Clothing and Carpeting	Hydrogen cyanide, Ammonia
Polyvinyl-fluoride	Cabin fittings in aircraft	Hydrogen fluoride
Melamine resins	Household and Kitchen goods	Hydrogen cyanide, Ammonia Formaldehyde
Acrylic materials	Textiles, wall coverings, Aircraft windows	Acrolein

Table 4. Compounds causing irritation to the mucous membranes

Acrolein[a] (p.p.m.)	
1	Immediately detectable — irritation
5.5	Intense irritation
≥ 10	Death in a few minutes
24	Unbearable
Hydrogen chloride (p.p.m.)[b,c]	
5–10	Mild irritation of mucous membranes
50–100	Barely tolerable
1000	Danger of lung oedema after short exposure

[a] Data from the UK Fire Research Station Report, *Basic Aspects of Combustion Toxicology.*
[b] Information previously published in *Fire Safety Journal* (1984) 7, 283
[c] The effects of HCl are primarily irritation of upper respiratory passages. High concentrations result in eye irritation. Fatal lung injury has been reported following a single massive exposure. Atmospheric concentration immediately hazardous to life is 1000–2000 ppm.

nitric oxide to nitrogen dioxide. The latter then reacts with reactive species in smoke such as isoprene β-methyl butadiene. Relatively large quantities of combined nitrogen are found in modern furnishing mater-

Table 5. Major chemicals in smoke and their toxic levels

Toxic compounds	*Irritant and toxic compounds*
10 000 ppm (1%) CO	1 000 ppm HCl
50 000 ppm (5%) CO_2	500 ppm HF
400 ppm HCN	100 ppm SO_2
200 ppm NO_x	20 ppm Acrolein

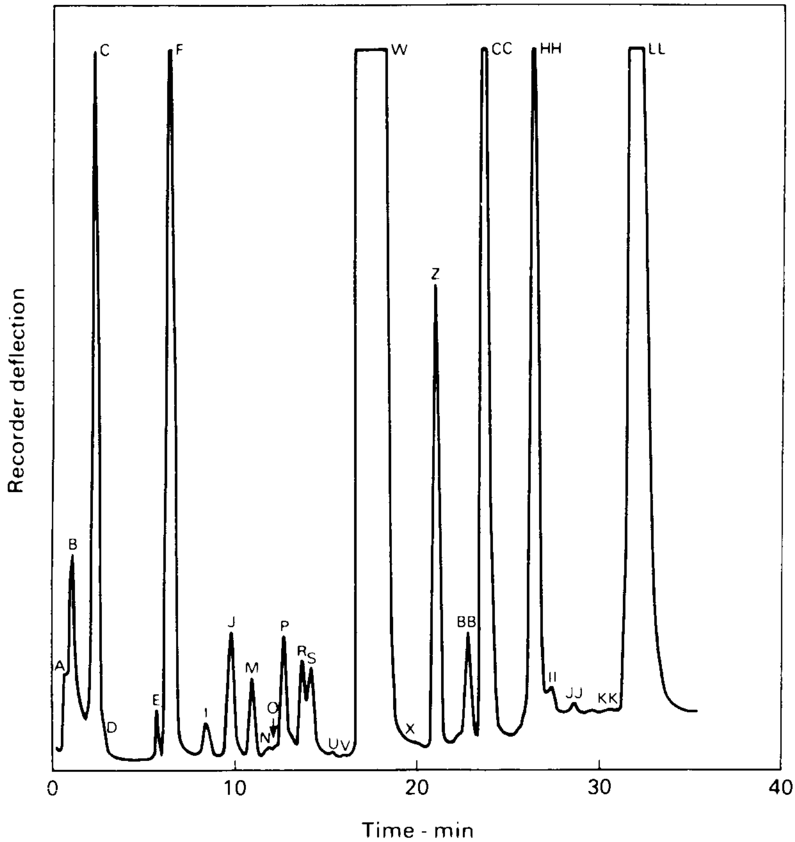


Figure 7. Fingerprint chromatogram indicating components in combustion gases present 7 min after fire ignition. Figure previously published in the *Fire Safety Journal* (1984) 7, 276

Table 6. Molecules containing 2–10 carbon atoms.

Peaks A-F	Simple straight chain hydrocarbons and the unsaturated derivatives.
Peaks I and J	Nitrogen containing compounds.
Peaks M and N	Chlorine containing compounds.
Peaks P and R	More complex nitriles (i.e. nitrogen containing).
Peaks W-HH	Cyclic hydrocarbons, some with nitrogen containing side chains.
Peak LL	bi- or tri-cyclic hydrocarbons.

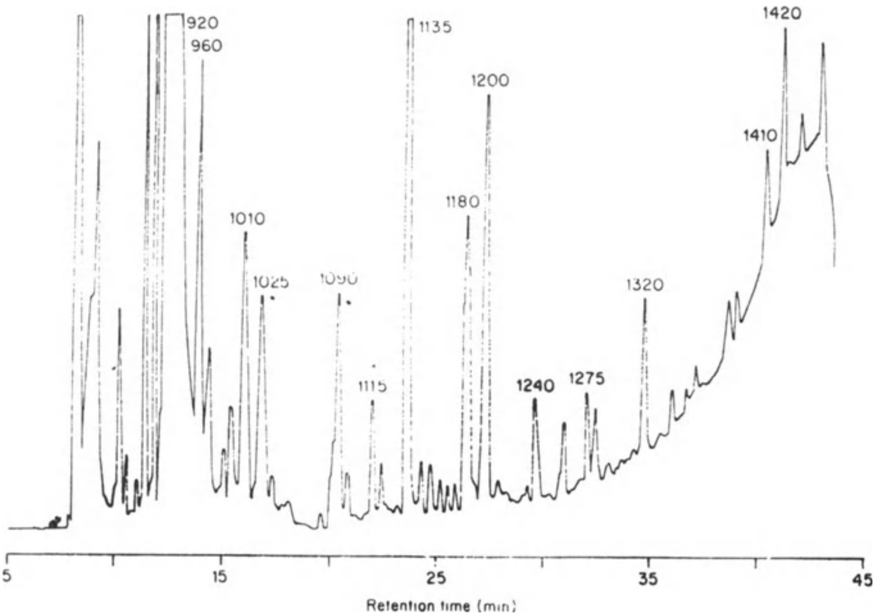


Figure 8. GLC chromatogram of volatiles extracted from blood from a fire death. The blood cyanide level in this case was 238 nmol/l, and the HbCO level was 48%. Methylene unit values are given for major peaks. Previously published in *Fire and Materials* (1979) 3, 98

ials (see Figure 2) which, when burned, liberate significant quantities of the various oxides of nitrogen as well as copious amounts of hydrogen cyanide.

The toxic effects of these various free radicals lie in:

- their ability to activate various cells, i.e. macrophages, with the production of deleterious cytokine activities
- the initiation of cascade reactions, the by-products of which are harmful
- the inactivation of various enzyme inhibitors, allowing undesirable enzyme activities.

An analysis of these biochemical responses is beyond the scope of this review. However a large amount of relevant information is contained within the book *Respiratory Injury, Smoke Inhalation and Burns* (Haponik and Munster, 1990).

BIBLIOGRAPHY

Church, D. F. and Pryor, W.A. (1985). Free radical chemistry of cigarette smoke and its toxicological implications. *Environ. Health Perspec.*, 64, 111–26

Davies, J. W. L. (1986). Toxic chemicals versus lung tissue – an aspect of inhalation injury revisited. *J. Burn Care Rehab.*, 7, 213–22

Davies, J. W. L. (1990). Challenges for the future. In Haponik, E. F. and Munster, A. M. (eds) *Respiratory Injury, Smoke Inhalation and Burns.* New York: McGraw Hill, 383–99
Haponik, E. F. and Munster, A. M. (1990). *Respiratory Injury, Smoke Inhalation and Burns.* New York: McGraw Hill
Willetts, P., Anderson, R. A., Farmer, J. G. *et al.* (1982). Inorganic elements in the tracheas of fire fatalities. *Fire Materials* **6**, 32–7
Woolley, W. D., Ames, S. A. and Fardell, P. J. (1979). Chemical aspects of combustion toxicology of fires. *Fire Materials* **3**, 110–20
Woolley, W. D., Smith, P. G., Fardell, P. J. *et al.* (1984). The Stardust Disco Fire, Dublin 1981. Studies of combustion products during simulation experiments. *Fire Safety J.* 7, 267–83

44
Inhalation trauma diagnostic screening test for fire victims

MARGARETA MALAKHOVA, OKSANA DMITRIENKO and STANISLAV OBOLENSKY
St Petersburg, Russia

INTRODUCTION

Analysis of 500 cases of inhalation trauma showed that the main causes of death were intoxication, pneumonia and septicaemia. It is thus very important to carry out a rapid and reliable diagnosis before these clinical symptoms develop. We have elaborated three biochemical tests to analyse the condition of burn victims. The tests measure the degree of intoxication, the extent of inhalation trauma, and sepsis.

MATERIALS AND METHODS

We used clinical and experimental materials, and considered not only burn victims but also patients with a variety of pathologies, including respiratory distress syndrome and septicaemia, and a group of healthy persons with no pathology. Experimental models of sepsis and lung oedema were established using white rats.

RESULTS

Intoxication was evaluated quantitatively as the measure of the reaction of the animal to thermal insult. We measured the quantity of elements of low and medium molecular weight (L and MMW) molecules recorded as a pool in weak acid surroundings at a wavelength of 236–300 nm in plasma and in erythrocytes. We also measured oligopeptides, including endotoxins (cutaneous burn toxin), and the index of endogenous toxaemia was evaluated.

$$IT = L \times MMW \text{ concentration} \times \text{oligopeptide concentration}$$

Analysis of patients with pulmonary pathology and peritonitis supported the existence of the relationship between this index, the results of the Lumulus test and mortality. Examination of the intoxication of burn patients also showed that it is related to the area, depth and location of the burns.

We propose three screening tests for the diagnosis of inhalation trauma. The first test is based on the determination of the arteriovenous difference of L and MMW molecules in plasma and in erythrocytes in venous and arterial blood. The principle of this test is the following:

1. In normal conditions there is a standard distribution of L and MMW molecules of plasma and erythrocytes in venous and arterial blood: in venous plasma the concentration of L and MMW molecules is always higher than that of arterial plasma, while the concentration of erythrocytes is higher in arterial blood than in venous blood.
2. When the bronchi are affected the arteriovenous difference becomes negative, i.e. the concentration of L and MMW molecules in arterial blood exceeds that of venous plasma. The correlation of L and MMW molecules in erythrocytes remains the same and does not vary from the norm.
3. When the bronchi and the parenchyma are affected a negative difference of the L and MMW molecules exists in both plasma and erythrocytes.

These changes occur in the first hours after the inhalation trauma and continue until full recovery.

The second screening test is based on the measurement of protein concentration, following Biurette's method, in venous and arterial plasma. In normal conditions total protein concentration in venous blood is always 1–3 g/l higher than in arterial blood (see Table 1).

Table 1. Total protein concentration in plasma (g/l)

		Normal	*Acute pneumonia*	*Pulmonary oedema*
Artery	M	68.1	59.0	53.8
	m	0.8	1.3	1.4
Vein	M	70.1*	58.7	51.7*
	m	0.6	1.3	1.5
H_2O	M	18.5	–0.61	–16.8
(ml)	m	2.7	0.3	3.2
		of the lung	in the lung	in the lung

* A–V, $p < 0.05$ (non-parametric statistic)

The same applies to haemoglobin concentraction. This is due to the return of metabolic water from the lung and of water caused by the escape of CO_2 into the atmosphere, in the arterial basin. The quantity of water found is related to the concentration of aldosterone, which is the main hormone controlling water balance in animals. When there are equal concentrations of total protein in venous and arterial blood pulmonary oedema may be observed. If the concentration of total protein in arterial blood is higher than that of venous blood, pulmonary oedema is evident.

The third test, which can be performed in 30–40 min, measures the degree of septicaemia. In cases of sepsis there is a 'jag' effect on the spectrograms after the *complementary procedure*. This test was first tried in white rats in experimental conditions with simulation of septicaemia and in clinical conditions in patients suffering from septicaemia, measured by culturing of blood bacteria using classic microbiological methods. In burn patients the 'jag' effect is observed in the first 2 days in the erythrocytes and urine, and later, with the appearance of symptoms of septicaemia, in blood plasma.

45
Pulmonary inhalation injury

CONSTANCE C. M. HOWIE
St John's Hospital at Howden, Livingston, Scotland

The toxic effects of inhaling smoke were first documented following the Cleveland Clinic disaster in Ohio on 15 May 1929 and later after the Coconut Grove Nightclub Fire in Boston on 28 November 1942.

We became familiar with a clinical condition occurring in burned patients who had been trapped for a prolonged period in a smoke filled area. These patients were treated with humidification, their copious secretions were removed by repeated bronchoscopy and eventually by tracheostomy. Cyanosis was treated with oxygen and they were given antibiotics. The mortality rate was high – not surprising, for our equipment for all of these was woefully inadequate by present standards. Assessment was purely clinical. We had no scientific information to tell us what was happening in the lung and no other means of therapy.

It was only in the 1950s that sophisticated ventilators were developed. Blood gas analysis first became available to the clinicians in the 1960s. Simultaneously, there were improvements in humidifiers and smaller, but very important, minor items of respiratory equipment and in monitoring. These developments and experience gained in their use in other pulmonary conditions happily preceded the appearance in the 1970s of a new and life-threatening pulmonary problem in burned patients as a result of the inhalation of the products of the combustion of modern plastic materials widely used in the home.

We undoubtedly made errors in the care of these patients. Increasing experience, and advances in respiratory care, have been paralleled in the last two decades by improvements in burn wound management, in infection control and metabolic support. Together, these have increased the survival rate among patients who would previously have died as a result of the thermal skin injury alone. The majority of us do not deal with a sufficient number of patients requiring ventilation for our results to be statistically significant. But as clinicians, we anticipate that at the present time considerably more than 50% of ventilated burned patients will survive. Nevertheless, respiratory damage remains a significant cause of mortality.

Bulls's Index of Mortality Probability based on age and extent of injury, published in 1949 and revised in 1971, remains a classic, but the influence of inhalational damage on mortality soon became clear. Many subsequent indices have included this and some have included multiple other factors. Reviewing these indices in 1992, Zoch concluded that a simple index, based on age, extent of injury and the presence of inhalational damage, was best. An index is invaluable retrospectively for assessing results and progress. Apart from the most extreme cases, if used prognostically, such indices are not without serious danger. They cannot allow for constantly improving care nor for the individual patient who survives against all the odds. They are, however, well known to everyone working with burned patients and can erode staff morale when dealing with a ventilated burned patient to an extent that can affect care and influence the outcome.

Successful treatment depends not just on sophisticated equipment, on science and on skill – it is very labour intensive. It demands patience, persistence and commitment by all involved and meticulous attention to detail. These last two can suffer if staff become convinced on the basis of a mortality probability that the patient has no chance of surviving. At present, we still have to accept that, as in many other intensive care situations, not all our patients will survive, but we must continuously assess the causes of failure and try to correct them and improve survival. There will always be some patients who will succumb, usually in the early days post-injury, from overwhelming skin injury or an overwhelming pulmonary injury. Renal or hepatic failure may occur as a result of the skin injury or absorption of toxins from the lung, and may be preventable.

While many useful guides, both clinical and biochemical, are now available to us we still lack a precise, simple, prognostic indication of the need to ventilate. The good clinician will serve his patient well by instituting the ventilation on the basis of the age of the patient, the extent of the injury, the early signs of respiratory damage and on previous knowledge and experience, and will not wait for obvious biochemical changes. Prolonged ventilation for about 3 weeks is necessary. The criteria used to indicate that ventilation may be stopped in other groups of patients do not apply. Until the lung has virtually returned to normal, the patient with a large thermal skin injury will not be able to manage without respiratory support. We are all familiar with having to institute ventilation in extensively burned patients who have no pulmonary injury and no biochemical changes but who are becoming exhausted, and in whom this would otherwise lead to progressive pulmonary failure and respiratory death.

Many patients will have an uncomplicated course. In the resuscitation phase, pulmonary oedema may be a problem. The damaged lung does not appear to be able to cope with the necessary fluid resuscitation and with the fluid shifts which take place. Later, bacteriological or fungal infection may invade the damaged lung. We must ask ourselves whether any factor contributing to this bacteriological invasion is iatrogenic and preventable. We must also ask ourselves whether any of the immediate complications or the long-term lung damage is a result of avoidable biochemical disturbance or physical damage produced by our equipment or respiratory routines, rather than a result of the initial injury.

What then of the future? There is little likelihood that the incidence of this pulmonary problem is likely to diminish in the near future. Improvements in burn management and in respiratory management will continue. Already high frequency ventilators seem to be diminishing iatrogenic problems and improving survival. Our ability to monitor will increase and many future methods may be non-invasive. Pulmonary by-pass and lung transplantation may have a future valuable role.

There can be little doubt that with advances in medical expertise, in science and in equipment, we will progressively see in the years that lie ahead a greatly improved survival probability.

46
Lung metabolic function as a factor of homeostasis support after thermal injury

I. R. VAZINA and S. N. BUGROV
The Republican Burns Centre, Research Institute of Traumatology and Orthopaedics, Nizhniy Novgorod, Russia

The lung is an organ whose importance has been little investigated. It has been established that apart from its well-studied respiratory function it possesses a complex and less well known metabolic function (Heinemann and Fishman, 1969; Syromiatnikova, 1974; Syromiatnikova *et al.*, 1987; Urazaeva and Dubilei, 1975; Said, 1977; Junod, 1982). The pulmonary blood circulation results in complex degradation, activation and inactivation of various endogenous agents influencing the blood circulation (vascular tension, their permeability, coagulation system, fibrinolysis). Arterial blood differs greatly from venous blood owing to the active metabolic processes. We showed (Vazina, 1988) that in the short period of pulmonary blood circulation changes appear in the coagulation system and the main bioenergetic substrate content (such as glucose and non-esterified fatty acids) increases significantly. The pulmonary metabolic function is also involved in increasing the bioenergetic potential of arterial blood. There has been discussion of the pulmonary detoxication function. All this testifies to the fact that the complex metabolic function of the lung plays an important role in homeostasis.

This chapter describes a study of pulmonary metabolic disturbances in burn trauma.

MATERIALS AND METHODS

Eighty-seven animals (60 dogs and 27 rabbits) were used in the experiment; 25 dogs and 10 rabbits were in the control group, the rest were in the experimental group. Third–fourth degree burns were inflicted in

15–18% of the total body surface area of the experimental animals. After intravenous anaesthesia with 1%+ Pentothal sodium (10–14 mg/kg) and 0.5% Novocain anaesthesia, the jugular vein and carotid artery were exposed. Venous blood was taken from the right atrium with a silicone catheter inserted through the jugular vein. Arterial blood was taken by puncture of the carotid artery. The investigations were made on day 1, 7 and 14 postburn.

Fibrinogen and heparin content, the fibrinolytic activity and erythrocyte deformability of blood were measured. As the increase of heparin level in the blood after it passes through the lung is connected with the fat cell function of the organ, some lung tissue fragments were obtained from the peripheral parts of the lung after sacrifice of the animals. These were fixed in 10% neutral formalin solution, covered with paraffin, cut and the sections stained with 0.01% toluidine blue to evaluate the number of fat cells and their condition. The fat cells were counted only in the lung tissue in 40 fields of vision at × 40 magnification. The results show their average statistics in 10 fields of vision.

RESULTS

After passing through the lung, the heparin content in the blood and fibrinolytic activity increased and fibrinogen concentration decreased (Figures 1 and 2). Erythrocyte deformability increased from 73.2 ± 4.4% to 82.0 ± 3.6%. Many oval or stretched fat cells in the lung tissue of the control group contain a large number of granules in their cytoplasm and are capable of showing metachromasia on toluidine blue staining: 39% of the fat cells of healthy animals were degranulated, indicating the high functional activity of this lung cell population.

A decrease in heparin was seen in the venous blood on day 1 postburn. The arteriovenous difference was positive, though lower than normal. The number of fat cells decreased, while that of the degranulated forms reached 70%. By this time the difference between the fibrinolytic activity and the fibrinogen level in the arterial and venous blood had diminished, though it is still detectable. The capability for erythrocyte deformability in venous blood decreased (66.2 ± 6.9%) but was at the former level in arterial blood.

One week postburn the arteriovenous difference in fibrinolytic activity and fibrinogen concentration changed. A further reduction of erythrocyte deformability was observed. In one-third of the animals heparin release ceased, while in the others it was preserved on a much lower level. The average arteriovenous difference in heparin content was reduced four times compared with normal values. The number of fat cells decreased but the intensity of the process was less than on the first day postburn. Degranulated cells represented 60% of the total number.

There was no arteriovenous difference after 2 weeks. In some animals an inverse ratio was observed: the heparin level in arterial blood was

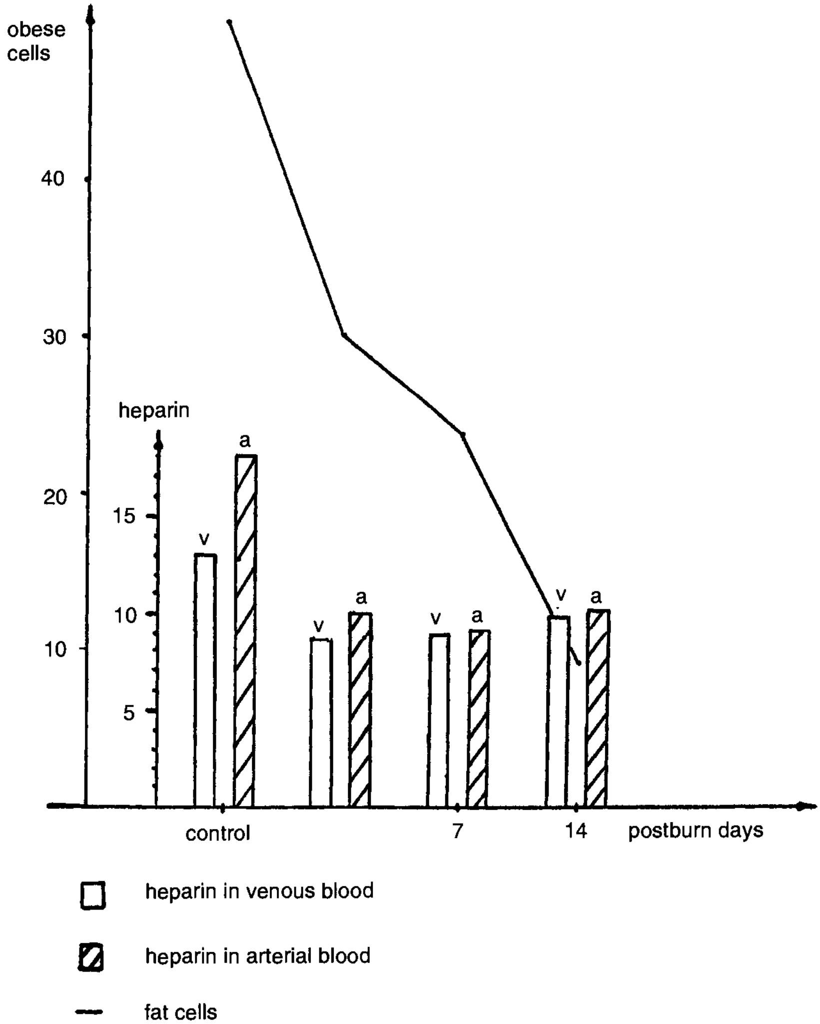


Figure 1. Dynamics of the arteriovenous difference of heparin level in blood and the quantity of fat cells in the normal condition and after the experimental burn

lower than in venous blood. This was associated with the exhaustion of the fat cell population, which manifested itself in their five-fold reduction in the lung tissue. Most of the fat cells had granules in the cytoplasm capable of weak β-metachromasia.

DISCUSSION

Our data testify to the fact that the thermal trauma greatly influences the ability of the lung to support haemostasis. This manifests itself in a

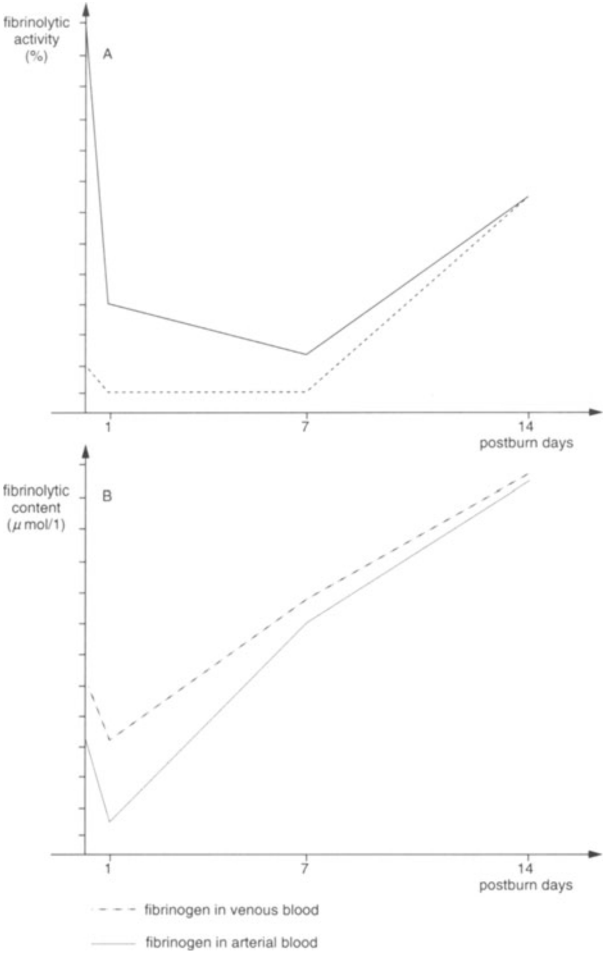


Figure 2. Dynamics of the arteriovenous difference of fibrinolytic activity (A) and fibrinogen content (B) in the reduced circulation in the normal condition and after the experimental burn

reduction of ability of the lung to induce heparin release in the blood, which results in the absence of this phenomenon 2 weeks after the trauma. In some animals an inverse ratio was observed when the heparin level in arterial blood was lower than in venous blood.

The decreased ability of the lung to release heparin in the blood is connected with the increasing exhaustion of the fat cell population. As a rule, the fat cells of the lung have a high functional activity (degranulated forms make up 39%). Having an interalveolar septum location near the capillaries, they release heparin to the external medium during degranulation. Heparin has considerable physiological activity:

counteracts more than 20 enzymatic systems, activates lipolysis and participates in the adaptation test on the cell level. Under normal conditions, heparin secretion by fat cells is performed with the release of granules to the external space. Full degranulation of the fat cell, with its subsequent partial or full death, is due to stress (such as a burn), which explains the significant decrease of the number of fat cells on day 1 post-trauma. The burn is associated not only with the quantitative reduction in fat cells but also with a decrease in their ability to synthesize such a highly sulphated product as heparin. This results in an increase of fat cell granules, with the weak β-monochromasia connected with heparin-monosulphate production without the physiological activity of heparin.

There is a reduction in both heparin secretion and the ability of the lung to increase the fibrinolytic potential of arterial blood. We consider this enzymatic process to be connected with the endothelium of the lung microvessels. It has been shown by electron microscopy (Vazina and Vasilchuk, 1982) that pulmonary blood circulation disturbances after the burn trauma (blood flow decrease, blood cell aggregation, especially blood platelets and leukocytes, and their degranulation) produce oedema not only in endotheliocytes and the basal membrane but also cell destruction and sometimes full lysis. Fibrinolysis reduction causes a decrease in the lung's capacity for diminishing fibrinogen concentration in arterial blood, which is associated with fibrinogenaemia increase. The primary elimination and the loss of the lung's capacity to increase heparin content, to improve the fibrinolytic potential of arterial blood and to diminish fibrinogen concentration are aggravated with the increase of erythrocyte deformability. This is the main cause of multiple microthrombogenesis producing pathological changes in the inner organs.

The disturbances of the lung's capacity to stabilize haemostatic homeostasis is therefore one of the mechanisms of the burn disease.

SUMMARY

In the experiment on dogs and rabbits with third–fourth degree burns on the 15–18% of the total body surface area it was established that thermal injury causes the disturbance of the lung's capacity to support haemostatic homeostasis of arterial blood (to enlarge heparin level, fibrinolytic activity and to reduce fibrinogen concentration), to improve erythrocyte deformability on passing reduced circulation.

REFERENCES

Heinemann, H. O., Fishman, A. P. (1969) Nonrespiratory lung fucntion. *Physiol. Rev.*, **49**, 2–47

Syromiatnikova, N. V. (1976) *Lung Metabolic Activity: Biochemical investigations by the lung pathology: collection of research works*, Leningrad, pp. 54–65

Syromiatnikova, N. V., Goncharova, V. A., Kotenko, T. V. (1987) *Lung Metabolic Activity.* Leningrad: Medicina

Urazaeva, Z. V., Dubilei, P. V. (1975) The influence of the vagus nerve irritation on the lung serotonin inhibition. *Physiol. J.* **61**, 96

Said, J. (1977) Nonrespiratory functions of the lung. *Proc. Int. Union Physiol Sci, 27th Int. Congr.*, Paris, **12**, 96

Junod, A. F. (1982) Lung metabolism pulmonary handling of circulating bioactive substances. *Paed. Respir. Physiol. Clin. Aspects Paed. Pneumol.* Proc. 3d Annu. Meet. Europ. Paed. Respir. Soc. (EPRS), Bern, Sept. 24–26, 1981. Basel, p. 54–60

Vazina, I. R., Vasilohuk, O. A. (1982) Lung ultrastructural changes by the thermal trauma in the experiment. *Arch. Pathol.*, **44**, 34–39

Vazina, I. R., (1990) Thermal injury and nonrespiratory function of the lung: *Proc. 6th Republican Conf. on Thermal Injuries, Gorky*, pp. 12–14

47

Application of enterosorbents in the acute period of burn disease

A. V. NEDELIAEVA and G. YA. LEVIN
Republican Burns Centre, Research Institute of Traumatology and Orthopaedics, Nizhniy Novgorod, Russia

The role of endotoxins produced by gastrointestinal (GI) bacteria in the genesis of endogenous sepsis in burn disease has been little investigated. This question is of great importance nowadays due to the appearance and wide application of enterosorbents to decrease endotoxaemia of varying aetiology in different fields of medicine.

MATERIALS AND METHODS

A total of 1990 animals (390 white rats and 1600 mice) were used in the experiment. The rats received third–fourth degree burns in 20–25% of their total body area. The investigations were held on day 1, day 3 and one week postburn.

The middle mass molecular peptides (MMP) level was determined for the assessment of the general toxicity of the blood (Gabrielian and Lipatova, 1984). Biotesting in mice (Kiseliov and Shuls, 1981) with dactinomycin administration for sensitization was used to determine the GI endotoxin level in the blood. Reference to calibration curve showed that bacterial endotoxin (BET) was present at lethal levels.

ACT and ALT enzyme activity in the blood serum was investigated with the dinitrophenylhydrazine method based on the transamination reaction.

We studied both the total protein (with refractometry) and caeruloplasmin content in the blood of burned animals.

We also carried out a histological investigation of the liver of burned rats. The glycogen content (Best's staining) and adipose degeneration were determined.

Enterosorbent was perorally infused through the probe once a day for 1, 3 or 5 days. Five types of enterosorbents were used: carbonfibrillar adsorbent (vaulen; 40 mg/kg); the Dneeper-activated carbonfibrillar material (ACFM; 40 mg/kg); low-molecular polyvinylpyrrolidone (enterodes; 200 mg/kg); polymethylsiloxan (enterosgel; 1000 mg/kg); and polyphepan; 250 mg/kg.

Endotoxaemia was significant in the first 3 days postburn: administration of serum drawn from the rats in the 24 h after thermal injury to sensitized mice resulted in the death of 72.7 ± 4.2% of the animals (BET dose, 0.4 mg/kg); at 3 days postburn, 61.2 ± 3.3% (BET dose, 0.158 mg/kg); and at 7 days 46.3 ± 5.2% (BET dose, 0.0398 mg/kg).

The MMP content (both aromatic and nonaromatic) in the blood of rats increased greatly, the highest concentration being observed immediately after the burn. In 24 h the MMP-level increased twofold. After 3 and 7 days this value was still high (Table 1).

Table 1. The influence of enterosorption on the aromatic MMP concentration in the blood of burned rats (g/l)

Time of investigation	*Untreated burn*	*Enterosorbents*				
		Vaulen	*ACFM-MN*	*Enterosgel*	*Enterodes*	*Polyphepan*
Day 1 postburn	0.75 ± 0.06[a]	0.45 ± 0.04[b]	0.25 ± 0.08[b]	0.29 ± 0.07[b]	0.29 ± 0.04[b]	0.24 ± 0.02[b]
Day 3 postburn	0.51 ± 0.06[a]	0.30 ± 0.05[b]	0.29 ± 0.04[b]	0.29 ± 0.07[b]	0.30 ± 0.05[b]	0.48 ± 0.07
Day 7 postburn	0.55 ± 0.04[a]	0.50 ± 0.06[b]	0.48 ± 0.06[b]	0.56 ± 0.14	0.51 ± 0.04	0.20 ± 0.02[b]

[a] Differences significant compared with normal indices; [b] differences significant compared with control group indices ($p < 0.05$)

Severe endogenous toxicity (especially connected with GI endotoxins) was associated with organ pathology, above all hepatic dysfunction. Histological investigations showed hepatic adipose degeneration in all burned rats at 3 days and glycogen reduction affecting hepatic protein production was observed. Together with vascular permeability disturbances, this results in essential hypo- and dysproteinaemia.

The largest total protein decrease was observed on day 1 after the burn: 56.6 ± 3.3 g/l; after 3 days: up to 60.3 ± 1.8 g/l; and after 1 week: up to 69.3 ± 1.4 g/l (in intact rats, 78.1 ± 4.5 g/l).

Caeruloplasmin concentration changed greatly after the burn: in the first 24 h its content in the blood decreased (mean: 22%), but subsequently its level greatly exceeded the norm (in intact rats 653.2 ± 53.8 mg/l; Table 2).

Further investigations were devoted to the possibility of endotoxaemia treatment with enterosorption. Enterosorbent administration caused a significant decrease in endotoxaemia (according to biotesting). Lethality in mice injected with the serum of treated burned rats decreased by 26–48% on the first day postburn, after 3 days by 12–26%, and after a week by 3–18% depending on the type of sorbent. The

Table 2. The influence of enterosorption on caeruloplasmin concentration in the blood serum of burned rats (mg/l)

Time of investigation	*Untreated burn*	*Enterosorbents*		
		Vaulen	*Enterodes*	*Polyphepan*
Day 1 postburn	500.2 ± 63.5	586.3 ± 62.3	662.1 ± 31.6[a]	548.3 ± 50.1
Day 3 postburn	991.7 ± 94.6	788.1 ± 57.1	770.0 ± 63.1	680.3 ± 67.1[a]
Day 7 postburn	998.6 ± 76.3	512.0 ± 71.6[a]	429.3 ± 68.2[a]	796.3 ± 79.6

[a] Differences significant compared with control group indices ($p < 0.05$)

efficacy of the enterosorbents differed. The greatest effect was observed with enterosgel and ACFM. On the first day postburn vaulen had the maximum detoxification effect.

Enterosorbents greatly reduced not only the GI endotoxin level but also the MMP concentration (Table 1). The maximum MMP decrease was observed after polyphepan application (in 1 day and 1 week after the burn trauma). Three days postburn the MMP level was normal after enterosgel and ACFM application.

Enterosorption in the acute period of burn disease prevented hepatic dysfunction. ACT and ALT activity was much lower in enterosorbent-treated rats in the first hours postburn. Enterosgel was the most effective.

Hyperproteinaemia reduced considerably under the influence of enterosorbents. In the first 24 h postburn total protein concentration increased from 56.6 ± 3.3 g/l to 64.5 ± 1.8 g/l ($p < 0.05$) during polyphepan treatment. There was a tendency towards normalization of the CP level after enterosorbent administration in burned rats: its concentration increased in the 24 h postburn and decreased thereafter (Table 2). This effect can be explained by the hepatic protein-producing function: hypo- and dysproteinaemia decrease may result in protein normalization in the acute period (for example, α_2-macroglobulins).

The improvement in hepatic function was associated both with glycogen normalization and reduction in hepatic adipose degeneration. Enterosgel had a hepatoprotective effect (glycogen content in the liver was normal and adipose degeneration manifestations were insignificant or practically absent).

The significant decrease in endogenous intoxication under the influence of enterosorption is therefore the main reason for the reduction of hepatic parenchyma degenerative changes and results in the improvement of its most important function – protein-production. Polyphepan and enterosgel seem to be the most effective in this respect.

As different enterosorbents influence various manifestations of endogenic intoxication we suppose that enterosgel could be more effective when combined with enterosorbent complex. After the application of vaulen, enterosgel and enterode combination in the first 24 h postburn, GI endotoxins in burned animals' blood were absent. This is of great importance in the first 3–5 days postburn, when the role of these endotoxins in the pathogenesis of burn disease is considerable.

SUMMARY

In this chapter we report our experience with the use of enterosorbents such as vaulen, Dneeper ACFM, enterodes enterosgel and polyphepan. It was established that ES greatly reduced I bacteria endotoxin concentration in blood and MMP level and prevented hepatic dysfunction.

REFERENCES

Gabrielian, N. I., Lipatova, V. I. (1984) The experience of the MMP index usage in diagnostics of nephrologic diseases in children *Lab. Work,* **3**, 7–12

Kiseliov, P. N., Shuls, G. S. (1981) Bacteriological endotoxin determination in blood of irradiated animals and humans. *Lab. Work,* **9**, 561–563

Section VIII

Burn infection care

48
Infection in the burn patient

R. HERRUZO CABRERA, G. GÓMEZ BAJO, V. GARCÍA TORRES and J. REY CALERO
Hospital La Paz, Universidad Autónoma di Madrid, Spain

INTRODUCTION

Infection continues to be the main cause of death in the burn patient, if we exclude the inhalation syndrome, and is the most serious complication in burns. Infection plays a part in about 70–80% of deaths occurring within 5 days of admission to hospital of critically burned patients, a percentage that has remained unchanged despite all the progress made in the treatment of burn patients. For example, in the last 20 years, the proportion of deaths in patients with > 50% body surface area (BSA) burned has been reduced by half; however, infection was responsible for three out of four deaths both at the beginning and at the end of this 20 year period.

This association of burns and infection has to be added to the risk factors in these patients, together with the fact that the burn is a good culture medium for micro-organisms. The main factors affecting infection in burns are:

- destruction of the mechanical barriers (skin and mucosa) against micro-organisms as a result of the thermal insult
- destruction of the bacterial flora present in these barriers (which provide protection against invasion by other micro-organisms)
- the high mobility of burn-colonizing micro-organisms, which facilitates the invasion
- endotoxins, exotoxins and permeability factors produced by germs colonizing the burned area; these cause greater diffusion in depth, local and distant reduction of immunity, cell necrosis, etc.
- the resistance of colonizing micro-organisms to antibiotics, which makes them difficult to treat in the event of sepsis
- loss of plasma proteins, because of the burn, including gammaglobulins, which may alter oncotic pressure and immunity
- non-specific alteration of immunity: consumption of the complement, reduction of fibronectin, functional deficit of the phagocytes

- specific alteration of immunity, particularly of the cells, reduction of lymphocyte IL-2, etc.
- non-vascularity or hypovascularity of the eschar, which may prevent the arrival of gammaglobulins, antibiotics, etc.
- burns sequelae
- previous pathologies, which aggravate or complicate the clinical course

All these factors occur with greater frequency in extensive and deep burns.

The classification of burns

It is often difficult to make a diagnosis of infection in burn patients because the classic signs of infection may be present (with or without infection) or absent (also with or without infection); for example, in extensive burns, fever is an almost constant factor because of the production of endogenous pyrogens while in cases of serious sepsis, hypothermia develops. The white blood cell count is very variable (although a large leftward shift may suggest infection); there may be hypotension, paralytic ileus, tachycardia, hyperpnoea etc. without a clear relation to infection, or vice versa.

Despite these problems we can use the McMillan classification, dividing burn infections into the categories given below.

Non-invasive burn infection

Infection is very frequent in burns, occurring in some part of the traumatized area. In general it is caused by a single species of bacteria or fungus (this distinguishes it from colonization). The devitalized eschar may contain from as little as 10 to as many as 10^9 micro-organisms per gram of tissue. There is however no evidence of invasion of non-burned areas. This great number of micro-organisms produces degradation enzymes, leading to hydrolysis of the burn zone. Systemic syndromes may develop due to the production of toxins, which pass into general circulation.

A characteristic feature of non-invasive infection is the rapid separation of the dead eschar and the marked exudation of the burn. Biopsy recounts in the burn area exceed 10 000 bacteria per gram, while in the area adjacent to the lesion the recount is lower. The symptoms are mild, with a slight increase in body temperature and moderate leucocytosis without leftward deviation.

In the aetiology of these infections an important role is played by Enterobacteriaceae (25–30%), *Staphylococcus aureus* (20–30%) and *Pseudomonas aeruginosa* (20–25%), micro-organisms now appearing in forms extremely resistant to antimicrobial agents, together with fungi and viruses. However this aetiology may be considerably modified with the aid of surgical therapeutic techniques.

Invasive burn infection without bacteraemia

Invasive burn infection is considered to be present when a count of > 100 000 bacteria per gram is obtained in a healthy area adjacent to the burn. The clinical condition of the patient depends on the genus and species of the organism, but generally the granulation tissue is oedematous, pale and tending to dryness, crusty and necrotic in a patient who previously presented abundant secretion from the burn. Episodes of fever are frequent and pronounced, and there is leucocytosis with leftward deviation. In severe cases body temperature may fall below normal and there may be septic shock. Blood cultures, however, remain negative. The diffusion may be due either to contiguity or to an as yet undiagnosed bacteraemia, the initial focus of which is the burn.

Invasive burn infection with bacteraemia

This usually develops out of invasive infection without bacteraemia, but it may be caused more directly by lymphatic diffusion of micro-organisms from the locally infected burn. The clinical condition is similar to that described above, but with positive blood cultures.

Other infections: sepsis not originating from the burn

This generally develops from multiple organ involvement as a consequence of the generalized dissemination of infection, and may lead to multiple organ failure. Early sepsis can be related to the intestinal translocation of micro-organisms; if sepsis occurs intestinal translocation may continue, with micro-organisms passing from the intestine to the blood and other systems or organs. Other sources of sepsis are the point of entry of the catheter and to a lesser degree infections of the urinary tract, pneumonia, etc.

Our criteria of local infection in burn patients are clinical (fever not explained by other types of infection with negative blood cultures, deterioration of granulation tissue or suppuration of the burn) and microbiological (> 100 000 micro-organisms of a single species per gram). We have replaced the burn biopsy with semiquantitative study of the eschar, which gives results very consistent with those of biopsy but without any loss of blood. This can be performed routinely as part of the microbiological monitoring of the patient. No distinction was made between invasive and systemic invasion, as advised by Tompkins, and we have only considered systemic infection, as diagnosed by the criteria described above, together with the observation in the blood culture of the same micro-organism as that found in the burn. Other infections can be diagnosed following the criteria of the CDC. Among the primary bacteraemias we can distinguish those attributable to the catheter. The differentiation between colonization and infection of the point of entry of the catheter is performed following the semiquantitative technique described by Maki in 1977.

FREQUENCY OF INFECTION

Local (non-invasive) infections of the burn constitute the majority (> 50%) of infections in conventional Burns Centres, but they can be considerably reduced by adequate general and local prophylaxis. For example, in our Centre, there has been a drastic drop in their frequency, with a reduction in the rate of infection of the burn both in real time (rates in different periods) and by comparison with standards, i.e. compared to what would have occurred if we had not introduced therapeutic changes in the Unit. We have also made standardizations in relation to BSA in order to be able to compare all the different years. There was a reduction of nearly 90% in the 2-year period 1988–1989.

If instead of expressing infections as density of incidence they are expressed as accumulated incidence, only 5% of our patients suffered from an infection in this class, which indicates a reduction from 55% to 14% of the total hospital infection after the application of the preventive programme introduced in our Unit.

Invasive infection with septicaemia accounts for the majority of cases of septicaemia in burn units. In our unit, however, its frequency has dropped from 30–35% to 3% or less of total hospital infection (i.e. < 1% of patients). The remaining cases of septicaemia (12% of total hospital infection, i.e. 5–6% of patients) had the vascular catheter as their point of entry.

Other infections not due to the burn had a lower incidence. The most frequent originated in the genitourinary tract (7%); infections of respiratory origin were less common (3.6%), as also sepsis due to the catheter (4%).

AETIOLOGY OF INFECTIONS IN BURNS

There has been a substantial modification in the aetiology of infections parallel to the observation of patients with HIV. There was a change from the prevalence of *Streptococcus* to that of *Staphylococcus*, then *Pseudomonas* and Enterobacteriaceae; now the predominant germs are *Staphylococcus* and Enterobacteriaceae resistant to multiple antibiotics, as well as fungi and viruses.

The relative frequency of the various aetiologies of infection in burns is: *S. aureus* (24%), *Pseudomonas aeruginosa* (21%), Enterobacteriaceae (> 25%), *Candida*-type fungi (2.3%).

The results in our Burn Unit show a drastic change in the aetiology of burn infection, passing from a rate similar to that in a study of the NNIS in 1984–5 to the present state, in which we see a tendency for elimination of Enterobacteriaceae and anaerobic bacteria and a reduction in *S. aureus* and *P. aeruginosa*, although to a lesser degree, with the result that today these are the only micro-organisms infecting burns in our unit, with a ratio of four *P. aeruginosa* infections to one *S. aureus* infection.

In order to appreciate the real reduction of burn infection, according to aetiology, expressed as a density of incidence, in addition to that observed in real figures, we have used standardization, based on BSA, so that all years are comparable. We can thus observe that infection from *S. aureus* has dropped by more than 90%, from *Pseudomonas* by 83% and from Enterobacteriaceae by 100%.

With regard to the aetiology of other infections, we find:

- sepsis due to catheter: *Pseudomonas* (9.7%), Enterobacteriaceae (9.7%), *S. aureus* (6.4%), fungi (6.4%) and other gram-positives (61.3%);
- infections of the urinary tract: *Pseudomonas* (21.7%), Enterobacteriaceae (38.3%), *S. aureus* (5%), fungi (8.3%) and other gram-positives (18.3%);
- respiratory infection: *Pseudomonas* (27.8%), Enterobacteriaceae (11.1%), *S. aureus* (27.8%), fungi (5.5%).

PREVENTION AND CONTROL OF INFECTION IN BURN PATIENTS

Microbiological monitoring of infection

Microbiological monitoring of infection is performed by taking biopsies of the burn zone and of adjacent tissue (for detection of invasive infection), with count, identification, antibiogram, etc. of the micro-organisms isolated. A useful alternative (sensitivity 97%, specificity 88%, positive predictive value 92%, negative predictive value 96%) consists of a semi-quantitative study performed on a sample taken with a swab in an area of 2–3 cm^3, which enables us to make a count based on powers of 10, is easier to realize in serial form and less traumatic, and also provides information about all biopsy findings, except for the invasion of adjacent healthy tissue.

We also monitor the flora of other areas (pharynx, rectum, nasal fossae, unburned surface, urine, etc.) so that we have ample information about the micro-organisms colonizing or infecting the patient and about his sensitivity.

Prophylaxis and topical treatment of burns

Although we have at our disposal a considerable number of topical antimicrobial agents, none completely satisfies the requirements of the ideal topical antimicrobial agent. The main objective of antimicrobials is to limit the growth of the micro-organisms that colonize the burn in order to prevent or at least delay the evolution from colonization to infection.

Prophylactic and therapeutic use

The main use is prophylactic. Antimicrobial agents are applied to the burn from the initial moments until surgical treatment of the area in order to prevent or limit colonization and/or infection from the pharyngeo-naso-intestinal reservoir and from hair follicles in the zone. Considering the great bactericidal efficacy of some of these products (0.5% chlorhexidine or 1% silver sulphadiazine plus 2.2% cerium nitrate, which we use), they can be used as therapy, although this is not very effective in infection in extensive burns (exceeding 30%) and does not reduce mortality in patients with burned BSA greater than 70%.

Owing to the relative or complete nonvascularity of the eschar, antibiotics administered systemically are unlikely to attain elevated concentrations in infected burns. For this reason various researchers recommended the local administration of antibiotics beneath the eschar, inoculating 25 ml of normal saline solution or 1/2 N., with antibiotics such as ticarcillin, aminoglucosides etc., at intervals of 7.5 cm, using size 22 needles.

Surgical treatment

Surgical treatment has contributed more than anything else to the increased survival of burn patients. It is the most (sometimes the only) effective treatment against burn infection and is usually performed after clinical stabilization of the patient. The reason for its effectiveness may be the removal of necrotic tissue, which eliminates toxic subproducts (of the burn or of the bacteria in it) and permits improvement of the general state and of immunity. Surgical treatment is more conservative in the young and old and in cases of inhalation syndrome.

The aggressiveness of surgery is also a function of the infection. Debridement is required in infection due to sensitive *Straphylococcus*; excision as far as the fascia is required in infection due to gram-negative bacteria and methicillin-resistant *S. aureus*; while excision as far as healthy tissue (including fascia and muscle) is used to treat fungal infections. The operated area must be covered with skin grafts (auto- and allografts, cell culture skin), for until this is performed the danger of infection persists.

Prophylaxis and systemic treatment

As stated above, systemic antibiotics do not normally bind in sufficient quantity in the burn area. They are however very effective in the control of the spread of infection to adjacent healthy tissue and the blood. It is also necessary to bear in mind during treatment the physiological changes (renal hypertrophy, etc.) and other alterations as the patient improves that produce modifications in the pharmacokinetics of these antibiotics. It is therefore useful and sometimes essential to determine the level of the antibiotics in order to establish the correct dosage. The number of micro-organisms growing in burns is enormous (as many as 10^8), with the result that there are frequent phenomena of mutation and transmission of resistance to antimicrobial agents, with selection of micro-organisms that are resistant to nearly all antibiotics available. Hence the importance of the microbiological monitoring of the patient and the necessity of using associations of antibiotics in cases of poly-resistant germs.

Pharyngo-naso-intestinal decolonization and intensive decolonization of the burn

The most frequent origin of colonization or infection of burns is the intestinal flora. Attempts have been made to reduce the incidence of this complication by the administration of antimicrobial agents which antagonize this flora. Jarret demonstrated that intestinal decolonization reduced infection in burns. However there is now some doubt about the technique, in the light of some research performed with a similar decolonization protocol showing a limited number of patients and a short period of decolonization (10 days), and research indicating that it was not the better decolonization protocol that protected the flora resistant to colonization (anaerobics), as shown by Van Saene. For this reason they propose an alternative protocol, although they do not demonstrate a reduction of the disease, but only of colonization of the burn.

The objective is to keep the potentially pathogenic flora under control without altering the rest of the flora colonizing the mucosae, which constitute the main reservoir of micro-organisms in our body.

Our protocol is colimycin 400 mg/day in 4 doses, plus tobramycin 300 mg/day in 3 doses, plus nystatin 100–150 000 units/kg/day in 3 or 4 doses. All these are administered per os for intestinal decolonization, together with hexetidine (applied with a swab or spray 3 times a day) in the buccal cavity, and nitrofurazone cream in the nasal fossae. This continues unless antibiotic or surgical treatment or other manipulations, such as assisted respiration, intravascular catheter, etc, are required.

If selection appears in the intestine of micro-organisms with natural or acquired resistance to these products (e.g. *Proteus*, *Serratia*, Enterobacteriaceae, etc.) they are replaced according to the following protocol: colimycin by norfloxacin (0.8 g/day in two doses) tobramycin by amikacin (1.5 g/day in three doses) and nystatin by fluconazol (2 capsules per day) or amphotericin B (0.25 mg/kg/day), all per os. In the nasal flora there may also be selection of Enterobacteriaceae or *Pseudomonas* which are not very sensitive to nitrofurazone. In this case it is replaced by 0.5% chlorhexidine or 1% silver sulphadiazine plus 2.2% cerium nitrate. The alternative prophylaxis is administered until elimination of the resistant strain.

We apply the term 'intensive decolonization of the burn' to this control of colonization, plus therapy or topical prophylaxis of the burn, plus antisepsis (0.5% chlorhexidine) of the entry point of the catheter, which is changed every 2 days.

Perisurgical prophylaxis

During excision and debridement of burns a considerable number of micro-organisms infecting or colonizing the trauma area pass to the blood. It is necessary to control their diffusion by maintaining an adequate level of antibiotics in the blood, the choice of which depends on the sensitivity of the organisms. If there are no particularly resistant micro-organisms we can use a first-line β-lactam (e.g. cefazolin, active against *Staphylococcus*) plus an aminoglycoside (tobramycin is more effective than gentamycin against *Pseudomonas*). If methicillin-resistant *S. aureus* is isolated, cefazolin is replaced by vancomycin, and tobramycin by amikacin or some other antibiotic (ceftazidime, imipenem, etc.) to which the micro-organism(s) in the burn is/are more sensitive.

The dosage is as in normal therapy: cefazolin 1–2 g, tobramycin 100 mg, vancomycin 500 mg, amikacin 500 mg, etc. Duration should not exceed 24 h, always beginning 1 h before surgery. We recommend prophylaxis in two doses, 1 h before surgery and 6 h after surgery.

Treatment of systemic infections

For empirical treatment, a combination of cefazolin (8 g/day) and tobramycin (300 mg/day) or more (double or triple the quantity) is used if it is possible to monitor the antibiotic levels. In cases of suspected sepsis associated with the catheter cefazolin is replaced by vancomycin (500 mg four times a day), and in possible anaerobic infection by penicillin ($12–20 \times 10^6$ u/day). Directed treatment is undertaken according to the sensitivity of the micro-organism(s) causing (or suspected of causing) the infection. The dose is the maximum normal dose or more (double or triple) if the antibiotic levels are monitored. Most commonly used is a combination of vancomycin with aztreonam, ceftazidim, amikacin or imipenem.

Complementary measures

The burn patient must receive 2800 kcal/m^2 body surface. Of this 15–22% must be protein, containing 2% arginine, 10% must be lipids and the rest carbohydrates. To reduce cross-infection, which is the least frequent kind of infection (endogenous infection accounts for a least 80% of infections in burn patients), we recommend isolation from 'contact', i.e. washing of hands and use of gloves, cap and mask when treating the burn area, washing of hands and/or gloves if only treating the burn area covered with bandages or applying catheters, etc. In open care, if the burns are not colonized, or in cases of infection of the burn zone by *Staphylococcus*, this isolation is supplemented by keeping the patient in a single-bed room. In all cases there must be careful elimination and disinfection or sterilization of fomites. Intravascular catheters, urinary probes, assisted respiration equipment, etc. must be properly maintained and manipulated using normal standards, always remembering that their use should be suspended as soon as possible. Microbiological monitoring of the environment is generally not necessary. In special circumstances, such as epidemics, etc., appropriate preventive medicine measures will need to be taken.

Attempts have been made to complement burn treatment with hyperimmune serum against gram-negative bacteria as soon as the patient's immune system has returned to normal. It is also possible to stimulate this return to normal by successive applications of *Staphylococcus* and *Pseudomonas* antigens which produce a specific immune response, in order to reduce late infectious complications (i.e. more than a month post-trauma); also, in cases of re-infection by a particular microorganism, e.g. *Staphylococcus*, it is possible to administer an autovaccine after isolation of the infecting germ and its use to produce immunizing antigens.

Immunomodulators are used to counteract immunosuppression in burns. Various substances improve lymphocyte function, although experience in their use is still limited: ibuprofen, interleukin-2, vaccination with *Corynebacterium parvum* etc. Plasmapheresis has been used to eliminate toxic substances derived from the burn. The results we have obtained are not very encouraging, although they could improve if we reduced the number of lesions, maintaining for as short a time as possible the intravascular route which is the origin of the majority of infectious complications in the use of this technique.

MORTALITY

Sepsis and its consequences, e.g. multiorgan failure and pulmonary complications, continue to be the main causes of death in burn patients. Infection plays a part in 70–80% of deaths occurring within 5 days of hospitalization of the critical burn patient, and this percentage remains steady in the face of all the progress achieved in this field of therapy. The reduction of infection rates in our Unit brought with it a parallel reduction in the mortality rates. Experience in our Unit in the last 20 years, with the introduction of successive variations in burns treatment, shows that between the early days, when treatment was strictly conservative and monodisciplinary, and more recent times, with an early and aggressive surgical approach, a multidisciplinary management, and successive preventive means, there has been a considerable reduction in the percentage of expected mortality. Thus, between the mortality rate in the period 1971–84 and the 4-year period 1984–87, the earlier and more aggressive surgical approach led to a reduction in mortality of 14.35%. In the period 1987–91, with the introduction of a multidisciplinary approach, increasingly earlier and more aggressive surgery, and the adoption of a complete preventive programme (naso-pharyngeo-intestinal decolonization, etc.), we have achieved an improvement in expected mortality rates of 37.3% compared with the period 1971–84 and of 25.8% compared with the period 1984–87.

BIBLIOGRAPHY

Deitch, E. A. and Berg, R. (1987). Bacterial translocation from the gut: a mechanism of infection. *J. Burn Care Rehab.*, **8**, 475–482

Demling, R. H. (1983). Improved survival after massive burns. *J. Trauma*, **23**, 179

Deutsch, D. H., Miller, S. F. and Finley, R. K. Jr (1990). The use of intestinal antibiotics to delay or prevent infections in patients with burns. *J. Burn Care Rehab.*, **11**, 436–442

Guia para la prevención y control de la infección hospitalaria (1992). Hospital La Paz, Madrid

Guiot, H. F. L. and van Furth, R. (1977). Partial antibiotic decontamination. *Br. Med. J.*, **1**, 800

Herruzo-Cabrera, R., Lenguas-Portero, F., Martinez-Ratero, S. Garcia-Torres, V. and Rey-Calero, J. (1990). Evolution and results of the prophylaxis and management of infection in a burn unit, over a four-year period. *Ann. Medit. Burns Club*, **3**, 276–284

Herruzo-Cabrera, R., Garcia-Torres, V., Rey-Calero, J. and Vizcaino-Alcaide, M. J. (1992). Evaluation of the penetration strength, bactericidal efficacy and spectrum of the action of several antimicrobial creams against isolated microorganisms in a burn centre. *Burns*, **18**, 39–44

Herruzo-Cabrera, R., Vizcaino-Alcaide, M. J., Mayer, R. F. and Rey-Calero, J. (1992). A new *in vitro* model to test the effectiveness of topical antimicrobial agents. Use of an artificial eschar. *Burns*, **18**, 35–38

Herruzo-Cabrera, R., Vizcaino-Alcaide, M. J., Pinedo-Castillo, C. and Rey-Calero, J. (1992). Diagnosis of the local infection of a burn through a semiquantitative recount of the eschar surface. *J. Burn Care Rehab.*, **4**, 639–641

Hi, M., Guang-Xia, X., De Wong, W. and Ngao, L. (1986). Endogenous microbial dissemination following severe burns in rats. *Burns*, **12**, 325–329

Inoue, S., Peck, M. D. and Alexander, J. W. (1991). Fungal translocation is associated with increased mortality after thermal injury in guinea pigs. *J. Burn Care Rehab.*, **12**, 19–22

Jarret, F., Balish, E., Moylan, A. and Ellerbe, S. (1978). Clinical experience with prophylactic antibiotic bowel suppression in burn patients. **83**, 523–527

Jones W. G. II, Barber, A. E., Minei, J. P., Pahey III, T. J., Shires III, G. T. and Shires, G. T. (1991). Differential pathophysiology of bacterial translocation after thermal injury and sepsis. *Ann. Surg.*, **214**, 24–30

Kagan, R. J., Matsuda, T., Hanumadasos, M. and Jonasson, O. (1985). Serious wound infection in burned patients. *Surgery*, **98**, 640–647

Manson, W. L., Westerweld, A. W., Klasen, H. J. and Sanez, E. W. (1987). Selective intestinal decontamination of the digestive tract for infection prophylaxis in severe burned patients. *Scand. J. Plast. Reconstr. Surg. Hand Surg.*, **21**, 269–272

Manson, W. L., Klasen, H., J., Sauer, E. W. and Olieman, A. (1992). Selective intestinal decontamination for prevention of wound colonization in severely burned patients: a retrospective analysis. *Burns*, **18**, 98–102

Monafo, W. W. (1979). An overview of infection control. *J. Trauma*, **19 (Suppl. 11)**, 879–880

Rothman, K. J. (1987). *Epidemiologia Moderna.* (Madrid: Diaz de Santos.)
Stoutenbeek, C. P., van Saene, H. K. F. and Miranda, D. R. (1987). The effect of oropharyngeal decontamination using topical nonabsorbable antibiotics on the incidence of nosocomial respiratory tract infection in multiple trauma patients. *J. Trauma,* **27**, 357
Tompkins, R. G. and Burke, F. F. (1992). Infections of burn wounds. In Bennett and Mandell (eds.) *Hospital infections* (3rd edn.) Boston: Little Brown, 711–730
Van Saene, H. F. K. and Nicolai J. P. A. (1979). The prevention of wound infections in burn patients. *Scand. J. Plast. Reconstr. Hand Surg.,* **13**, 63–67

49

Histological assessment of the level of burn wound infection: diagnostic and therapeutic strategies

A. DI LONARDO, M. FERRANTE, G. MAGGIO, V. BUCARIA, M. DEL ZOTTI and E. BRIENZA
Istituto di Chirurgia Plastica Ricostruttiva ed Estetica, Università degli Studi, Bari, Italy

The frequency and severity of septic complications in the seriously burned patient impose the need for an accurate diagnostic and therapeutic approach. The microbiological monitoring of surface swabs and biopsies from burn wounds provides precise information as to the type of infection present and the bacterial charge, but it gives no indication as to the depth of the infection. Microbiological investigation should therefore be complemented by histological examination in order to detect the possible presence of micro-organisms in the tissues beneath the eschar.

This study combines the results obtained by microbiological monitoring and by histological analysis, and establishes the infection rate in burn-damaged areas on a scale of values of increasing severity. Our experience has shown this method to be a very reliable criterion of assessment for the choice of therapeutic strategies, particularly as regards the timing and the site of surgical intervention.

PATIENTS AND METHODS

The study included all burn patients admitted to the Bari Burns Centre Intensive Care Unit between January 1990 and December 1991 within 24 h of the burn and belonging to classes III, IV and V of the Roi index.

Biopsies were taken from each patient, both from the burned areas and from apparently healthy areas in the vicinity of the burn, on the basis of a predetermined map. Two samples were taken from each biopsied area. One of these was fixed in 10% formalin and subjected to histological examination; the other was kept dry in a sterile container and examined microbiologically.

Biopsies were taken on the first, fourth, eighth and twelfth day. Further biopsies were taken only from patients requiring more than one reconstructive surgical operation. The time interval was maintained at every fourth day.

The number of biopsies performed in each patient was related to the extent of the burn area in order to obtain statistically significant evaluations (one biopsy every 10 cm^2) (Brienza *et al.*, 1989).

All biopsies were by disposable sterile biopsy punch (diameter 4 mm).

Histological technique

The biopsies fixed in 10% formalin were sent to the Bari University Pathological Histology Laboratory. After embedding in paraffin, serial sections were prepared perpendicular to the skin surface, with a thickness of 5 μm (Kim *et al.*, 1983; Jim *et al.*, 1985).

Twenty slides were prepared for each histological sample using haematoxylin-eosin, Gomorj Grocott, gram-modified and methylene blue, stains. The histological specimens were examined by optical microscope (magnification 400 and 1000 times).

The depth reached by the bacterial invasion was graded according to the following scale (Brienza *et al.*, 1989):

Grade 0: no micro-organisms; Grade 1: some micro-organisms (1a: low bacterial number, 1b: high bacterial number); Grade 2: invasion of surface dermis; Grade 3: invasion of all dermis; Grade 4: invasion of hypodermis and/or underlying tissues.

Microbiological technique

The biopsies were weighed, homogenized, diluted as necessary in physiological solution and inoculated in doses of 1 ml into sterile Petri dishes to which about 15 ml of ordinary broth were added for the bacterial count and 15 ml of Sabouraud's agar for the cultivation of fungi.

After 48–72 h of incubation at 37°C a count was made of any colonies that had developed. At the same time, the 1/100 dilution in physiological solution was used for seeding the following cultivation media: Sabouraud's agar; Murtz's lactose agar; mannitol salt agar (MSA); *Cryptococcus* specific medium and blood agar.

A portion of the solution (about 0.1/0.2 ml) was seeded in ordinary broth and in Sabouraud's agar from which subcultures were prepared after 24 h on Murtz medium and on MSA from ordinary broth and on Sabouraud's agar from Sabouraud's broth.

CASE HISTORIES AND RESULTS

Using the above methods we studied 40 patients admitted to the Bari Burns Centre Intensive Care Unit between January 1990 and December

1991. The patients belonged to classes 3, 4 or 5 on the Roi prognostic index and were aged between 26 and 45 years. The burns ranged between 30% and 70% BSA.

The results were obtained using the double-blind technique and relate to a total of 352 biopsies (176 histological and 176 microbiological).

Histological results

Both the level of infection in the tissues and the search for possible fungal contamination were considered. Haematoxylin-eosin staining enabled us to distinguish the various tissue planes and to detect the presence of fungi, and also to hypothesize the possibility of bacterial infection. Gram-modified and methylene blue staining made it possible to detect the presence of bacteria in the tissues and to assess the depth reached.

Table 1 shows the histological results related to the grading of infection observed in the 176 biopsies examined.

Table 1. Histological and microbiological results

Histology			*Microbiology*		
Biopsies	*Grading*	*Fungi*	*bacteria*	*10 bacteria*	*10 fungi*
72	0	/	72	/	/
33	1a	/	33	/	/
22	1b	3	18	4	/
24	2	5	15	9	3
14	3	5	6	8	2
11	4	3	5	6	/

Microbiological results

The microbiological assessment of the various biopsies supplied a number of parameters. Here we give only those relative to the tissue bacterial charge (expressed as the number of bacteria per gram of tissue) and to the presence of fungal colonies. The results of the 176 biopsies are given in Table 1.

DISCUSSION

Two main considerations can be made on the basis of these results.

First, there is a clear discrepancy between the septic risk expressed by microbiological assessment and the actual extent of the tissue sepsis as demonstrated histologically (Pruitt *et al.*, 1973; Neal *et al.*, 1981). Table 1 shows that the histological finding in 11 biopsies of deep tissue invasion (4th grade) – a clear indication of considerable systemic septic risk

(Brienza *et al.*, 1989) – corresponded to a microbiological finding in only six biopsies with a bacterial count of > 10 bacteria/g tissue. Also, the 22 grade 1b biopsies (massive surface contamination) corresponded to the proportionately high number of four findings of a bacterial count > 10, which would suggest generalized sepsis.

Second, the histological study enabled us in some cases to detect significant fungal contamination in the lesions not revealed by the corresponding microbiological analysis.

The reasons for this discrepancy are still being studied. It would appear likely that a phenomenon of bacteria/fungi competition may inhibit the development of mycotic colonies *in vitro*.

On the basis of these findings the following clinical and prognostic considerations can be made:

1. From the point of view of reconstructive surgery, the concept of early escharectomy in the severely burned patient (which in our experience means operations performed before day 10) must be associated with that of emergency necrectomy when, in the presence of documented massive bacterial invasion of the viable tissues underlying the eschar, it is necessary to operate very early (day 4 or 5) in the areas most exposed to risk.
2. The level to which escharectomy should extend depends on the histological assessment of the depth of the infection. In areas where bacterial colonization of the subcutaneous tissue is demonstrated (grade 4) necrectomy must be performed as far as the muscle fascia independently of the apparent viability of the tissues as observed intraoperatively.
3. Targeted systemic antibiotic therapy may therefore be initiated immediately in order to sterilize the viable, well vascularized deep sublesional tissues which have been reached by the bacterial colonization.
4. The histological monitoring of the extent of the infection in the tissues confirms the effectiveness of the topical antiseptic therapy practised or suggests alternative techniques (Brienza *et al.*, 1989). Progressive extension of the infection in the tissues, associated with a simultaneous increase in the bacterial charge, is a clear indication for more energetic topical therapy (more frequent daily medications, use of alternative topical antiseptics preselected on the basis of their microbiological effectiveness) (Brienza *et al.*, 1989).
5. The histological visualization of fungal contamination, even if not confirmed by the corresponding microbiological finding, makes it necessary in therapy to associate specific systemic antifungals selected on the basis of the antimycogram.
6. The numerical value of 10 bacteria/g tissue loses its significance as a point of reference for the maximum limit for systemic sepsis if it is not associated with the histological demonstration of the level of bacterial and/or fungal invasion in the peri- and sublesional viable tissues.

In the light of the above considerations our therapeutic approach in the patients was conditioned by the specific histopathological and microbiological indications.

CONCLUSIONS

The histological investigation conducted on burn lesion biopsies represents in our experience a further step towards a better understanding and definition of the intricate problem of infection in seriously burned patients.

The method described here, followed according to standardized protocols described in the literature (Brienza *et al.*, 1989), allowed a more rational analysis of the parameters supplied by microbiological tests and thus enabled us to grade the tissue infection more accurately.

This method made it possible to adopt a personalized therapeutic approach on the basis of precise laboratory indications, and not merely a standard therapy.

The results obtained in these first years of application have been sufficient to allow us to make some surprising and interesting considerations that amply confirm the importance of the study.

BIBLIOGRAPHY

Baxter, C. *et al.* (1973). The control of burn wound sepsis by the use of quantitative bacteriological studies and subeschar clysis with antibiotics. *Surg. Clin. North Am.*, **53**, 1509–1518

Brienza, E. *et al.* (1989). Protocol for the treatment of burn patients admitted to the Bari Burns Centre. *Ann. Medit. Burns Club*, **2**, 22–25

Dioguardi, D. *et al.* (1989). La valutazione della istotossicità dei topici antisettici nel trattamento dei pazienti ustionati. Note preliminari. *Atti XXXVIII Cong. Naz. Chir. Pl.* 777

Jim, S. H. *et al.* (1985). A rapid section technique for burn wound biopsy. *J. Burn Care Rehab.*, **6**, 433–435

Kim, S. H. *et al.* (1953). Use of frozen section technique for burn wound biopsies: comparison with standard section technique. ABA 15th Annual Meeting, 1983.

Lobel, *et al.* (1981). The method of quantitative burn-wound biopsy cultures and its routine use in the care of the burned patient. *Am. J. Clin. Pathol.*, **75**, 532–537

Mitchel, V., Galizia, J. P., Fournier, L. (1989). Precise diagnosis of infection in burn wound biopsy specimens. Combination of histologic technique, acridine orange staining and culture. *J. Burn Care Rehab.*, **10**

Neal, G. D. *et al.* (1981). Burn wound histologic culture: a new technique for predicting burn wound sepsis. *J. Burn Care Rehab.*, **2**, 35–39

Pruitt, B. A. *et al.* (1973). The use of biopsies in burn patient care. *Surgery*, **73**, 887–897.

Pruitt, B. A. *et al.* (1984). The diagnosis and treatment of infection in the burn patient. *Burns*, **11**, 79–81

Woolfrey, B. F. *et al.* (1981). An evaluation of burn wound quantitative microbiology. Quantitative eschar cultures. *Am. J. Clin. Pathol.*, **75**, 532–537

50
Modern approach to treatment of contaminated burn wounds by local ozone therapy

T. M. GASSANOV
Association Medair-T, Moscow, Russia

Early elimination of local pathogenic microflora is very important for local treatment of contaminated burn wounds. Bacteriological investigations have shown that multiple strains of bacteria colonize burn wounds, which makes it very difficult to choose an adequate local agent. Experience with the application of different agents has shown that the main reason for unsatisfactory results in the treatment of burned patients is the influence of pathogenic microflora on the course of the wound process, as well as the development of complications due to absorption of products of necrosis.

Modern antibacterial agents may sometimes damage or irritate tissues, delay epidermal growth, and promote burn wound extension. The negative aspects of their action therefore prevail over the positive effects, following their application (Rudowski *et al.*, 1976).

These considerations prompted a search for more specific agents of local application, with a broad bactericidal action.

Since 1985 we have used the bactericidal effect of ozone in combination with the treatment of patients with contaminated burns of different extent in a non-bacterial medium of aerotherapeutic devices of ATU-3 and ATU-5 types for suppression of local pathogenic wound microflora and stimulation of regenerating processes in it.

To conduct medical ozone therapy it was necessary to determine, first the clinically important ozone concentration and second its therapeutically effective exposure. Having established these parameters we followed the main principle – to determine the lowest ozone concentration capable in a short time of suppressing any local pathogenic microflora. We also bore in mind that according to the literature low ozone concentrations promote wound repair (Rilling and Viebahn, 1985).

For the determination of a therapeutically effective ozone concentration and exposure, preliminary laboratory studies were performed. Petri dishes seeded with clinically important microbic strains of *S. aureus, P. aeruginosa, E. coli, A. calcoaceticus, Candida albicans, A. niger* at a concentration of 10^8–10^9 g.f.u. per dish were placed in ozone-resistant plastic isolators where with the aid of the 'Ozonosan PM83K' apparatus different increasing ozone concentrations were forced in for 2, 4, 6, 8 or 10 min. After ozonization, 24-h incubation was performed in a thermostat with further counting of colonies and mean values.

On the basis of the laboratory data, the most effective concentration for ozone therapy was 24 μg/ml, and the best duration was 10 min. The same parameters were used in clinics.

The developed method of treatment – local ozone therapy combined with treatment in a non-bacterial medium of ATU-3 and ATU-5 – was applied in 58 patients with a burned surface area of 1–20%. There were 18 patients with superficial contaminated burns and 40 patients (main group) with deep burns. Besides the main group of patients, 39 patients with similar surface and depth of burn injury were chosen for the control group.

After the primary management of the burn wound, without application of local medicinal agents, local ozone therapy (concentration 0–24 μg/ml) was performed for 10 min. An injured extremity was then placed into an abacterial isolator. The aeration regimen was switched on and the treatment was performed in an abacterial medium with stage changes of its parameters – pressure, temperature, humidity in accordance with the method already elaborated. Changes of abacterial medium parameters depended on burn depth.

The aim of the first ozone therapy exposure was not only to decrease the level of contamination but also to 'sterilize' undamaged skin around the burn area that prevented recontamination of the burn surface. The most important aspect was that there was no need for 'classic' skin management with iodo-spirit solution (or any antiseptic solution used in surgery for these purposes), or for management of the wound itself.

On the basis of our clinical observations, on average two exposures of ozone therapy were sufficient to achieve marked bactericidal effects in patients with superficial and deep contaminated burns.

Adequate selection of concentration and O_3 exposure made it possible to achieve very rapid spontaneous epithelialization in patients with superficial burns. There were no cases of the burn wound deepening. Wounds in patients with deep burns became ready for autoplasty in a shorter time.

The effectiveness of treatment was evaluated by the clinical state of the patients, and bacteriological, morphological and cytological studies. For examination of microcirculatory changes around the wound, transcutaneous determination of partial pO_2 and pCO_2 pressure was used.

Studies of the number of microbes in 1 cm^2 and 1 g of tissue in patients with superficial and deep burns were performed before ozone exposure and repeated immediately after ozone therapy. The results of the bacteriological studies in patients with superficial burns are shown

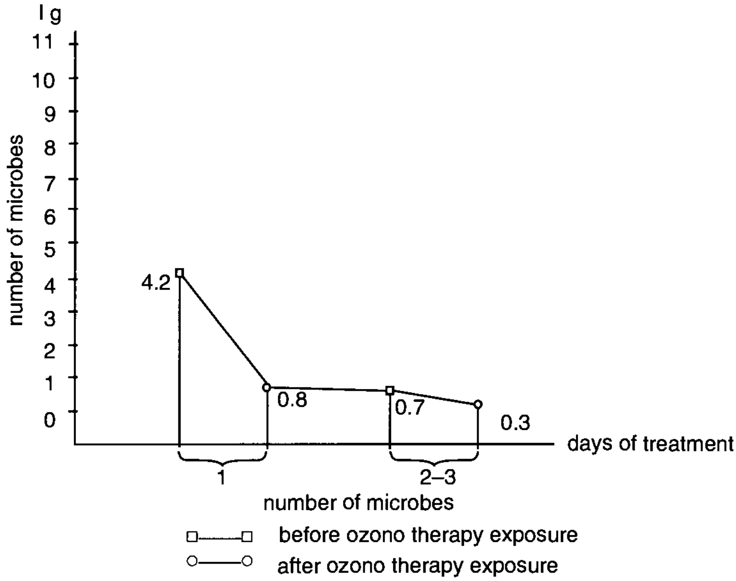


Figure 1.

graphically in Figure 1. Even after the first ozone exposure, at a concentration of 24 μg/ml O_3, a sharp decrease in the number of microbes from 4.2 ± 0.09 to 0.8 ± 0.05. (i.e. a decrease of 5 fold) was observed; after the second ozone exposure a further decrease of up to 0.3 ± 0.03 (initial data 0.7 ± 0.03) was seen.

In the control group of patients with superficial contaminated burns a decrease in the number of microbes of up to 1.2 ± 0.6 in 1 cm^2 was observed after 2–3 days of therapy (initial data 2.9 ± 0.9; Figure 2).

Patients with superficial contaminated burns treated in an abacterial medium in combination with local exposure to ozone therapy (the main group) therefore showed a sharp decrease in the number of microbes in 1 cm (up to 0.8 ± 0.05) even the first day after ozone therapy exposure. Similar results in the control group of patients were achieved after 2–3 days of treatment (1.2 ± 0.6), in spite of the fact that the initial data in the main group were higher (4.2 ± 0.9).

Examination of the dynamics of the contamination level in patients with deep contaminated burns treated with local exposures of ozone therapy in combination with treatment in an abacterial medium (the main group) showed that superficial-vegetal microflora of burn wounds (number of microbes in 1 cm^2) tended to decrease sharply even after the first ozone therapy exposure, i.e. in 10 min, from 3.4 ± 0.6 to 1.6 ± 0.5 (on scale of decimal logarithm), in deeper lying tissues – from 4.8 ± 1.1 to 0 (Figure 3).

Further examinations showed that the number of microbes both in 1 g of tissue and in 1 cm^2 was lower 10 min after the second ozone therapy exposure performed 2 or 3 days after initiation of treatment (Figure 3).

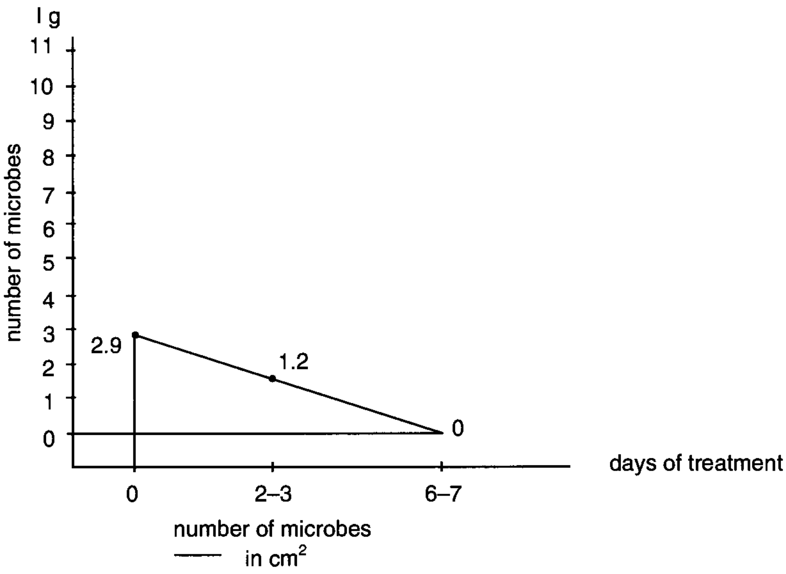


Figure 2.

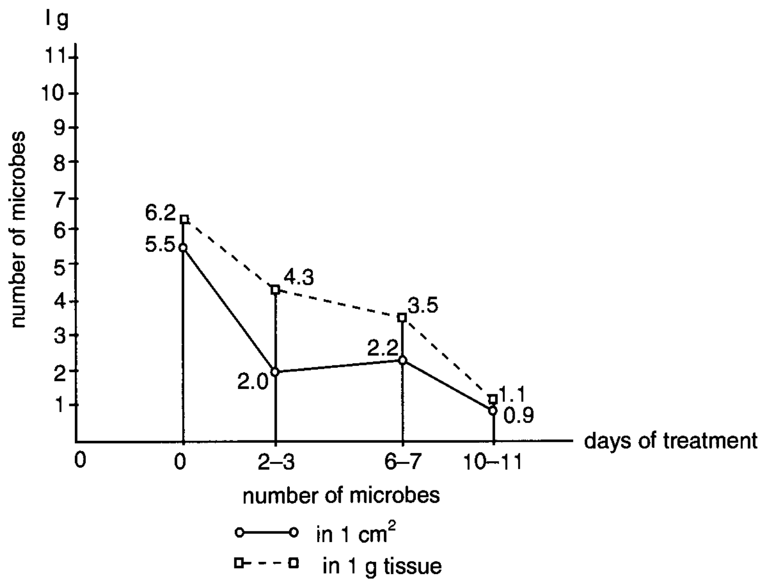


Figure 3.

A decrease in the level of contamination of burn wounds of up to 10 or < 10 in examination of the number of microbes in 1 cm² or 1 g of tissue in patients of the control group with deep contaminated burns

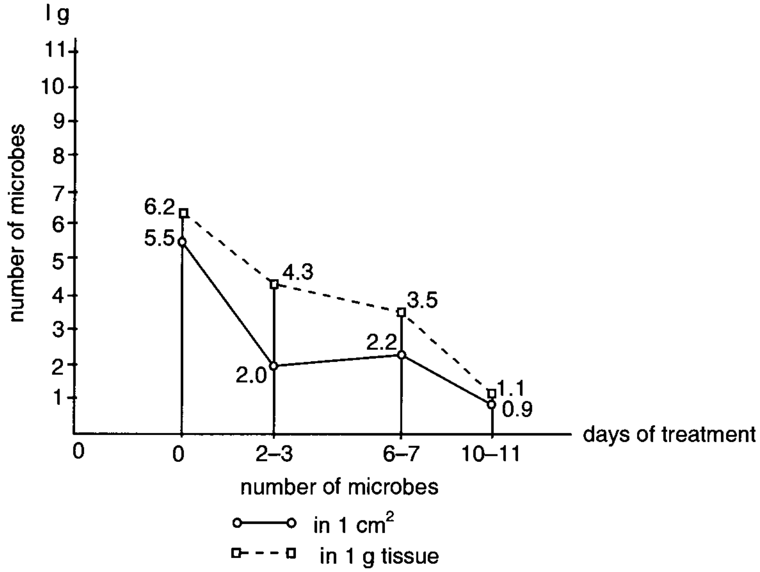


Figure 4.

was achieved in only 10–11 days after initiation of treatment in an abacterial medium (Figure 4).

Comparing the results of the examination of the number of microbes in 1 cm^2 or 1 g of tissue in patients with contaminated burn wounds, we can note that in the combination of treatment in an abacterial medium with ozone therapy exposure the data of the contamination level of burn wounds received after two exposures (or in 2–3 days) corresponded to the results of the control group of patients 10–11 days after the beginning of treatment.

Regardless of the type of local pathogen microflora, in the course of one or two exposure to ozone in combination with treatment in an abacterial medium of aerotherapeutic devices of ATU-3 and ATU-5 types we achieved a sharp decrease in the number of microbes in the wound, thus maintaining favourable conditions for epithelialization of superficial burns and more rapidly preparing the patients with deep contaminated burn wounds for autodermoplasty.

The reason for conducting a transcutaneous study of partial O_2 and CO_2 pressure was to reveal whether there were changes in the microcirculation near the burn area in the course of ozone exposures, depending on the concentration parameters of exposure to O_3, (Ozone influences as a strong oxidizer, increasing or decreasing the partial pressure of O_2 in soft tissues.)

For this study a combined transducer (Combi pO_2/pCO_2) was fixed on intact skin at a distance 3–5 cm proximal from the wound edges. In all subsequent studies the transducer was fixed strictly in the same place. Apparatus calibration was performed first, and then initial data were taken. Every minute during the course of 10 min ozone therapy exposure, pO_2 and pCO_2 were fixed. In the following 10 min the examination was continued, with the injured extremity being placed in an abacterial isolator. The pO_2 and pCO_2 measurements were repeated as mentioned above, depending on the repeated exposures of local ozone therapy.

In the course of the studies there were 484 changes of pO_2 and pCO_2 in dynamics. Assessment of their mean values showed that there were no essential changes of partial O_2 pressure after 10 min exposure to ozone therapy with monitoring each minute of values for 10 min more. Thus initial pO_2 was 73.0 ± 5.0 mm MC but at the end of an exposure 74.0 ± 4.6 mm MC.

There were no marked changes in partial pCO pressure. Initially there were values of 36.5 ± 1.0 mm MC after the first exposure to local ozone therapy. After 10 min pCO_2 was 37.8 ± 1.0, and the mean values during an ozone therapy exposure were 37.4 ± 1.1 mm MC.

In the course of treatment in an abacterial medium (examinations were performed during the next 10 min with monitoring of values every minute) partial pCO_2 pressure was 36.4 ± 1.6 at the beginning of treatment. No further marked changes were observed. Mean values were 37.0 ± 0.9 mm MC.

Changes of partial O_2 and CO_2 pressure during the second ozone therapy exposure and treatment in an abacterial medium showed that there were no marked changes in mean values of pO_2 and pCO_2: pO_2, 63.9 ± 6.2 and 64.1 ± 4.8 mm MC; initial values were 59.2 ± 8.4 mm MC; pCO_2, 38.6 ± 0.7 and 38.5 ± 0.8 mm MC; initial values were 38.2 ± 0.5 mm MC.

Our examinations thus showed that exposures to local ozone therapy in definite values of ozone concentration (24 μg/ml and 10 min exposure) did not significantly influence partial O_2 and CO_2 pressure in transcutaneous examination and proved the correctness of the selection of the optimal ozone parameters.

On the basis of these clinical and laboratory studies it may be concluded that the method developed for local ozone therapy combined with treatment of contaminated burns of different depth* in an abacterial medium with scientifically based parameters (O_3 24 μg/ml; 10 min exposure) makes it possible:

- to achieve elimination of any local pathogen microflora even when multiple strains are present, also after the second ozone therapy exposure and thus rapidly to achieve epithelialization in patients with superficial burns;
- to prepare deep burn wounds for more rapid autodermoplasty (1.4 to 1);
- to decrease the number of autodermoplasties (1.3 to 1) compared with the control group of patients;

*The degrees of burn depth used in the CIS countries (previously USSR) are not mentioned in this work as they differ from the European degrees and might confuse readers.

- to decrease the hospitalization of patients from 40.8 days ± 10.8 to 26.3 ± 5.7.

On the basis of this method, a new aerotherapeutic device with an ozonator and software development ('AEROOZON-7') was developed in cooperation with the Dr. H. Hensler GmbH company. There is no other similar device in medical practice. At present it is undergoing clinical tests.

BIBLIOGRAPHY

Rilling, S., Viebahn, R. (1985). *Praxis der Ozone–Sauerstoff–Therapie*. Heidelberg: Verlag fur Medizin Dr. Ewald Fischer GmbH

Rudowski, W., Nasilowski, W., Zietkiewicz, W., Zienkiewicz, K. (1976). *Burn Therapy and Research*. Baltimore: The Johns Hopkins University Press

51

Evaluation of conservative ambulatory burn treatment with nitrofurazone-embedded fine mesh gauze in 100 consecutive patients

N. UÇAR and M. HABERAL
Turkish Transplantation and Burn Foundation Hospital, Ankara, Turkey

INTRODUCTION

The majority of burns are treated on an out-patient basis. To date, various methods and topical agents have been recommended for the treatment of burned out-patients; and the introduction of synthetic materials has led to significant progress in the local treatment of these patients. Despite the greater cost compared with materials used previously, there has been in recent years, a considerable trend towards greater use of the new materials in our out-patient department. This prospective clinical study concerning a relatively large series of out-patients was therefore performed in order to evaluate the success of a simple but effective local treatment method used widely in our out-patient department prior to the introduction of synthetic materials.

PATIENTS AND METHODS

The effectiveness of the methods used in the out-patient burn department at the Turkish Organ Transplantation and Burns Foundation Hospital was evaluated by a prospective study in 100 consecutive out-patients treated between 1 February 1992 and 4 July 1992. Out-patient burns are treated in our burn unit as conservatively as possible, following premedication, whenever needed. The wound is cleansed with povidone iodine scrub solution and isotonic NaCl solution as gently as possible, without excision of blisters and crusts that are not infected. Roofs of perforated blisters are not removed and are used as a biological wound dressing material. A sheet of nitrofurazone-embedded fine mesh gauze is placed on the wound and a bulky dressing is applied, except to burns of the face and neck. In most circumstances, no topical ointment is used for burns of the face and neck. Dressings are changed three or four times a week. No attempt is made to remove the adhered portion of fine mesh gauze. Epithelial regeneration is usually complete either under this gauze or under the blister cover. Patients are routinely followed up for at least a month.

RESULTS

Of the 100 out-patients, 54 were children aged up to 15 years and 46 were over 16 years old. Thirty-one had burns of the upper extremity and 35 of the lower extremity, six in the head and neck region and one in the trunk. In 27 cases thermal injury affected multiple sites of the body (Figure 1). Fifty-seven out-patients sustained second-degree burns. Thirty-two had first-degree or superficial second-degree burns and 11 had deep second-degree or third-degree burns (Figure 2). Early and late complications are summarized in Table 1. Fifteen patients had infected burns which had been treated elsewhere, usually with topical application of silver sulphadiazine. Except for one case, the infection was easily controlled. Nine patients developed wound infection during our treatment and this was managed by topical therapy. One patient presented

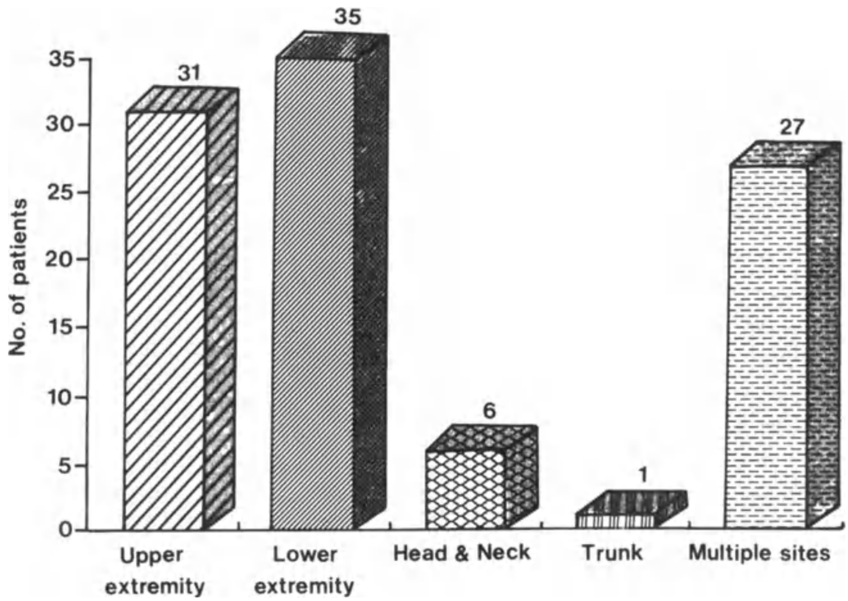


Figure 1. Distribution of the patients according to burn site

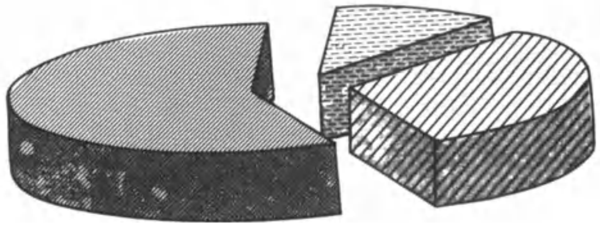


Figure 2. Distribution of patients according to burn degree

Table 1. Complications

Complication	*No. of patients*
Infection	
present already on admission	12
occurred during treatment	9
Skin colour disturbances and / or hypertrophic scars	1
Nitrofurazone allergy	2
Contractures (treated conservatively)	2

with contact dermatitis, probably due to nitrofurazone. Only two patients with third-degree burns needed a skin graft. None of the patients with infected deep second-degree burns underwent skin grafting or any other plastic surgery procedure. Two patients had to wear splints in order to prevent axillary contracture, but only minimal functional disturbances were noted after second-degree deep burns had been treated using the method described above. Twelve patients suffered from skin colour disturbances and / or hypertrophic scars, which were usually seen following wound infection. Hypertrophic scars could usually be controlled by compression using either bandages or silastic sheets. In one patient with a hand burn, resurfacing of the dorsum of the hand was planned. This patient had not followed his treatment schedule regularly.

DISCUSSION

Treatment modalities in out-patient burn management have been debated for many years and various treatment methods have been recommended. Exposure treatment has widely been accepted as a cheap and long-established method (Sorenson and Thomsen, 1971). However, some disadvantages of exposure treatment, such as aggravation of the dermal injury following desiccation of the wound, have been noted and closed treatment has been the method of choice. Since the coverage of burns has an immediate and sustained pain-relieving effect, we have never used the tedious method of rinsing the wound with copious amounts of water for hours. By covering the burn, the wound can be kept moist and infection is avoided (Hinman *et al.*, 1963; Zawacki, 1974). We therefore apply a bulky dressing that delivers little oxygen permeability, which may also provide more rapid and safe healing (Horikoshi *et al.*; Alvarez *et al.*, 1983; Varghese *et al.*). Although some authors favour the excision of blister, and this is to be found even in textbooks (Curreri and Arnold, 1984), blisters and fluid in the blisters provide an almost ideal environment for wound healing (Zawacki, 1974). The excision of blisters and blister covers was therefore not carried out in the present study. No infection in the blisters was observed in patients treated in this manner.

In recent years different synthetic and biological wound dressing materials have been recommended. Most of these have also been used in our centre. Biological dressings such as allografts used to be the most favourable method until transmission of the AIDS virus came to be considered a possible risk (Leicht *et al.*, 1988). We achieved excellent results with silver nitrate-impregnated amnion membrane, introduced by the senior author of this chapter, which eliminated the risk of transmission of AIDS (Haberal *et al.*, 1987). Synthetic dressing materials were also used successfully in our department. The cost-effectiveness of these materials is however a subject of debate. Therefore, Furacin-embedded fine mesh gauze was preferred in this study, since it is cheap and easy to apply without pain, and prevents infection in out-patients. The present data supported the effectiveness of this conservative method, with lower complication rates when compared with the studies of other authors (Davies, 1984; Golan *et al.*, 1985; Hermans, 1987; Queen *et al.*, 1987; Cristofoli *et al.*, 1986).

In our opinion, if the following conditions can be maintained, no significant difference in success in out-patient treatment will be noted, even when using a simple dressing material:

1. Maintenance of a sterile environment by cleansing with a solution effective against bacterial, fungal and viral agents and maintenance of blister intactness.
2. Application of a topical agent or dressing that does not interfere with epithelial regeneration and wound healing.
3. If possible, any kind of occlusive dressing for the prevention of further contamination and capillary thrombosis, desiccation, superficial necrosis and a subsequent increase in burn depth.
4. Meticulous debridement and dressing changes without causing the loss of newly regenerated epithelium.

CONCLUSION

The conservative method for out-patient burn treatment with application of nitrofurazone-embedded fine mesh gauze is still one of the most reliable methods, since it is inexpensive and easy to apply without pain, does not conceal or aggravate wound infection, and allows the permeation of secretions and microorganisms as well as topical agents. The use of fine mesh gauze should not be considered old-fashioned even after the development of some synthetic materials for the topical treatment of burn wounds.

REFERENCES

Alvarez, O. M., Mertz, P. M., Eaglestein, W. H. (1983). The effect of occlusive dressing on collagen synthesis and re-epithelialization in superficial wounds. *J. Surg. Res.*, **35**; 142

Cristofoli, C., Lorenzini, M., Furlan, S. (1986). The use of Omiderm, a new skin substitute, in a burn unit. *Burns*, **12**; 587

Curreri, P. W., Arnold, L. (1984). Burns. In: Schwartz, S. I., Shires, G. T., Spencer, F. C., Storer, E. H., (eds). *Principles of Surgery*. Baltimore: William & Wilkins, p. 75

Davies, J. W. L. (1984). Synthetic materials for covering burn wound. Progress toward perfection. Part I. Short term materials. *Burns*, **10**; 94

Golan, J., Eldad, A., Rudensky, B., *et al.* (1985). A new temporary synthetic skin subtitute. *Burns*, **11**; 274

Haberal, M., Oner, Z., Bayraktar, U., Bilgin, N. (1987). The use of silver nitrate-incorporated amniotic membrane as a temporary dressing. *Burns*, **13**; 159

Hermans, M. H. E. (1987). Hydrocolloid dressing (Duoderm) for the treatment of superficial and deep partial thickness burns. *Scand. J. Plast. Reconstr. Surg.*, **21**; 283

Hinman, C. D., Mailbach, H., Winter, G. D. (1963). Effect of air exposure and occlusion on experimental human skin wounds. *Nature*, **200**; 377

Horikoshi, T., Balin, A. K., Carter, M. D. Effect of oxygen on the growth of human epidermal keratinocytes. *J. Invest. Dermatol.*, **86**; 424

Leicht, P., Muchardt, O., Jensen, M. G. *et al.* (1988). Allograft versus exposure in the treatment of scalds – a prospective randomized controlled clinical study. *Burns*, **15**; 1

Queen, D., Evans J. H., Gaylor, J. D. S. *et al.* (1987). Burn wound dressing – a review. *Burns*, **13**; 218

Sorensen, B., Thomsen, M. (1971). Exposure treatment method. In Matter, P., Barclay, T. L. and Koniekova, R. (eds.). *Research in Burns*, Berlin: Hans Huber, 154–158

Varghese, C. M., Balin, A. K., Carter, M. Local environment of chronic wounds under synthetic dressings. *Arch. Dermatol.*, **122**; 52–56

Zawacki, B. E. (1974). Reversal of capillary stasis and prevention of necrosis in burns. *Ann. Surg.*, **180**; 98

Section IX

Burn surgery

52
Dilemmas in burn surgery

FRANJO ZDRAVIČ
University Department of Plastic Surgery and Burns, Medical Center, Ljubljana, Slovenia

After a lifetime in medicine and surgery I have seen many dramatic changes and had the good fortune to be able to take an active part in the development of burn therapy. I would like to consider some dilemmas concerning early delayed excision of burns followed by immediate grafting, make some remarks on the diagnosis of the burn wound and present some problems concerning the use of homografts.

One of the most fascinating approaches to burns was the idea of excising necrosis soon after the accident and covering the defect with skin grafts. This technique was practised in the early 1960s by a few surgeons and limited at the beginning to the excision of full-thickness burns. We gained more experience with this technique in the years to follow and advocated the application of this technique particularly for functional areas of the body (Derganc and Zdravič, 1963). The first results were encouraging. Most of the work in this field was performed by Dr Janžeković, who presented convincing evidence of the advantages of this active approach at a symposium in Maribor in 1968.

What is the situation today, almost three decades later? Is early excision of the burned layers of skin still the best procedure? Should it be performed in all instances, or should we become more conservative again?

The idea of the early excision of all devitalized tissue is scientifically sound. It is not a new concept, but is one of the basic rules of surgery. It is only on sound, healthy, well-irrigated tissue that skin transplants have a chance of survival. However, the procedure itself is very demanding and time-consuming because of the very narrow dividing line between the dead and the living skin layers. Hence the danger of excising too little or too much. Taking into consideration the complex structure of the skin, with its many functions, one can easily understand that more harm than good can be done to a patient who presents for instance a deep dermal burn in both hands, if the surgeon is not experienced. From this point of view, I can well understand the reluctance of many surgeons to operate on badly burned hands. They say that one year after treatment, whether surgical or conservative, the results are the same. This is not true, as we know from experience. It is true, however, that badly performed excisions or the wrong indication for operation are the main causes of failure.

It is most important to know how to differentiate between the dead and the living layers of the skin. Bleeding is of course the best indicator. Capillary bleeding – deep dermis contains larger capillaries than superficial dermis – proves the vitality of the tissue and such a wound will no doubt accept a skin graft. However, there are instances where the excision of burned extremities must be performed under tourniquet in order to save blood and the appearance of the deep dermis, which must be pearl-white in colour, is the only indicator of vitality, apart from the absence of thrombosed capillaries. Some of our errors are tolerated and nature can overcome them. Bleeding itself does not mean 100% vitality of the tissue, but even if the damaged dermis is only half alive it will still take a graft. We can measure the vitality of the tissue by the oxygen absorption method.

Mistakes in diagnosis of the burn are followed by mistakes in treatment. We know all the signs and tests which help us to diagnose the depth of a burn. Even so, it is sometimes useful to look at a burn through a microscope or even to take a biopsy. It is also important to remember that the structure and thickness of the skin are different in different parts of the body. Healing ability also varies. What we need is a more microanalytical approach to the burned body. The other important dilemma is whether to perform early excision or not in a very extensive burn, i.e. > 50% of the body surface.

In the very severely and critically burned patient a special strategy of treatment has therefore to be established from the very beginning, taking into consideration all factors influencing the patient's condition and taking the expert advice of specialists from various fields.

After many thousands of operated patients, early delayed excision is here to stay. It is a valid method in expert hands. It is a hard method too and should be based on a good diagnosis of the depth of the burn. Caution is necessary when operating on patients with very extensive burns. Better tools for burn excision are necessary to facilitate the procedure.

The second dilemma concerns the use of homografts. We have used them since 1951 and I am sure they have helped us to save many lives. However, the appearance of AIDS has made us limit their use because of the risk involved. However, there might be a way around this problem. In many instances we have used mesh autografts in severely burned children, covering the mesh grafts with homografts from the skin bank. It seems on the basis of the work done that equally good results are achieved if mesh autografts are covered by meshed skin homografts. These should preferably be taken from the parents in order to be sure of preventing transmission of the AIDS virus. Grafts from the parents are genetically the closest possible choice with the exception of identical twins. This assists in rapid closure of the wound with very little disfigurement.

It does not seem to us that it is justified to use any immunosuppressive drugs, such as cyclosporin or the new drug FK 506, which is ready for testing and is 100 times more powerful.

REFERENCE

Derganc, M., Zdravič, F. (1963). Advantages of early and active treatment of the deep dermal burn. *Excerpta Medica Intern. Congress*, 66, 142–145

53
The evolution of surgical procedures in the acute phase of burns

S. BAUX
Hôpital Rothschild, Paris, France

Although burns have long engaged the attention of physicians, local treatment was for many centuries only medical.

The description of burn lesions was the object of numerous publications, and that of Dupuytren is still used. However, the only treatment remained the application of a wide range of substances, some of which are merely amusing while others are more pertinent, e.g. exposure to air (Valesco, 1490) or cold water (Avicenne, 1506).

Surgical intervention is now considered essential in the very first hours post-burn. We will not concern ourselves here with associated operations such as tracheotomy, colostomy or cystostomy, which are aids to resuscitation or local treatment. The first surgical procedure often consists of escharectomy. The first historical description of this technique goes back to 1607, when Fabricius Hildanus recommended incising deep wounds to allow the 'humours' to flow out. Today this is a routine procedure. The technique is simple: the extent and depth of the incision are controlled by pain and bleeding, two unmistakable signs which indicate the limits of the incision.

The aim of creating an incision is to reduce the tourniquet effect exerted on the underlying oedema by the non-elastic eschar. Circumferential burns of the limbs are typically treated in this way, as are burns on the back of the hands (the only site of oedematous expansion at this level), anterolateral burns of the neck to free cephalic vascularization, and anterolateral burns of the thorax to permit respiratory expansion. The technique is clearly important, although there may be some complications, including bleeding (often due to technical error), and infection. Precautions against such problems can be taken, such as spongel-type anti-haemorrhage resorbable compresses and topical antiseptics.

In patients seen late, however, escharectomy has to be postponed until correct diuresis has been established; it may even be advisable to accompany escharectomy with osmotic diuresis to prevent the risks of massive myoglobinuria (after cessation of the tourniquet effect). In electric burns escharectomy is not enough. Extensive aponeurotomies are required: these are also recommended in the lodge syndrome.

The real breakthrough in the surgical treatment of burns came with early excision. Pollock in 1871 performed the first grafts following the publication of Reverdin's work in 1868. Despite the activity of pioneers such as Lugarten (1871), Wilms (1901) and Weinenfeld and Zumbusch (1905), who performed excisions in the first 3 days post-burn, the surgeon's intervention was generally postponed until after cleansing and preparation of granulation tissue. It was only with Janzekovic in 1968 that the concept of early excision and grafting was revived.

Two fundamental notions are involved:

1. With respect to functional considerations, it is universally agreed that the greater the delay in scarring, the more severe are the functional and aesthetic sequelae.
2. Regarding survival, the presence of burned tissues leads to the release of metabolites such as thromboxane, prostaglandin, oxygen free radicals and toxins, which have a detrimental effect on the patient's general state. The burned tissue also offers fertile ground for the growth of microbes.

However, excision will resolve the problems only if it is followed by coverage of the skin.

Excision techniques vary. They include:

- Avulsion, which is faster and offers better control of bleeding;
- The tangential approach, which is more precise in depth but causes more bleeding, takes more time and is technically more difficult;
- Laser, which reduces bleeding but presents technical difficulties.

The following coverage techniques can be used:

- Autografts, which are the ideal solution, though difficult to use in severely burned patients who have limited donor sites;
- Homografts, which constitute an ideal temporary dressing but involve difficulties of supply as well as risks of contamination. Homografts can be associated with autografts (Mowlem-Jackson technique, Chinese intermingled graft, sandwich techniques);
- Skin substitutes, none of which is as yet perfect.
- Keratinocyte cultures, which require lengthy preparation and therefore impose the need for temporary coverage;
- Flaps, which may be necessary in certain zones.

Even if early excision and grafting seems to be the ideal treatment, at least in deep burns, there still remains the primary problem of the diagnosis of burn depth. Surgery also represents a major act and involves a number of problems, not so much in the slightly burned patient in whom the operation is simple – apart from considerations of coverage and the diagnosis of burn depth – as in the patient with severe burns.

An endeavour was made to reach a consensus of opinion on this subject during a Round Table at the Franco-Italian Congress of Surgeons and Resuscitators in June 1992. It was generally agreed that the optimal time for early excision and grafting is as soon as possible after haemodynamic equilibrium has been established.

The participants were unanimous that the surface to be excised in each session should be 10–15% body surface area (maximum 20%); and that the operation should not last more than 2 h, which presupposes a numerous and experienced team.

Despite its limitations, early excision and grafting remains the approach of the future in burn treatment. Progress still remains to be made in the fields of assessment of burn depth, effective resuscitation, development of epidermis and dermis cultures and to reduce production times, the use of growth factors to accelerate scarring in minor burns and the growth of mesh grafts and the improvement of skin substitutes.

REFERENCES

Avicenne. *Liber canonis avicenna.* Venise Burien; 1507

Baux S., Galizia J. P., Griffe O., Wassermann D. Inter-relations entre l'état clinique et l'acte chirurgical dans les brûlures thermiques aigues. ler Congrès Italo-français de Brûlologie. *Atti Del Congresso.* 1992; 1: 209–14

Costagliola M. Intérêt de la décompression précoce dans le syndrome des loges de la main brûlée. *Chirurgie.* 1990; 117: 363–7

Dupuytren. *Lecons orales de clinique chirurgicale.* Paris: Baillere; 1832; I et II

Fabricius Hildanus. *De Combustionibus.* Bale; 1607

Janzekovic Z. A new concept in the early excision and immediate grafting of burns. *Trauma.* 1970; 10: 1103–8

Lugarten S. Theoric der primarem Todessursache dei Verbrennungen. *Wien Klin Wochenschr.* 1891; 29: 528

Pollock G. D. Cases of skin grafting and skin transplantation. *Trans Clin Soc Lond* 1871; 4: 37

Valesco De Tarenta. *Philonium pharmaceuticum et chirurgicum.* Venise Cleyn; 1490

Weidenfeld S., Weitere Beitrage, Zumbusch L. Zur pathologie und therapie schwerer verbrennungen. *Arch Derm Syph.* 1905; 76: 163

Wilms M. Studien Zur pathologie dei Verbrennungen. *Mitteil Grenz Bed Med Chir.* 1901; 8: 393

54
The aesthetic repair of severe neck burn sequelae

S. JOUCDAR, H. KISMOUNE and T. LAOUAMRI
Hôpital Universitaire de Douera, Douera, Algeria

INTRODUCTION

Neck burns are common occurrences which expose the victim to functional and aesthetic complications that may be very serious. The Douera Hospital Plastic Surgery Department in Algeria treated 123 cases of neck burn sequelae between 1982 and 1987, during which period 40 patients with major cervical sequelae were subjected to one or more procedures of surgical correction. More than half of these had over 3 years' regression.

Like all other surgeons concerned with this type of procedure, we had to overcome the functional and cosmetic problems posed by the cervical region, which is an important aesthetic unit in man (Bagozzi, 1958; Chippaux *et al.*, 1959; Grignon *et al.*, 1976).

Our experience enabled us to lay the foundations for an approach to the aesthetic treatment of major cervical sequelae. After a descriptive and topographic classification of this type of problem we will give an account of the techniques we have used.

PATIENTS

The 40 patients treated consisted of 23 males and 17 females aged 8–65 years. The Douera Burns Department admits exclusively adults, but three children aged under 15 years were treated. There were 25 young adults (16–30 years) and 12 adults aged 31–65 years.

The burns causing the sequelae were all of thermal origin: gas explosion in 70% of the cases, followed in frequency by petrol burns and scalding by water or cooking oil. The time interval between initiation of treatment of the sequelae and the original burn was relatively long: 3 months in six cases, 12 months in 26 cases and 18 months in eight cases.

MORPHOLOGY OF CERVICAL SEQUELAE AND THEIR FUNCTIONAL AND AESTHETIC EFFECTS

The Lilloise classification proposed by Françoise Vandenbussche is mainly a topographical subdivision which divides the neck into nine zones bounded by three meridians and three parallels (Krizek, 1978; Vandenbussche *et al.*, 1978, 1981) (Figure 1). The cervical lesions treated consisted of 32 major global necks with sternomental fusion or global engulfed neck, and eight medium segmentary necks with 'harp-fold' scars or keloid plaques. In addition to the topographical aspect the system also considers burn extent. In 35 patients the lesions exceeded 30% body surface area and extended, especially at the level of the cephalic extremity, to the thorax and the upper limbs (Laouamri, 1987; Lavergne, 1981; Mimoun, 1983).

The patients' intellectual and psychological state has to be taken into account, as their cooperation is a basic condition for a good result; it is necessary to explain to them that they will have to make considerable efforts over a long period of time before they can achieve valid and durable functional and cosmetic results. The main functional effect, particularly for major global injuries, is due to the disappearance of the cervicomental angle. This causes severe difficulties in movement of the cervical spine, phonation and deglutition. Labial ectropion, sustained by

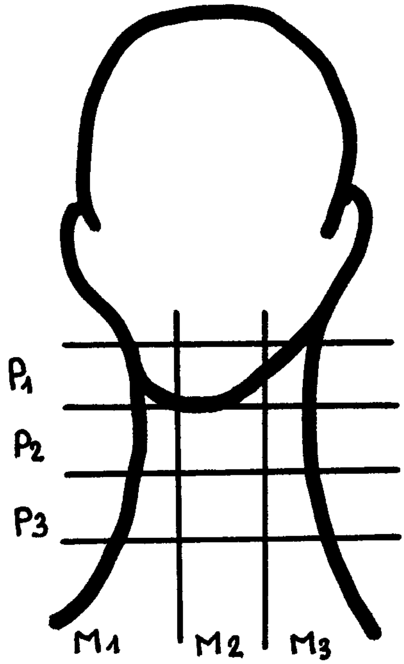


Figure 1. Lillioise classification (F. Vandenbussche)

the cervical retraction, a compensatory kyphotic posture and a strained appearance combine to aggravate the unfortunate aspect of this kind of sequela (Baux, 1980; Bunchman *et al.*, 1975; Chippaux *et al.*, 1959; Pons *et al.*, 1977).

SURGICAL TREATMENT

Timing

Surgical treatment was undertaken 1 year after the initial accident in 26 cases, after 18 months in eight cases, and after 3 months in six cases. These were total engulfed necks that had been neglected, i.e. not grafted, involving the three meridians on three parallels.

Surgical procedures

Basically, two types of surgical procedure were performed.

The Michel Texier operation

The Michel Texier operation (Texier, 1963) restores the neck/chin angle. It is a liberatory act with cicatricial excision in most cases, exclusion of the platysma muscle, induction of granulation using a pro-inflammatory dressing and the secondary positioning of one or two large medium-thickness grafts that are variably perforated and maintained by a Lagrot compress.

Secondary procedures

There are various secondary gestures, including keloid excision and Z-plasties to correct residual imperfections (residual distal bridles, bridles appearing in the graft, functional bridles visible in extreme movements of the neck; Bunchman, 1975; Chippaux, 1959; Krizek, 1978; Lavergne, 1981; Mimoun, 1983; Talaat, 1989; Pons, 1977; Vandenbussche, 1978). The extent of the burns prevented the use of local or local-regional flaps. Free transfers and skin expansion procedures were not used in this series.

Particular points of the technique

Excision of the platysma

As recommended by Texier, the platysma was excised in all cases subjected to surgery. Excision of this muscle in old lesions and its broad

A

B

Figure 2. (**A**) Pre-operative aspect. (**B**) Peri-operative aspect.

C

D

(C) Neck collar. **(D)** Post-operative: 9 months later

A

B

Figure 3. (**A**) Pre-operative aspect. (**B**) Peri-operative aspect.

C

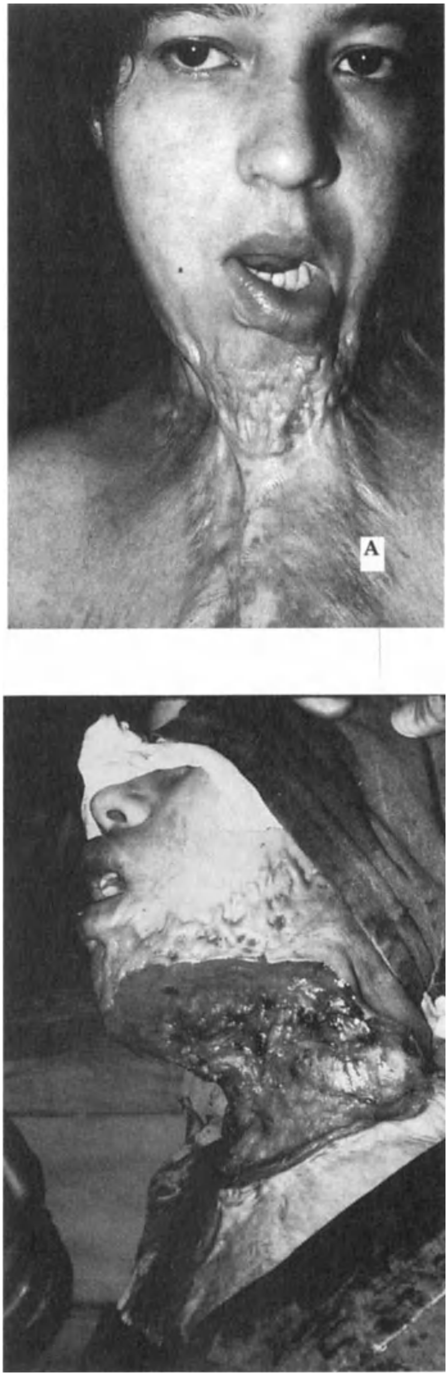
(C) Result after 12 months

horizontal incision in more recent lesions make it possible to achieve better hyperextension of the head and a better shaped cervicomental angle (Texier, 1963).

Preparation of underlying layers for grafting

During liberatory excisions of severe neck sequelae, which are particularly haemorrhagic procedures, haemostasis is never perfect. Some haemorrhagic microfoci of venous origin may remain and become manifest in the immediate post-operative period; these may not be dangerous for the patient but they create haematomas leading to partial graft failure and disastrous aesthetic results.

It would therefore seem advisable to postpone grafting for at least 1 week, as was in fact done in this series. The delay makes it possible to obtain rapid granulation, correct haemostasis and above all to prevent perforation of the grafts using Vaseline- or paraffin-based pro-inflammatory dressings to obtain rapid granulation, with better aesthetic results.



A

B

Figure 4. (**A**) Pre-operative aspect. (**B**) Peri-operative aspect.

C

(C) Result after 6 months

The graft

In our opinion, in view of the extent of the surfaces subjected to surgery, the grafting of medium-thickness skin is the best means of coverage. If possible the graft is removed in a single piece in order to avoid supplementary scars. If the graft zone is extensive, two or three grafts will be necessary, however.

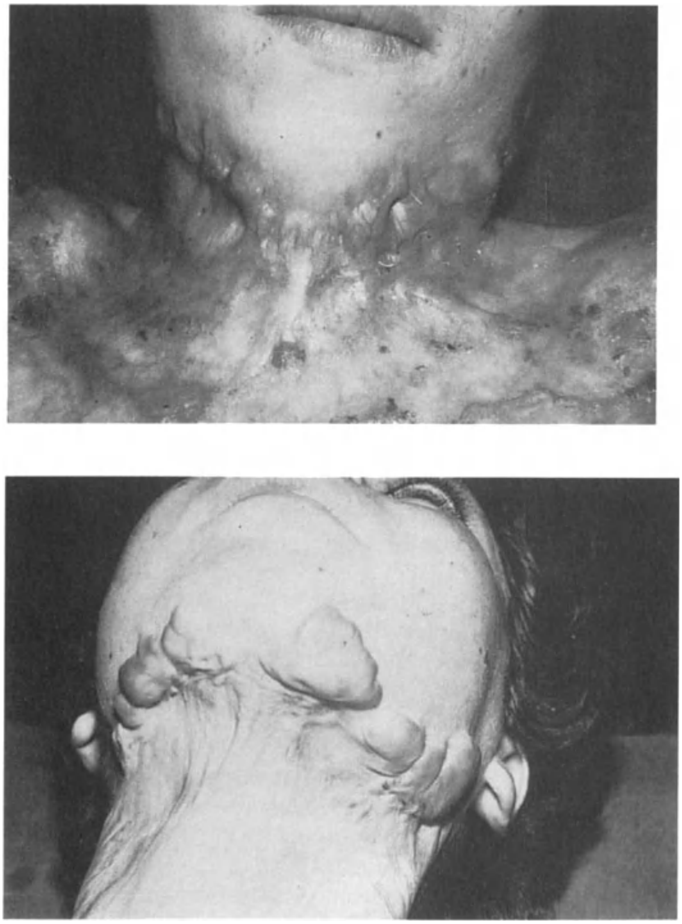
Usually one graft covers the superhyoid region and one or two cover the subhyoid region. The grafts must cover the entire exposed area, without any stretching, and they must be joined by horizontal sutures. Good fixation of the graft and strict immobilization of the neck are absolute imperatives.

As the neck is a concave region it is necessary to have central padding points, as well as a Lagrot compress. The neck must be immobilized in hyperextension. This can be achieved by means of layers of bandages, cotton or even sufficiently voluminous sponges in order to counteract flexion (Bagozzi, 1958; Grignon, 1976; Talaat, 1989; Texier, 1963; Vandenbussche, 1978). The dressing is maintained in position by bandages placed circularly around the neck and passing under the armpit.

Post-operative immobilization

Numerous authors have recommended immobilization of the neck for some weeks post-operatively (Bagozzi, 1958; Bunchman, 1975; Chippaux, 1959; Colin, 1973; Laouamri, 1987; Vandenbussche, 1981). The development of better materials has improved functional and aesthetic results and offered the patient more comfort. There is general agreement that a neck collar should be worn night and day for at least 6 months in order to prevent contractions.

At Douera all patients were fitted with neck collars during the week following graft take. Laouamri (1987) proposed a simple polyethylene neck collar permitting extension, immobilization and compression of the neck tegumenta. This last characteristic is important in a hot climate

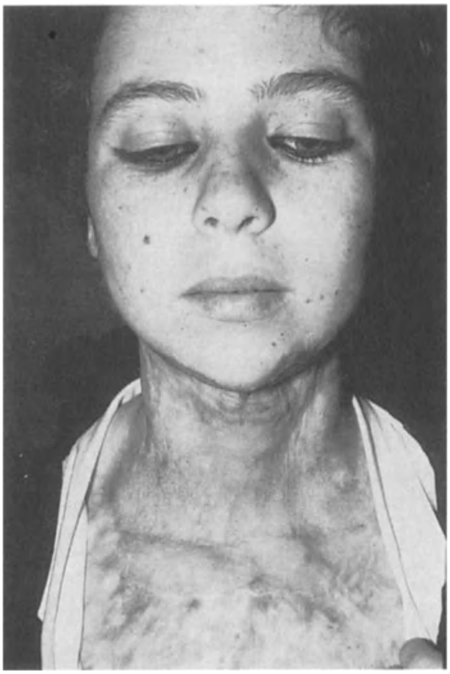


A

B

Figure 5. (**A**) Pre-operative aspect. (**B**) Result after 9 months.

C



(C) Result after 18 months following excision of keloids

because hypertrophic scars and keloids are extremely common. This particular neck collar (thickness 1 cm) is made of polyethylene foam (Plastazote).

A sheet is pre-cut to the shape of the neck and heated at a temperature of 140°C for some minutes. As soon as the temperature permits, the sheet is strongly moulded onto the grafted neck and maintained in position for some seconds. As soon as the collar has taken on the shape of the neck it is fixed back with Velcro strips. The aim is to keep open the existing neck/chin angle, to immobilize the neck and to exert adequate pressure on the graft, on the edges of the graft and on the more or less cicatricial adjacent skin.

This procedure takes about 5 min. The collar is very light and porous and prevents maceration, which is an important advantage in a hot climate. It gives good protection to the clavicular and mandibular pressure points. It is non-toxic and easily washed with ordinary soap. The apparatus is worn by our patients night and day for at least 9 months, and sometimes even 18 months in those with hypertrophic or keloid zones. In such cases the compressive nature of the material is exploited as much as possible.

The collar should be removed only during personal toilet and washed once a day with cotton wool and surgical spirit. Once a week it can be washed in soapy water. It has to be renewed as soon as its power of extension or compression shows any sign of reduction. The material necessary for making the collar is inexpensive.

ASSESSMENT OF RESULTS

The results are assessed every 3 months for 2 years, when scar evolution may be considered to have terminated. The assessment covers clinical condition (colour of grafts and adjacent tegumenta; thickness and elasticity of the cervical skin region) and the functional condition (mobility of neck, particularly in extreme amplitudes). A note is also made of the patient's personal impression.

Patients are examined jointly with the physiotherapist, the apparatus technician, the re-education physician and the plastic surgeon. It is important that the whole team should be present as this reassures patients and helps them to accept the necessity of a long and constricting therapy that will in time be satisfactory (Laouamri, 1987; Lavergne, 1981; Mimoun, 1983; Pons, 1977; Talaat, 1989; Texier, 1963; Vandenbussche, 1981).

CONCLUSION

Despite all the care taken in the treatment of severe neck burns and the efforts of the multidisciplinary team to obtain what are certainly appreciable functional and aesthetic results, the sequelae of the trauma will always be visible.

Ideally, cervical contraction should be avoided. The patient with burns in the cervical area should be placed without a pillow in an absolutely flat position. Recent burns should be treated with a moulded postural dressing maintaining the neck in extension. Grafting should be performed early, on young granulation tissue, and if the lesions are deep an early exeresis graft should be performed, as with hand burns.

In cases of established sequelae it is important to operate as soon as the patient's general condition allows, especially in children.

We would insist in particular on the important role of the neck collar which exerts pressure and extension for at least 9 months; it prevents cervical contractures and ensures that the results obtained by surgical correction are permanent.

BIBLIOGRAPHY

Bagozzi, I. C. (1958). Traitement des brûlures de la face et du cou. *Ann. Chir. Plast. (Suppl. Sém, Hôp. Paris)*, **3**, 289–297

Baux, S. (1980). Les séquelles de brûlures. *Rev. Prat.*, **4**, 577–588

Bunchman, H., Huang, T., Larson, D. L. and Lewis, R. (1975). Prevention and management of contractures in patients with burn of the neck. *Am. J. Surg.*, **130**, 700–703

Chippaux, C. and Marcotorchino, J. D. (1959). Cicatrices rétractiles étendues du cou après brûlures. *Ann. Chir. Plast.*, **4**, 61–66

Colin, B. and Janvier, H. (1973). Appareillage pour prévenir les rétractions après réparations du cou brûle. *Ann. Chir. Plast.*, **18**, 15–17.

Grignon, J. L. (1976). Brûlures du cou. In: Tubiana, R. and Baux, S., eds. *Monographie de chirurgie plastique*, 120–127. Paris: Masson

Krizek, M. (1978). Les séquelles de brûlure du cou, classification, indications thérapeutiques (à propos de 50 cas). *Thèse pour le Doctorat en Médecine.* (Lille)

Laouamri, T. (1987). Prévention et traitement des séquelles de brûlures du cou (à propos de 70 cas). *Thèse pour le Doctorat en Sciences Médicales.* (Bibliothèque Université d'Alger, Alger)

Lavergne, D. (1981). Séquelles des brûlures du cou – méthodes de traitement. *Thèse pour le Doctorat en Médecine.* (Nantes)

Mimoun, M. (1983). Traitement des séquelles des brûlures du cou. *Thèse pour le Doctorat en Médecine.* (Paris)

Pons, J. *et al.* (1977). Bridage du cou. *Ann. Fr. Chir.*, **22**, 209–214

Talaat, H. A. (1989). Burns of the neck. *Ann. Medit. Burns Club*, **2**, 87–88

Texier, M. (1963). Les rétractions cicatricielles du cou après brûlures. *Thèse pour le Doctorat en Médecine.* (Paris)

Vandenbussche, F. and Bernier, J. M. (1981). Brûlures de la face et du cou: leurs séquelles. In: Simon, L., Dossa, J., eds. *Brûlures et Médecine de Rééducation.* Paris: Masson

Vandenbussche, F., Vandevord, J., Decoopman B. and Decoulx, P. (1978). Trente cas de séquelles cervicales de brûlures. Morphotypes et points techniques particuliers. *Ann. Chir. Plast.*, **23**, 39–44

55
A local skin grafting method in the treatment of postburn scar contractures in the neck

G. I. DMITRIEV and L. A. OKHOTINA
Republican Burns Centre, Research Institute of Traumatology and Orthopaedics, Nizhniy Novgorod, Russia

---

The problem of postburn scar contractures in the neck is of great concern in reconstructive surgery. Despite successes in the treatment of burn patients there has been no decrease in the number of postburn neck scar deformities and contractures. The application of modern methods of burn management and scar contracture prophylaxis has only reduced the number of severe cases. Half the patients with full-thickness burns have neck scar contractures requiring surgery (Yudenich and Grishkevich, 1986). Neck burns are often associated with facial, chest, and shoulder injuries. Neck scar contractures cause functional and cosmetic disturbances that need surgical correction.

Different skin grafting methods are used for the surgical treatment of neck scar contractures: local grafting and/or skin grafting, flap grafting (including tube flaps). Flap grafting with microvascular anastomoses has been used lately (O'Brien *et al.*, 1974).

Interchanging triangular flap grafting or Z-plasty is one of the most widely used methods of local skin grafting (Limberg, 1963; Gillies and Millard, 1957; Dufourmentel *et al.*, 1959). Flap grafting is used to provide tissue replacement. When it is impossible to cut flaps because of scar changes in the neighbouring sites, skin grafting is recommended (Kazanjian and Converse, 1959). This has some disadvantages however and other reliable and rational methods are needed.

The choice of surgical technique depends on the degree of contracture, scar maturity and character, its form and size, and the general condition of the patient and the presence of associated diseases. In the Republican Burns Centre (Nizhniy Novgorod, Russia) 165 operations for neck scar contractures have been performed in the last decade. The method and timing of the operation depend on the character and degree of neck deformity. Skin grafting was performed in 33 patients. Split-thickness and full-thickness grafts were utilized. Most authors consider skin grafting to be the method of choice whatever the location of the scar and its size, although they also recognize its drawbacks (frequent occurrence of contracture due to graft scar degeneration, retraction and hyperpigmentation). Combined skin grafting was performed in 62 patients. Skin flaps were cut from the anterior neck surface for wound closure. Other defects were covered with skin grafts.

In addition to utilizing other surgical methods for neck scar contractures we applied in 70 patients local skin grafting with two pairs of flaps. Lateral and vertical folding flaps were formed by crossing the neck scar stricture. After flap mobilization and removal of scar stricture, the lateral folding flaps are sewn together at the top and translocated vertical flaps are attached to them. This method meets the main requirements of neck contracture management: longitudinal scar stricture release and cervicomaxillary angle formation. The method has the advantages of a simple technique, short duration of the operation, reduction of the post-operative period, and absence of donor wound.

To prevent longitudinal scar stricture formation at the top of the sewn lateral folding flaps, splints are used in the post-operative period in order to fix the neck in the correct position. When this is achieved, it can be released by means of Z-plasty.

Skin mobility and displacement disturbances are a peculiarity of burned neck deformities. Scars and scar areas are often seen in the middle of the neck and sometimes in the lateral triangles. Our method makes it possible to use scar tissues by cutting out the folding flaps. After conservative treatment they become quite flat and sufficiently soft to be used in local skin grafting.

At first this method was used to release limited scars from the open site anterior neck surface to the submaxillary region and the anterior thoracic wall. The method then appeared to be appropriate for patients with extensive scar deformities of the neck and adjoining sites in whom complex flap translocation from the neighbouring parts is impossible.

This short and simple method can also be recommended for patients with extensive scars who have associated diseases that prevent more complex operations.

REFERENCES

Dufourmentel, C., Mouly, R. (1959). *Chirurgie Plastique*, Paris

Gillies, H., Millard, D. R. (1957). *The Principles and Art of Plastic Surgery*. Vol 1–2. Boston-Toronto

Kazanjian, V. H., Converse, J. M. (1959). *The Surgical Treatment of Facial Injuries*. Baltimore

Limberg, A. A. (1953). *Planning of Local Plastic Operations*. Leningrad, 595 pp

O'Brien, B. M., Morrison, W. A., Ishida, H. *et al.* (1974). Free flap transfers with microvascular anastomoses. *Br. J. Plast. Surg.*, **27**, 220–230

Yudenich, V. V., Grishkevich, V. M. (1986). *Manual on the Rehabilitation of the Burned Patients*. Moscow, 366 pp

56

Management of the burned patient: a surgical and anaesthesiological protocol

A. BOCCHI, E. CALEFFI, C. D'ERAMO* and S. TOSCHI
Divisione di Chirurgia Plastica, USL N.4, Parma, Italy
**I Servizio di Anestesia e Rianimazione, USL N.4, Parma, Italy*

INTRODUCTION

Early escharectomy is a way of reducing hospitalization time and increasing survival in severely burned patients who can tolerate anaesthesia. The physiopathological effects of the total area of body burn are reduced and, after skin grafting, the chances of survival are enhanced. The procedure is not however without risk, because of the blood loss and increased metabolic catabolism caused by surgery.

In our experience the best results are obtained in deep burns in the head and upper limb, especially in young patients and when general anaesthesia is tolerated. If possible, skin grafts or cultured epidermal cells are applied at the same time. This increases the chances of survival and reduces wound healing time.

CLINICAL DATA

Between 1987 and 1992, 152 severely burned patients were treated at our Clinic with early escharectomy (day 3–6 after injury) followed by immediate skin grafting (131 traditional grafts, 21 cultured epidermal cells). The age range was from 2 to 38 years (median 20.8 years). Eighty-four patients were male and 68 were female; burned BSA varied from 45% to 75%.

The control group was composed of 56 patients with third-degree burn in 40–80% BSA treated with late escharectomy (10–20 days after injury).

ANAESTHESIOLOGICAL PROTOCOL

The anaesthetic technique comprised atropine 0.005 mg/kg i.m. 1 h before surgery for premedication; fentanyl 2.1 μg/kg + propofol 2–2.5 mg/kg i.v. and atracurium 0.6 mg/kg i.v. for induction and tracheal intubation; and N_2O/O_2 (7:3) + clinically appropriate inspired concentration of isoflurane+fentanyl-bolus on demand for maintenance.

Patients were ventilated mechanically to maintain normal blood-oxygen tension and normocardia. HR, NIBP, F_iO_2, P_{aw}, $ETCO_2$, SaO_2, arterial blood gas, diuresis, and body and room temperature were measured perioperatively.

RESULTS

Table 1 compares duration of hospital stay and survival rate between the early escharectomy group and the control group.

Table 1. Comparison of early escharectomy group and control group

Variable	*Early escharectomy (EE)*	*Control group*
Hospital stay (days)	44	67
Survival (number of patients)	135 (88.8%)	39 (69.6%)
Average age (years)	20.8	22.4
Sex		
M.	84 (55.3%)	34 (60.7%)
F.	68 (44.7%)	22 (39.3%)
Overall	152	56

Note: Hospital stay refers only to patients surviving; stay was significantly lower in the EE group; survival rate was significantly higher in the EE group.

Patients with head and upper limb burns had a significantly higher survival rate and shorter hospital stay (Table 2).

Table 2. Comparison of anatomical sites

Variable	*EE group*		*Control group*	
	Hospital stay (days)	*Survival (%)*	*Hospital stay (days)*	*Survival (%)*
Head	34	94.2	60	71.4
Trunk	52	83.7	71	60.3
Upper limb	37	91.4	58	73.1
Lower limb	54	82.1	73	59.5

Note: Patients are divided according to the anatomical area first treated.

COMMENT

The study demonstrates the crucial role of early escharectomy in the reduction of hospital stay and the higher survival rate in severely burned patients, probably as a result of a significantly lower risk of complications such as infection or multi-organ failure, and better anaesthesia.

The better results in upper limb burns may be related to postoperative rehabilitation, which is more comfortable for patients with burns in this site.

The reason for the higher incidence of wound healing in head burns may be explained by the better local vascularity.

BIBLIOGRAPHY

Berry, C. C., Wachtel, T. L., Frank, H. A. (1982). An analysis of factors which predict mortality in hospitalized burn patients. *Burn Inck. Term. Inj.*, **9**, 38

Curreri, P. W., Luterman, A., Braun, D. W. Jr., Shires, G. T. (1980). Burn injury: analysis of survival and hospitalization time for 937 patients. *Ann. Surg.*, **192**, 472

Kadey, M. K. M., Bemelmans, D., Cate, A. (1991). Early excision and grafting for burns of the hand. *Ann. Medit. Burns Club*, **4**, 33

Low, E. J., McMillan, B. G. (1973). Excision of acute burns with immediate meshed autograftings. Presented at American Burn Association, Dallas, TX

Luengo Matos S., *et al.* (1992). Comparative study of burn patients after treatment with more aggressive surgical techniques in wound care. *Ann. Medit. Burns Club*, **5**, 18

May, R. S. (1984). Burn rehabilitation in the United States. *J. Burn Care Rehab.*, **5**, 69

O'Connor, N. E., Mulliken, J. B. *et al.* (1981). Graftings of burns with cultured epithelium prepared from autologous epidermal cells. *Lancet*, **1**, 75

Teich-Alasia, S., Magliacani, G., Bormioli, M. (1979). Considerations on early surgery in the treatment of extensive burns. *Scand. J. Plast. Reconstr. Surg.*, **13**, 111

57
Sedation and analgesia: an i.m.–i.v. technique for dressing procedures

C. D'ERAMO*, E. CALEFFI** and A. BOCCHI**
*1° Servizio Anestesia e Rianimazione, U.S.L 4, Parma, Italy
**Divisione Chirurgia Plastica, U.S.L 4, Parma, Italy

INTRODUCTION

Patients with thermal injury undergo frequent and repeated procedures for which suitable analgesia is required. A study was carried out to determine the safety and effectiveness of midazolam-fentanyl-propofol sedation and analgesia and in burned patients undergoing dressing procedures.

MATERIALS AND METHODS

Fifty patients (21 male, 29 female; age range 18–71 years; body weight range 46–77 kg; burn size 15–50% TBSA) received a standard sedation–analgesia technique: premedication with midazolam 0.175 mg/kg + fentanyl 1.4 μg/kg i.m. 30 min before procedure and induction with propofol 0.5 mg/kg i.v. A large peripheral i.v. line was maintained throughout the procedure. Maintenance was with propofol infusion 2 mg/kg/h. All patients breathed room-air spontaneously. Heart rate, SaO_2 and arterial blood gas were measured peri-operatively.

RESULTS

Cardiovascular and respiratory parameters remained within the normal range. There were no cases of $SaO_2 < 90\%$ or of respiratory depression. All the patients made a rapid and complete recovery, with good acceptance of the technique.

CONCLUSION

Midazolam–fentanyl–propofol sedation and analgesia produced satisfactory surface analgesia and rapid and complete recovery and proved a safe and effective technique for skin dressing procedures in burned patients.

BIBLIOGRAPHY

Lamb, J. D. (1952) Anaesthetic considerations for major thermal injury. *Can. Anaesth. Soc. J.*, **29**, 630

Cockshott, I. D., *et al.* (1987). Pharmacokinetics of propofol in female patients. *Br. J. Anaesth.* **59**, 1103

58
Aesthetic reconstruction of deep facial burns

M. COSTAGLIOLA, D. ROUGÉ, J. P. CHAVOIN and
R. EL KOLLALI
Service de Chirurgie Plastique, Hôpital de Rangueil, Toulouse, France

---

Ideally, reconstruction is aesthetic. In severely burned patients, however, numerous factors combine to complicate reconstruction: there has been a major alteration in an organ, the skin, resulting from destruction, contraction (active phenomena) or attraction (passive phenomena). The greatest difficulty of all is encountered in the face, where the skin is fine and extremely mobile, and fundamental for facial expression. The face is the supreme aesthetic region, made up of an association of hard and soft structures, anatomical units and orifices where symmetry is absolutely perfect. For good aesthetic results we must set ourselves a triple aim:

1. To restore the skin as nearly as possible to its previous state, avoiding excessive sequelae in the graft areas.
2. To restore the underlying structures and even modify them when they are normal in order to recreate a harmonious profile.
3. To restore periorificial zones, where function and aesthetics come together.

Functional restoration depends on this anatomical restoration. A good anatomical result means a fine skin of normal colour moving easily over the underlying structures and around the orifices in the right position and without any deformity in the free edges. A good functional result is a mobile, symmetrical face which can show expression and can smile.

This triple aim is a true challenge for surgeons desirous of earlier and better reconstruction of patients who for their part are ever more demanding.

RESTORATION OF THE SKIN ORGAN IS AN ILLUSION. THE SURGEON CAN IMPROVE THE QUALITY OF SKIN OR ATTEMPT TO REPLACE IT IN ITS ENTIRETY

Improvement of skin quality

When lesions are still evolving (vitropressure test positive) various techniques can be used:

1. Pressure, as soon as scarring is established, using elastic balaclava-type masks, globally in the first instance and then selectively with the insertion of foam, transparent thermoplastic material prepared at high temperature on a rectified mould. These are effective but present certain problems (difficulties of manufacture, in particular in modifications to the mould); maceration in relation to initial treatment; intolerance to movements in the compressed area). However, the effectiveness of pressure therapy can be assessed thanks to the visibility and surveillance of relative ischaemia. The masks can be total or partial: with or without a mouth and nose modeller, and with or without a chinpiece.
2. Active means on the skin. These are used when the inflammatory processes are circumscribed. They involve mechanization of mobile areas (skin, subcutaneous muscles) and stimulation of active orificial function. Testing-type facial gymnastics is completed by massage and vibrated pressure and orthodermic stretching, and by hydrotherapy with filiform showers.

In the sequelae stage, when the vitropressure test is negative, it is possible to perform 'resurfacing' using palliative techniques to modify existing skin that has been partially damaged by the burn in order to improve its surface and colour.
Different techniques are possible:

1. Dermabrasion, a last resort as it does not treat the skin structure.
2. Overgrafting, an interesting technique which makes it possible to eliminate skin irregularities and dyschromia by means of the insertion of a thin skin graft, after abrasion of the scar layer.
3. Tattooing, a futuristic technique which is of some interest in cases of hypochromia that are difficult to treat in burn patients.

The problem of the quantity of skin required

This is a difficult problem. It is necessary to obtain an abundant skin supply while at the same time trying to minimize scarring in the donor zone and to prepare the recipient zone.

Skin supply

It is essential that the supply of skin should be complete in quantity by day 21, and in this sense the dogma of completion of cicatrization on day 21 must always be respected. Skin supply in aesthetic areas must be obtained in one of three ways:

- a continuous partial-thickness dermoepidermal graft (although this undergoes contraction and attraction);
- local autoplasty (although the skin supply is limited unless one makes use of skin expansion techniques);
- Wolfe-Krause full-thickness skin autografts which are the most difficult of the techniques but which cause little contraction.

It is now possible to obtain take on good granulation tissue of full-thickness skin measuring 25 × 15 cm and even 34 × 26 cm when it is necessary to treat the whole face.

The donor area must not be chosen at random: surgeons must always remember that they have to 'reconstruct without destruction'; this is an absolute necessity and an objective that can be achieved. It is no longer the practice to create unacceptable scarring in the donor areas, as this can always be avoided. It is possible to use skin from the scalp for partial-thickness dermoepidermal grafts. The scar damage is very slight as it is masked by the regrowing hair. The graft is often pale in colour and the quality of the skin is similar to that of the upper part of the face.

Use may also be made of skin expanders positioned before removal of full-thickness skin. This makes it possible to close the donor area without addition of graft, since a linear scar is always preferable to a graft scar. It is important to take into account skin contraction after expansion when calculating the size of a full-thickness graft.

The receiving zone must be prepared and chosen accurately. In most cases it will be necessary to respect the aesthetic topographical units defined by Gonzales Ulloa in 1954; this sometimes poses the problem of the sacrifice of healthy islets, as proposed by Millard in 1986. The advantage of aesthetic units is that they offer the possibility of masking scars in skin tension lines, avoiding the patchwork phenomena that are always so unsightly in the long term.

The need for good dermal granulation tissue varies depending on the use either of a partial-thickness skin graft, performed on day 5, or of a full-thickness graft, for which it is necessary to wait 10 days for perfect granulation tissue.

Early reconstruction with full-thickness skin graft

This concept is radically transforming prognosis in deep face burns. The technique is in three stages:

1. Total early excision of necrosis on day 3 until appearance of perfect granulation tissue about day 10.

2. Removal of a full-thickness skin graft of appropriate size from a normally non-visible area.
3. Coverage and immediate and prolonged pressure of the graft.

Total early excision of necrosis is performed as soon as diagnosis is possible on day 3; it is often completed by day 5. The incision must be drastic and extend as far as healthy tissue. Healthy or superficially damaged islands have to be sacrificed. Immediately after excision an algenate mould is made of the lost substance which will make it possible to prepare a positive plaster and to create a made-to-measure pressure mask with the shape of the operated zone made of perforated low-temperature thermoplastic material (Aquaplast). Detergent and pro-inflammatory dressings help to produce excellent granulation tissue by day 10 or 12.

Full-thickness skin is removed from the thigh or the laterothoracic region as these areas are easy to conceal. Pigmentation problems are possible but not inevitable. A model is made of the lost substance in order to remove a graft of exactly the right size as the area to be covered. The removal is performed step by step using a cold bistoury (blade 21) with firm traction on the skin. It is necessary to cut into the dermis and avoid fatty islands. A partial-thickness dermoepidermal skin graft is used to cover the loss of substance created by removal of the graft. The full-thickness skin graft has to be very carefully defatted. This process is long and exacting and is performed with the heel of the scissors, resting the upturned graft on the index finger of one's non-dominant hand. The process is essential and must be performed with the greatest of care, attacking the deep dermis of the graft.

Coverage of the loss of facial substance is performed as required. The cut corresponds to the size and shape of the loss, without creating any tension in the graft when it is positioned. Threads are inserted in the muscles and subcutaneous cell tissue, passed through the graft and the perforations in the pressure mask, and then knotted. The application of the pressure mask to the graft and of the graft to the face must be perfect, without any intervening space. At the level of the neck an arterial tension control armband covered with a biflex band is fixed to the mask and a pressure of 30 mmHg is applied to the whole device. This pressure has to be applied as soon as the graft has been performed and is maintained in order to occlude the cutaneous capillaries and thus avoid phenomena of cyanosis and necrosis that are so feared following full-thickness skin grafts. The band is kept in position for 3 days: surface phenomena created by the mask on the graft ensure that the 30 mmHg pressure lasts until its removal by cutting the threads on day 10. The graft must be totally revascularized when the mask is removed or necrosis may cause the loss of all or part of the graft.

The good quality of the full-thickness skin graft is a fundamental condition for aesthetic reconstruction of the face, as it prevents contraction and attraction, the causes of deformation and asymmetry which create so many problems in secondary reconstructions.

RESTORATION OF UNDERLYING STRUCTURES

The profile and the contours of the face depend on the hard structures of the face and on the thickness of the soft parts. Burns cause lesions in the subcutaneous tissue, atrophies and fibrosis or, conversely, dermal or even fatty hypertrophies, as well as contractions and attractions of semi-hard cartilaginous structures.

Modification of the osteocartilaginous structures

When deformations of the soft parts are fixed and it is impossible to act on them it is possible to act on normal underlying structures. The osteocartilaginous structure of the dorsum of the nasal pyramid can be reduced or the tip augmented by a cartilaginous or osseous addition. The projection of the point of the chin can also be augmented by a prosthetic addition or an advancement genioplasty. Exeresis of subcutaneous fatty tissue allows better definition of the cervicomental angle. The idea of modifying a normal healthy structure in order to compensate for irreparable cutaneous sequelae is a contribution of aesthetic surgery to reconstructive surgery, making it possible to achieve the desired goal, i.e. the symmetry and precise definition of the contours.

REPAIR OF PERIORIFICIAL ZONES AND FREE EDGES

The correction of deformities in periorificial zones and free edges is essential as these affect both the functional and the aesthetic prognosis.

In the eyelids, the classic method in the correction of ectropion is to use skin from partial-thickness dermoepidermal grafts. However, we find it preferable in many cases to use full-thickness grafts, particularly in the lower eyelid. This provides tissue of better quality that is less likely to contract and gives more stable long-term results. It is necessary to pay special attention to the absolute symmetry of the position of the canthi. They must be fixed by a periosteal stitch as their position varies when they are free, depending on skin contractions or attractions.

In the lips, the central bow-shaped part is a most delicate point in reconstruction, as the vermilion lip is often too wide and flat. The white and red line can be retouched using the 'thin lips' technique. It may be necessary to give the lip added relief by the addition of a dermal graft or a prosthetic implant. The smile is difficult to restore, especially because of lack of symmetry and the attractions that it causes to appear during facial gestures. Hopefully, the smile can be restored by the addition of uniform well-balanced skin of perfect mobility, as the underlying muscle effector is generally intact.

There is often considerable contraction of the free edges of the nostrils: this has to be corrected by a distal hinge reversal procedure to recreate the vestibular plane and the addition of surface skin (full-thickness skin graft or a nasomental flap which can be defatted secondarily).

The adnexa present the problem of the quality of the hair-bearing skin graft:

- For head hair, expansion procedures are undoubtedly the best solution, provided they respect the direction of the hair implant, which proves better in adjacent autoplasties than in transposition flaps.
- The eyebrows do not have the same speed of growth as head hair and they have a precise implant direction. It is better to make them too small than too large. Composite eyebrow grafts are superior to any other procedure and are always better than an overthick hair flap.
- The sideburns can be reconstructed using head hair or the beard in men. A more or less expanded autoplasty extending over the auricle is an excellent procedure.

CONCLUSION

Burn victims, deformed and disfigured as they are, have to face up to 'other people's stares' every day of their lives. If it is clear that a restoration *ad integrum* is impossible, it is also true that the aesthetic reconstruction of burn patients is no longer a mere utopia. It is now possible, but only through a therapeutic project consisting of protracted multiple operations which are sometimes abandoned by the patient along the way.

Although reconstruction of the skin organ may still be impossible with current techniques, it is nonetheless possible to improve the quality of burned skin enormously and even to replace it with skin of a similar nature and of excellent quality, despite its being grafted. The structure and lines of the face can be restored, in spite of deformations of the subcutaneous tissue, by modification of normal osseous or cartilage structures. Early restoration is an absolute necessity in the case of the orifices and the free edges. It is also necessary to minimize glaring sequelae in donor areas. The sometimes long and heavy calendar of multiple operations has to be explained to the patient, who requires considerable psychological support. The importance of aesthetic factors in surgical reconstruction must always be uppermost in the mind of the burns surgeon; more and more astonishing developments will be achieved as a result of the dual condition that we have already mentioned – that of the better informed patient and that of the surgeon, who will want to surpass himself, stimulated as he is by the very gratifying results he can hope to achieve.

Section X

Biomaterials

59
Skin substitutes: biomaterials and their use in covering substance loss and burns

M. COSTAGLIOLA, D. ROUGÉ, J. P. CHAVOIN, J. L. GROLLEAU and R. EL KOLLALI
Chirurgie plastique et réparatrice, CHU Rangueil, Toulouse, France

The objective of treatment of a burned surface (and of wounds in general) is to obtain good quality cicatrization as early as possible; many coverage materials exist but the best is without any doubt the patient's own skin, i.e. an autograft.

When this is not possible because of the patient's local or general state or because there is no possible donor zone (as may be the case in severely burned patients) various replacement biomaterials have to be used. These provide temporary coverage, acting as a surrogate skin and protecting the lesion until the occurrence of spontaneous or surgical cicatrization. To a certain extent they replace skin, whence the general term 'skin substitute'.

THE IMPORTANCE OF SKIN COVERAGE

The importance of temporary coverage is evident in deep burns, where there is a great risk of infection, dehydration and nitrogen loss. The patient's life is at stake: it is necessary to excise necrotic tissue as early as possible and to provide adequate coverage. Coverage, even if only temporary, is absolutely indispensable in this 'open' period, which begins after excision and lasts for at least 3–4 weeks.

Temporary coverage is equally important in superficial burns, which can of course also heal spontaneously. Whether superficial or deep second-degree burns, burns can easily become infected and become deeper; in any case they are painful and cause discomfort. The purpose of treatment in superficial burns is to achieve decontamination, prevent infection and obtain cicatrization as early as possible. Here too temporary coverage will prevent pain, infection and deepening of the burn, leading to epidermalization towards the end of the third week.

Temporary coverage is therefore necessary in deep third-degree burns but also in intermediate and deep second-degree burns. This justifies the need for of an ideal material, a biomaterial to be used in all types of burn, whether deep or superficial, for early, effective coverage which although temporary will be as resistant as possible.

CLASSIFICATION OF TEMPORARY COVERAGE PRODUCTS

Temporary coverage materials are variously called biomaterials, skin substitutes, biological dressings, skin equivalents and even artificial skin. These different terms engender a certain confusion, and at congresses and scientific meetings, even in the course of the same symposium or round table, one regularly hears the same term – biomaterials or substitutes – used in reference to products as different as homografts, skin cultures, biological products and synthetic products.

We therefore thought that it might be useful to clarify the situation by suggesting a new classification. According to the traditional classification there are two main groups: biological substitutes and synthetic (or semisynthetic) substitutes.

1. Biological skin substitutes include homografts or allografts, whatever their presentation. These do not necessarily have to be removed from a living donor – the best homograft is from a cadaver or from a brain-dead coma patient. It is also possible to use pieces of skin from plastic surgery exeresis (lipectomy, mammoplasty). Allografts can be used fresh, frozen, lyophilized or preserved in 98% glycerol. They can be used either as full skin or after meshing as mesh-grafts. Cell cultures of keratinocyte or of dermis are also available and can be autografts or allografts. Heterografts or xenografts are also classified here. These are obtained from animals, mainly pigs. Sometimes they are presented in lyophilized form.
2. Synthetic skin substitutes, also known as artificial skin, include semisynthetic substitutes and pure synthetic substitutes.

This classification is in our opinion debatable. Our first objection is that homografts or heterografts or cell cultures are not skin substitutes: they are real skin, and we would propose the term substitute skin for both allografts and xenografts. In fact, if we compare coffee with Nescafé we can say that Nescafé is not a coffee substitute but actual coffee, whereas chicory compared with coffee is a coffee substitute. The same reasoning can be made with sugar and sweeteners, which are sugar substitutes, while castor sugar is not a substitute of lumps of sugar but simply sugar!

We cannot, however, refer to synthetic or semisynthetic skin substitutes as artificial skin as they do not contain any cells. These are artificial membranes, or rather skin substitution membranes.

Keratinocyte cultures, sometimes presented on dermis cultures, are evidently biomaterials which are true artificial skins, although we prefer the term skin equivalents.

Here then is the terminology that we propose for this category of biomaterials used for the coverage of substance losses and burns:

1. Substitute skins (formerly biological skin substitutes): allografts or homografts and xenografts.
2. Skin equivalents: skin cultures that are true artificial skins, especially when they are complete with a keratinocyte culture on a dermal culture.
3. Substitute membranes: the former synthetic skin substitutes.

STUDY OF SYNTHETIC SUBSTITUTE MEMBRANES (SYNTHETIC SKIN SUBSTITUTES: CATEGORY 3 ABOVE)

These products are frequently confused with medications. Medications play a protective, cleansing and antibacterial role but they never replace skin. They need to be changed frequently – at least once or twice a day. The basis of a dressing is an inert substance that provides protection. Dressings are often impregnated with a topical agent to combat infection. They are too numerous to list comprehensively, but include tulle gras, Betadine tulle, Flamacerium and Jelonet. Hydrocolloids, e.g. Comfeel, are also typical dressings, very useful and active but never to be regarded as skin substitutes. Duoderm, which is presented as an occlusive activator of cicatrization, is also just another dressing. Cutinova is presented as a temporary skin substitute, but is not a true substitute either, as the dressing sometimes has to be changed twice a day.

What qualities are expected of a synthetic skin substitute (substitute membrane)?

The product must be:

- adherent for at least 10–15 days
- nonantigenic
- nontoxic
- permeable to water and oxygen
- permeable to antiseptics
- hydrophilic
- impermeable to bacteria
- able to protect fibroblast multiplication
- simple to use and easy to handle
- ideally, it would also be biodegradable.

A synthetic skin substitute usually consists of two layers, an outer inert layer of porous material, which may be an isolating plastic or a sheet of silicone or nylon, and a deep inner active layer which is either synthetic or semisynthetic, such as collagen.

Semisynthetic products

Semisynthetic products include first of all Yannas and Burke's membrane, which consists of an outer adhesive silicone layer and an inner collagen layer (chondroitin sulphate B). Pangen, which contains collagen and glycerol, is another semisynthetic membrane. Biobrane, with its outer silicone layer and inner collagen layer, is likewise a semisynthetic product that covers substance loss, allowing it to rest and making it possible to control cicatrization before final grafting. Biobrane has been presented as a 'biosynthetic temporary skin'. This term is however inappropriate: it is simply a synthetic membrane, albeit of excellent quality.

Synthetic products

Omiderm is a supple, transparent, adherent membrane that is permeable to water, antiseptics and antibiotics. Its composition includes polyurethane. It is manufactured in Israel. Epigard, manufactured by Park-Davies Laboratories, is a microporous membrane consisting of two layers: a thick inner meshed and spongy layer of polyurethane foam, and a thin, smooth outer layer of Teflon. It has good adherence and is gas permeable but impermeable to bacteria. It is resistant but not very extensible, which makes it unsuitable for irregular surfaces. Besichtin (Cassenne Laboratories) has been presented as an 'artificial skin' based on polysaccharide chitin extracted from crustacean shells. It is permeable to water and antiseptics. Chitin absorbs fibrinous exudates and encourages fibroblast proliferation and would appear to have antibacterial and haemostatic properties, qualities that are very useful in cicatrization.

In our opinion the best synthetic skin substitute that we have used is Inerpan, in both superficial and intermediate burns. Inerpan is a translucid nonporous film obtained by polymerization of two amino acids, combined with glycol polyoxyethylene. It is permeable to water vapour and antiseptics and adherent, but detaches spontaneously when cicatrization occurs. It is easy to keep under control because of its transparency, which reveals the slightest suppuration. Inerpan comes in sterile packets. It is very flexible and easy to handle, with a certain consistency which makes it suitable for irregular application sites, adhering closely to reliefs and contours. It can therefore be used in a wide variety of locations, e.g. trunk, hand, fingers and legs.

Once applied, it adheres very quickly. Pain stops immediately and it is possible to apply pressure to the covered area without triggering the slightest painful reaction. It usually adheres for 2 weeks and is then progressively eliminated, without any pain and without any need to replace the dressing. Skin abrasions and excoriations are an excellent indication for this synthetic skin substitute.

We have tested Inerpan in about 500 patients in relation to other products. It is undoubtedly very useful, especially in children, in whom the reduced frequency of dressing changes is an appreciable advantage. Inerpan has a skin-like effect in that it protects cicatrization, prevents evaporation and reduces exudation while remaining permeable to topical agents and impermeable to bacteria. Above all it has an analgesic effect.

It is thus very easy to use because of its plasticity, transparency and adhesiveness to the wound. It is also easy to remove. Monitoring is also easy and above all it reduces the frequency of dressing changes. In our opinion, Inerpan is the elective dressing for burns treated on an out-patient basis.

These substitutes have also been used in graft donor zones, in order to cover mesh grafts and for other losses of substance not of thermal origin.

We do not believe that this product in any way accelerates cicatrization. It does however bring undeniable comfort and, very importantly, it does not cause pain; above all, there is no need to renew the dressing, and therefore no need for manipulation.

CONCLUSION

Our first aim was to resolve a problem of terminology in an attempt to clarify the situation of synthetic skin substitutes in the field of biomaterials.

It is important to emphasize the quality of certain substitutes such as Biobrane for deep burns, which makes it possible to wait for autografts, and Inerpan for superficial and intermediate burns. Skin coverage is imperative in many situations – in extensive burns, but also in local burns, superficial or deep burns and extensive substance losses (giant nevi), as well as in more limited wounds and a variety of other circumstances: out-patient treatment, treatment of severely burned patients, simultaneous arrival of large numbers of burn patients.

The best material for temporary coverage is undoubtedly the homograft. There are however supply problems, and fear of HIV limits its use. There is therefore an indisputable need for synthetic skin substitutes, which will permit temporary coverage for at least two weeks until cicatrization occurs or which will make it possible to wait for repair by means of an autograft. A good skin substitute will thus at least protect spontaneous cicatrization – it may even accelerate it – and at the same time it will permit preparation for a skin graft when necessary.

In our opinion synthetic skin substitutes are the elective treatment for burns treated on an out-patient basis, immediately reduce the burned surface in severe burns and immediately neutralize the area of the surface burn, thus reducing the total surface of the burn. They are of great importance in disaster medicine in the event of a massive arrival of burn patients, as they provide temporary coverage for the majority of burned areas, protecting them from infection and facilitating dressing procedures.

60
Clinical experience with skin xenografts in burned patients

L. KLEIN, P. MĚŘIČKA and J. PREIS
Charles University, Teaching Hospital
Department of Surgery, Burn Unit, Tissue Bank, Department of Pediatric Surgery, Hradec Králové, Czech Republic.

To a surgeon, full-thickness skin defects and/or deep partial-thickness skin defects usually present a difficult problem. Injuries with loss of skin, as often in burns, require special surgical tactics. It is necessary to consider:

- the condition of underlying tissues – the basis of the defect
- necrectomy tactics
- wound-bed preparation for grafting
- the correct choice of a temporary or definitive cover

Temporary cover of burn wounds by biological materials as a part of this process has become a standard procedure in modern burns care. Most frequently human or animal skin substitutes, especially porcine, are used. Here we present our experience with skin xenografts at the Burn Unit of the Department of Surgery and at the Department of Pediatric Surgery in the University Hospital, Hradec Králové, Czech Republic.

Porcine skin is the most suitable for xenotransplantation because of its close resemblance to human skin: skin density, thickness of dermis, composition and quantity of subcutaneous fat, and vascularization. Pigskin is easy to handle as it can be transported and folded.

In the 6-year period January 1986 to December 1991 we used xenografts as burn cover in 79 adults and 93 children. In the adults, the most frequent injury was burns (direct effect of flame), with 43 cases in total. Seventeen suffered scalds caused by hot liquids and 19 cases suffered electrical, chemical or contact burns.

In the series of burned children there was a high predominance of scalds by hot liquids (coffee, tea, soup and/or children falling into hot liquids) – 63 cases. These injuries are typical of childhood. Seventeen

Table 1. Adults

	% TBSA burned				
	0–10	*11–20*	*21–30*	*31–40*	*< 41*
Second-degree	10	11	9	12	2
Third-degree	11	7	8	5	4
Total	21	18	17	17	6

Table 2. Children

	% TBSA burned			
	0–10	*11–20*	*21–30*	*< 31*
Second-degree	39	17	5	2
Third-degree	9	9	7	5
Total	48	26	12	7

children were burned by flame and in 13 cases had electrical, chemical or contact burns. The extent and depth of injuries in both groups are shown in the Tables 1 and 2.

Porcine xenografts were used for repair of second-degree superficial and deep third-degree burns in 107 patients. Grafted superficial lesions healed spontaneously. Xenografts were often left in place without change until the wounds healed. This treatment has several advantages. Correct early application of xenografts prevents further superficial damage due to wound surface dehydration. They promote epithelialization at the wound edges and simultaneously suppress overgrowth of granulations in the centre. The resulting cosmetic effect is favourable.

Necrectomy and wound preparation for autografting were carried out in 65 patients with third-degree burns. In adults necrectomy was performed as soon as the patient's condition permitted. In children we adopted a more conservative approach, waiting until most of the wound healed spontaneously. Necrectomy was performed only after complete demarcation of necroses, on average 10–12 days post-injury.

During treatment of necrectomized areas, xenografts were changed every 3–4 days, usually 2–4 times according to the condition of the wound bed. These frequent dressing changes facilitated debridement of the wound and prepared it for successful permanent closure with autografts. Alleviation of pain following application of the xenografts facilitated mobility of the burned limbs. Due to their analgesic effect, xenografts are also valuable in the therapy of minor burns in outpatients, especially in children. Despite close adhesion to the body surface, graft removal is easy and not painful.

There is only one drawback in this kind of therapy: the high demand for xenografts. Graft demand may be influenced by several factors, i.e. the extent and depth of the damage, the radicality of treatment and, in

Table 3. Average area of xenografts applied in adult and paediatric patients

	No. of patients		*Average area (m^2)*		*SD*	
Burn classification	*Adults*	*Children*	*Adults*	*Children*	*Adults*	*Children*
Minor	14	–	0.07	–	0.04	–
Moderate	32	28	0.27	0.11	0.27	0.11
Severe	33	36	1.01	0.21	0.67	0.25
Critical	–	29	–	0.46	–	0.43

children, changes of the body surface because of their age. Most of these factors are included in the burn injury classification (in children age is also considered) and this parameter was therefore taken into account in the demand for graft presented in Table 3.

In adults, a great difference is observed in demand between moderate and severe burns, and in children with severe and critical burns. A detailed analysis of this last group showed that the highest graft demand was 0.71 ± 0.48 m^2 in children with critical burns combined with second- and third-degree burns, which equals the demand in severely burned adults. This is the result of the more conservative approach in the treatment of burned children.

On the basis of our experience we can conclude that our results using xenografts confirmed the advantages of this biological cover, as described by Ben Hur and others in 1984:

- stimulation of granulation growth without overgrowth;
- restriction of wound evaporative water loss but with sufficient permeability;
- prevention of infection;
- sufficient adhesiveness to body contours;
- easy removal.

Xenotransplantation has become a standard feature of topical therapy within the framework of complete burn treatment in our department.

61
Present and future indications for the use of cultured epidermal autografts in the treatment of burns

FORTUNATO BENAIM
President and Medical Director of the 'Fortunato Benaim Burn Foundation' and Professor of Plastic Surgery and Burns, El Salvador University, Buenos Aires, Argentina

INTRODUCTION

Early excision and immediate skin coverage has been undoubtedly one of the most important advances in the surgical treatment of burns in the past 30 years. In the most severe cases, the early elimination of the dead tissue prevents or at least greatly diminishes the risk of bacterial reproduction, invasion through healthy structures, and its consequence, general infection. Different techniques have been used to provide skin replacement after extensive escharectomies.

Mowlem and Jackson (1960) utilized homo- and autografts applied as alternate strips. After the introduction in 1964 of the Tanner Vandeput Dermatome mesh grafts have been widely used to cover large raw surfaces.

In patients with extensive burns and few available donor areas, good skin grafts can be harvested from the scalp and the sole of the foot: these regions can be used again in a few days since they heal very rapidly.

Temporary skin coverage with substitutes such as pig skin and Biobrane allow the surgeon to wait until the conditions of the patient and the wound are optimum for take of the definitive skin autograft. Skin homo- or allografts are now recognized as the best skin substitutes. The organization of Skin Banks (May and Declement, 1980) has greatly helped Burn Units to provide stored cadaver skin in sufficient amounts to cover the most extensive raw surfaces after escharectomies. The intermingled skin graft utilized by Shih was another advance in the search for the best way to cover burn wounds quickly and definitively in critical patients.

New substitutes introduced in the last ten years, such as artificial skin (Burke and Yannas, 1981) have shown that it is possible to use a biological dermis created in the laboratory. A definitive autograft can be placed on top of it.

All of these advances have limitations in critical patients due to the use of the remaining healthy skin as donor areas in order to obtain tissue for autografts. The idea of culturing epidermis for therapeutic purposes probably arose when the expansion of skin grafts placed over a wound was observed. Attempts to cultivate epidermis were limited by the observation of the complex relationship between fibroblasts and epidermal cells. It was necessary to stop fibroblasts growing in order to allow the normal reproduction and differentiation of epidermal cells. Research carried out by Rheinwald and Green (1975) demonstrated that keratinocytes could be successfully grown *in vitro*. They succeeded in preventing the overgrowth of human dermal fibroblasts, which had hitherto been the greatest obstacle to this type of culture; they also achieved subsequent subcultures from primary cultures. They used a feeder layer of lethally irradiated 3T3 mouse fibroblasts at a correct density, ensuring good growth of the epidermal cells and inhibiting the growth of fibroblasts. Later on, they improved the medium by adding epidermal growth factor, which acts as a potent stimulator of keratinocyte culture, making possible the rapid expansion of the cell colonies and finally forming epidermal sheets.

Further advances in the technique were obtained with the addition of hormones such as hydrocortisone and insulin and by improving nutritional requirements with adequate calcium concentration.

In 1986, Pittelkow and Scott developed another culture method, based on a serum-free culture system, without any feeder layer. This method involves a two-step technique: step one is performed in a serum-free medium and yields large quantities of undifferentiated, highly proliferative, basal cell-like populations. In step two, cell differentiation is induced and stratified sheets of keratinocytes resembling normal epidermis are obtained. At any moment in the first step the cell can be subcultured for cell expansion or cryopreservation for further cell cultures.

When enough cells have been obtained and monolayers are formed, step two of this method starts when stratification and differentiation take place. The epithelial sheets are removed from the flasks by enzymatic treatment.

The cultured epithelial autograft (CEA) technique has been used for grafting in experimental models in athymic mice (Banks-Schlegel and Green, 1980) and rabbits (Karasek, 1986). Initial tests of human CEA were performed by O'Connor *et al.* (1981) and followed by Gallico *et al.* (1984), Teepe *et al.* (1986) and others. Over the last few years, a number of burn surgeons have recognized that CEA applied to a dermal base produces less contraction and scarring than CEA applied directly to excised full-thickness burns or to granulating wounds. Cuono *et al.* (1986, 1987) used CEA and dermal allografts and more recently Cuono

(1992) and Hickerson (1992) continued this work, applying the CEA to a dermal surface prepared from engrafted cadaver skin.

MATERIAL AND METHODS

We had the opportunity of treating in our burn centre in Buenos Aires, Argentina in 1991 two patients: the CEA technique was considered to be a life-saving means in one patient and in the other the hypotrophic quality of the patient's skin discouraged the use of conventional autografts.

Case 1

A 52-year-old male suffered 65% burn (44% full-thickness) when he fell into a receptacle containing boiling water that was used to cook meat in the factory where he was working. On day 3, after stabilization of his general condition, 20% of the eschar from the anterior part of both lower extremities was tangentially excised until healthy bleeding tissue was exposed. Autologous 1- to 6-mesh grafts were applied and covered with cadaver skin from the Bank. Homografts were utilized to cover the remaining raw surfaces. A Biobrane glove was used to treat the deep dermal burn of the left hand. Silver sulphadiazine was employed as local treatment for the deep dermal burns localized in the anterior part of the trunk. Several skin biopsies (2 × 2 cm) were taken and sent to Boston for culture.

Three days later, another 20% of the eschar was excised and homografts and artificial skin received from the USA were used for coverage. Thirty days after the biopsies were sent for culture, 150 sheets (5 × 5 cm) of cultured epidermal autografts were received from the laboratory in a special box, and applied to the left upper extremity and both lower limbs, on a previously prepared granulating bed. A modified Thomas splint was used to keep the lower limbs elevated, avoiding contact between the bed and the grafted posterior aspects of legs and thighs. Take of the CEA was only partial and a second graft of CEA was performed. In this operation 105 CEA sheets the same size as those used in the first surgical session were grafted.

The post-operative course was closely followed up and dressing changes were carefully performed in order to avoid mechanical disturbance of the CEA sheets.

The general and local evolution were satisfactory and treatment was completed with bath-tub sessions and rehabilitation. The patient was discharged on day 60 after the operations and continued rehabilitation at home.

Case 2

A 60-year-old woman with 8% deep dermal burns in both legs was treated with CEA because she had very thin and hypotrophic skin and conventional skin grafts were not considered advisable, in view of the risk of donor areas being converted into new raw areas. CEA sheets were applied to the granulating surface. Take was 60%, and the wound healed in 40 days.

RESULTS

In case 1, 150 5 × 5 cm CEA sheets were applied to cover the raw surfaces of the left upper extremity and part of both lower limbs in a 53-year-old man with 65% burned area (44% full-thickness). Take was estimated to be 70%. In a second operation 105 CEA sheets of the same size were used to complete skin replacement. Take was 50%. The average total take of the 255 CEA sheets was 60%.

The combination of 1 to 6 meshed grafts, cadaver homografts and CEA utilized in this case was effective for definitive closure of the burn wound. The Biobrane glove worked very well and total epithelialization of the left hand was achieved in 2 weeks. The remaining deep dermal burns healed spontaneously with combined local treatment: topical drugs plus bath-tub. In case 2, the take of CEA was also estimated to be 60%, with satisfactory healing of the wounds.

The experience obtained with the use of CEA in these two cases prompted our Foundation to set up an epidermis culture laboratory. This is now fully equipped and performing experimental work related to different applications of cultured epidermis on donor areas and to the covering of fresh raw surfaces after abrasion of burn scars.

DISCUSSION

In case 1, the use of CEA integrated with homografts and meshed autografts was indicated as a life-saving resource, taking into consideration the age of the patient (52 years), the total extent of the burn (65%) and the amount of full-thickness burn area (44%).

Although the CEA take was only 60%, the final result obtained with the combination of the above-mentioned techniques indicates that CEA may be used as a good complement when conventional autografts are insufficient for complete coverage of wide raw areas.

In case 2, a 60-year-old woman with 8% dermal burns in both legs, the quality of her skin, which was very thin and hypotrophic, caused the transformation of a deep dermal burn into a full-thickness lesion. Taking into consideration the characteristics of the patient's skin, it was considered inadvisable to use any type of current autografts since the delicate nature of the skin in the usual donor sites could have created new raw areas. For this reason, CEA was employed.

Once again, although the take of the CEA sheets was estimated to be 60%, it was possible to close the wound in a period of 40 days.

In both cases, the thin sheets of CEA applied to the granulation tissue had to be treated very carefully in the post-operative period, because they are easily damaged by any rough manoeuvre during dressing changes. On the other hand, its direct application on such a bed does not give too many guarantees of good long-term protection of the grafted areas.

These observations led to the search for a better bed for the cultured epidermis.

Cuono *et al.* (1986, 1987) suggested applying CEA on to a dermal surface prepared from engrafted cadaver skin. It was proposed to perform wound excision, application of cadaver allograft and reapplication of cadaver skin if necessary in such a way that the allograft becomes well engrafted. When cultured cells are available, the alloepidermis must be removed and the CEA applied to the new allodermis base.

Cuono (1992), Hickerson (1991–1992) and Rheinwald (1992) recently emphasized the advantages of this composite allodermis CEA method, which has given a higher and more consistent percentage take than that typically achieved by grafting CEA on to beds prepared by other procedures. If the allograft is meshed 1 to 1.5 or 1 to 2, a better overall take can be achieved.

Further histological and functional studies are necessary to confirm these advantages.

CONCLUSIONS

The 60% average take of CEA in both the cases presented combined with homografts and meshed grafts demonstrates that CEA can be recommended as a life-saving resource in severely burned patients and solves the problem of covering raw surfaces in patients with very thin and hypotrophic skin, when conventional autografts are not advisable in order to avoid creating new raw areas in the donor areas.

The new methods of preparing a more suitable bed for CEA with the allodermis base have given a higher and more consistent percentage take than that previously achieved by grafting the cultured epidermis directly on granulation tissue.

New methods to apply CEA onto engrafted allografts, open new ways in its use and give a promising future for these techniques.

BIBLIOGRAPHY

Banks-Schlegel, S., Green, H. (1980). Formation of epidermis by serially cultivated human epidermal cells transplanted as an epithelium to athymic mice. *Transplantation*, **29**, 308–313

Burke, J. F., Yannas, I. V. *et al.* (1981). Successful use of physiologically acceptable artificial skin in the treatment of extensive burn injury. *Ann. Surg.*, **194**, 413–423
Cuono, C. B. (1992). Burn wound management in preparation for composite alloautoskin grafting. *Technical Bulletin # 3*, Boston: BioSurface Technology Inc.
Cuono, C. B., Langdon, R., Birchall, N. *et al.* (1987). Composite autologous allogenic skin replacement: Development and clinical application. *Plast. Reconstr. Surg.*, **80**, 626–635
Cuono, C. B., Langdon, R., McGuire, J. (1986). Use of cultured epidermal autograft and dermal allograft as skin replacement after burn injury. *Lancet*, **1**, 1123–1124
Gallico, G. G., O'Connor, N. E., Compton, C. C., Kehinde, O., Green, H. (1984). Permanent coverage of large burn wounds with autologous cultured human epithelium. *N. Engl. J. Med.*, **311**, 448–451
Hickerson, W. (1992). Methods for grafting cultured epidermal autografts onto a dermal surface prepared from engrafted cadaver skin. *Technical Bulletin # 2*. Boston: BioSurface Technology Inc.
Jacksson, D., Topley, E., Cason J. S. *et al.* (1960). Primary excision and grafting of large burns. *Ann. Surg.*, **152**, 167–189
Karasek, N. A. (1986). Growth and differentiation of transplanted epithelial cell cultures. *J. Invest. Dermatol.*, **51**, 247–250
May, S. R., Declement, F. A. (1980). Skin banking methodology: an evaluation of package format, cooling and warming rates and storage efficiency. *Cryobiology*, **17**, 125–129
O'Connor, N. E., Mulliken, J. B., Banks-Schlegels, S., Kehinde, O., Green, H. (1981). Grafting of burns with cultured epithelium prepared from autologous epidermal cells. *Lancet*, **1**, 75–78.
Pittelkow, M. R., Scott R. E. (1986). New techniques for the *in vitro* culture of human skin keratinocytes and perspectives on their use for grafting of patients with extensive burns. *Mayo Clin. Proc.*, **61**, 771–777
Rheinwald, J. G. (1992). The 'allodermis' of homograft as a bed for cultured epidermal autografts. *Technical Bulletin # 1*. Boston: BioSurface Technology Inc.
Rheinwald, J. G., Green, H. (1975). Serial cultivation of strains of human epidermal keratinocytes: the formation of keratinizing colonies from single cells. *Cell*, **6**, 331–344
Tanner, J. C., Vandeput, J., Olley, I. F. (1964). The mesh skin graft. *Plast. Reconstr. Surg.*, **34**, 287–292
Teepe R. G. C., Ponec, M., Kreis, R. W., Hermans, R. P. (1986). Improved grafting method for treatment of burns with autologous cultured human epithelium. *Lancet*, **1**, 385

62
Problems created by the use of cultured epithelia

J. GUILBAUD
Hôpital Percy, Centre des Brûlés, Clamart, France

In patients with extensive burns, donor sites are limited. Escharectomy must be followed by the temporary covering of lesions, autografting being carried out as and when donor sites are available. As the size of the burned area increases, the possible donor sites for autografting obviously decrease. As burn victims survive longer, there comes a time when there is an inadequacy between the area of the donor sites and the need to cover the patient definitively with his/her own skin within a reasonable time limit. Traditional methods of wound closure, even with widely meshed grafts, in such cases become inadequate and in this context the only elegant and effective solution is the use of the cultural epidermal autograft (CEA), which here shows its real value. Since the first successful use of CEA in 1981, more than 400 patients have been treated in Europe and the USA, mainly for extensive burns.

The use of this technique not only causes problems but also poses basic questions. The problems are of two types: technical and organizational.

TECHNICAL PROBLEMS

Some technical problems are inherent to the nature of the cultured epithelium itself, while others are purely medico-surgical. Because of its extreme friability, the actual placement of the CEA on to an excised bed requires meticulous attention to detail.

All surgeons have received instructions as to the fragile nature of the CEA. It is classically fastened to a Vaseline gauze which facilitates use. New processes of assembly on to a layer of fibrin will allow the CEA to be handled more easily in the future. After placement the grafted site must be kept completely immobile so that the CEA remains in place. Its fragility is most apparent in cases of infection: the defence mechanisms of a split-thickness skin graft cannot be compared with those of the CEA. The high vulnerability of the cultured cell sheet to bacterial protease and cytotoxins during the first weeks of maturation and attachment explains why it is more sensitive to the effects of bacteria and fungi in the wound bed. Bacterial contamination can cause nearly complete loss of the CEA, while a similar level of colonization will have little or no effect on the take of a meshed autograft. In an American series of cases, at the time of take-down, patients who were clinically infected had an average take of 40% compared with non-infected patients who had an average take of 77%.

One of the difficulties of using CEA is therefore timing, together with the method of debridement and the materials used for temporary wound closure, on which the capacity for the CEA to become infected is partly dependent.

What strategies can reduce wound-bed colonization and infection?

The answer is simple: it is widely accepted that hypoperfused and poorly oxygenated regions of a wound diminish phagocytic activity and have a much higher probability of colonization and infection. A CEA placed over chronic granulation tissue has a poor chance of successful take.

The best method of obtaining a good take, with optimal characteristics for attachment of the CEA, is early excision followed by temporary coverage with allografts which stimulate vascularization: the earlier the excision the better the CEA will take. It is desirable to perform the excision and temporary coverage within the first week, before day 10 at the latest. The quality of the homografts and their viability must not be neglected, and they constitute an important aspect. It seems more and more evident that leaving a thin layer of the homograft when it is excised significantly improves the take, as if cultured epithelium can attach and mature more rapidly on dermal connective tissue than on other types of surfaces.

For 14 allodermis patients in the Odessey series, the average take of 90% was significantly better than that obtained when engrafted homograft was removed completely from the wound-bed before application of the CEA.

The latest results suggest that if the burn wound-bed is well prepared and not infected, a take rate of up to 90–95% should be expected.

If, in spite of all care in wound-bed preparation, an infection occurs, the use of topical antibiotics that are non-toxic for the CEA will be justified (but only for positive surface cultures): neomycin 40 μg + polymyxin 200 U/ml in the genitourinary irrigant proportions, or polymyxin + bacitracin + nystatin.

Another important problem is to know whether CEA is appropriate for all body areas. If possible, certain areas should be avoided for different reasons: the peri-sphincteric regions, for obvious reasons; the axillae and joints, for reasons of mobility which would prevent the take; and the ears, owing to poor vascularization. If there are available donor sites, traditional split-thickness skin grafts should be applied to the upper extremities in an attempt to provide the patient with a more resilient cover for these very important areas.

With regard to the posterior trunk and decubitus areas generally, the use of air-fluidized beds does not hinder a good take.

Assessment of CEA take immediately after removal of the petrolatum gauze is a difficult problem since the nascent epidermis lacks a differentiated keratin layer; but this ultimately depends on 'familiarization'.

More worrying is the timing of the initiation of routine physical therapy. Owing to the fear of compromising graft take, patients are sometimes put under sedation approaching anaesthesia. If perfect immobilization is essential for a good take, being too conservative with mobilization and rehabilitation for fear of losing the CEA is an error. The best way is to give the patients pre-operative instructions as to the fragile nature of the newly placed autografts and the importance of their cooperation during post-operative management. After surgery patients are encouraged to remain relatively immobile to prevent shearing of the grafts. The majority of authors recommend physical or occupational therapy between day 7 and day 12.

The best solution would be to stretch the durability of the grafts to their limit with a tensile strength gauge.

ORGANIZATIONAL PROBLEMS

The primary question is a basic one: has any individual burn unit enough candidates for its own CEA production? This is an essential question since it conditions the form that a 'culture laboratory' may eventually take.

Some burn centres have had the ambition to possess their own unit for epithelial culture production. As the number of candidates for CEA grafting is insufficient, financial, organizational and work-force reasons dictate that laboratories are organized for research and not for production. According to need, they are then sporadically deviated from their original assignment for the benefit of the patients, when they are not in fact equipped for that purpose. The quality of the grafts shows the effects of this type of organization, and they may or may not succeed. Little by little an imbalance builds up between the aim and the real use of the laboratory, and as it is impossible, for financial reasons, to perform all the necessary quality controls because of understaffing with competent scientists, the laboratory loses its credibility and has to be closed.

Another more or less acute problem, depending on local legislation, is the difficulty for burn centres to obtain homografts. Although the temporary coverage of wounds by synthetic biological medications or by xenografts may not seem to be important to authors like De Luca, an emerging consensus indicates that temporary closure with an allograft, following early excision, provides the best CEA take. Allografting remains the gold standard of all temporary covers and the best way of preventing infection of the wound-bed. It is therefore of primary importance to use cadaver skin, even if this means organizing regional skin banks.

Lastly, it is frequently said that post-operative management of the CEA is more complicated and time-consuming for nurses and physicians than traditional methods of treatment. CEA certainly requires meticulous wound care. In our experience, this delayed discharge from the Burn Unit for our first patients, the daily time devoted to the dressings of each patient being two or three times longer than normal. With experience, a comprehensive nursing care plan was developed in an effort to ensure successful graft survival, with more and more simple dressings. We can say in conclusion that the problems posed, be they technical or organizational, are not insoluble.

Is price a real stumbling block? Cost effectiveness cannot be a factor in medicine when lives are saved. The problem must therefore be reassessed and the obvious questions must be of another type: is there another treatment with results that do not demonstrably differ?

Does it really increase survival? What are the real indications? As to whether there is another treatment with results that do not demonstrably differ in relation to a conventional technique, the CEA allows coverage of very extensive lesions where conventional methods would falter.

The only other possible treatment is the Shanghai graft. This Chinese technique of micrografting, in which the autografts are minced and then applied in a pre-prepared piece of cadaver homograft (or xenograft), is a valuable technique that has not been widely applied in the West. The *in vitro* seeding of a collagen gel with cultured fibroblasts, as reported by Bell, and the bilayer sheet composed of a temporary silastic overlayer and a porous collagen-chondroitin-6-sulphate matrix to act as a template for a neodermis, as developed by Burke, are two incomplete forms of coverage which need secondarily to be overgrafted by cultured epithelium.

To the question whether the CEA really increases survival, the answer is probably 'yes' in cases of very extensive burns, although a prospective randomized study should be performed in order to find the real answer, which would anyway be difficult to assess because patients with large burns die from so many causes, such as pulmonary failure, cardiovascular complications and multi-organ failure.

The final point concerns the real indications. The American National Burn Information Exchange reports that a 70% TBSA full-thickness burn is associated with a mortality rate of 80%. In these conditions, and taking into consideration its high cost, the CEA should be used only in cases where traditional treatment has a poor chance of success: 65–70% TBSA full-thickness burns. Likewise, elderly patients, whose donor sites often do not heal, and very young patients, who have extremely thin skin, could be good recruits for the method. However, survival is not the only standard by which a new technique should be judged. There are many other considerations, e.g. cosmetic and functional rehabilitation, which are important end points.

To recap, the CEA is expensive to use and very sensitive to infection. It requires meticulous wound care and more professional time and effort than procedures with conventional autografts; but it still remains an irreplaceable technique which with correct use is able to save lives. Although keratinocyte cultures are a tremendous step forward for modern applied biology, as the dermis is believed to protect against secondary wound contraction and scar formation in the final wound-bed, the best alternative to autograft skin replacement would be bilayered grafts consisting of overlying epidermis attached to underlying dermis. Research has to move in this direction. Thus, wound coverage coupled with a reduced rate of sequelae could be the next step in using *in vitro* epidermis production.

63
Development and clinical application of keratinocytes cultured on a hyaluronic ester membrane in burn patients

L. DONATI, L. ANDREASSI, L. CASINI, S. GARBIN, A. M. VERONESI, M. MARAZZI, M. N. ORDANINI and P. TADDEUCCI
Institute of Plastic Reconstructive Surgery, University of Milan and Institute of Dermatology, University of Siena, Italy

INTRODUCTION

The availability of donor sites for autografting may be severely limited in patients with extensive skin thermal injuries. An alternative approach for increasing the availability of tissue suitable for grafting is the expansion of the patient's own skin by *in vitro* culturing. Cultured keratinocytes have been widely used in treating burns, but have not completely solved the problem because they do not take easily. This seems mainly due to infections, the difficulty of handling the thin epithelial sheets and inadequate preparation of the recipient site. Research has recently been concentrated on carriers or composite laminae consisting of keratinocytes cultured on suitable substrates. In this chapter we report an original model of reconstructed epidermis consisting of keratinocytes grown on a new biomaterial, a hyaluronic acid ester derivative.

MATERIALS AND METHODS

The biomaterial consisted of 100% benzyl ester of low molecular weight hyaluronic acid (Hyaff 11, Fidia Advanced Biopolymers, Abano Terme, Italy). On our request it was provided as flexible transparent sheets, 20 μm thick, with 40 μm and 2 mm diameter perforations. The idea of the micro and macro holes was to facilitate drainage under the graft of the exudate from the raw recipient site after surgical escharectomy, which so often impedes take and keratinocyte dissemination. This biodegradable material seems to assist the scarring process, activating PMNs and chemotactic factors, and interfering with the coagulum fibrin matrix. It allows good growth and differentiation of keratinocytes, as it is one of the few artificial dermis or skin substitutes.

Our study was divided into two stages: preparation of autologous basal keratinocyte primary cultures, according to the Reinwhal and Green modified method[1,2] and MCDB serum free medium according to the Pittelkow technique[3,4]; and seeding of high proliferative keratinocytes (obtained from the first phase) on the hyaluronic derivative membranes for secondary cultures.

After a confluent growth was obtained on the hyaluronic ester membranes, this composite was easily detached without using Dispase II. The time to achieve confluence was evaluated in these cultures. Samples of human keratinocytes grown on membranes were fixed with 10% buffered formalin at different stages of growth and embedded in paraffin for histological examination and fixed in phosphate buffer 2.8% glutaraldehyde, pH 7.4, embedded in a mixture of Epon 812-Araldite for ultrastructural examination.

Some composite membranes were used as an allograft in nude mice. With regard to clinical application, autologous keratinocyte composite membranes were grafted on 16 deep second- and third-degree burned patients, with TBSA ranging from 30 to 60%.

RESULTS

The hyaluronic ester membranes were easy to handle during the various stages of the cultures. They remained transparent and stable in the culture medium, even after 3 weeks, irrespective of the presence of cells. The transparency of the membranes facilitated monitoring of the cultures as they grew. Two days after sowing, colonies of 3–10 cells were already visible and these expanded to reach confluence after 10–12 days. Keratinocytes grew inside the holes. Two days after seeding, most of the holes were already colonized by keratinocytes which continued to grow at a faster rate there than on the membrane surface. In most of the cultures, the holes were full of cells before confluence was reached on the surface of the membrane. Histological studies of the composite laminae showed stratified epithelium with two or three layers of cuboid basal cells and flat cells, often without nuclei in the upper layers. In the perforations, the cells had a basaloid appearance, with frequent mitoses.

Electron microscopy showed multilayered epithelium with few desmosomes and many hemidesmosomes, no Langheran's cells, melanocytes, and early and fast growing keratinocytes in the 40 μm holes. The cells in contact with the membrane were rich in cytoplasmic organules with intermediate filaments arranged mostly towards the periphery of the cell bodies and perpendicular to the membrane. They were in close contact with the underlying membrane by means of structures resembling hemidesmosomes.

The composite grafts were strong, and easy to handle during surgery and presented a good take rate. The composite graft was transparent, allowing easy visual examination of the wound healing process, while the macroholes allow good liquid drainage. Human keratinocytes cultured on hyaluronic ester membranes, showed a high proliferative rate both on the membrane and above all in the 40 μm perforations.

Composite laminae grafted on full-thickness wounds on the backs of nude mice (Balb/C strain) promoted re-epithelialization in about 10 days, encouraging further utilization for human allografts.

The clinical results showed a 70% take rate in seven patients, 30–45% in seven patients and no take in two patients[6,7].

DISCUSSION

The search for new techniques to solve problems related to the clinical application of *in vitro* keratinocytes has shown the need to find a new membrane able to support growth and differentiation of human keratinocytes[8–11]. Compared with other macromolecules used for the preparation of membranes, such as collagen, collagen derivatives, allogenic dermis and silicone, hyaluronic acid should be less immunogenic and prevent viral infections[12–16]. Low molecular weight hyaluronic acid seems to stimulate cell proliferation and it has been shown that esterification of its carboxyl groups does not alter its pharmacological and therapeutic properties. Compared with other composite membranes used as substrates for keratinocyte growth, hyaluronic acid membranes required lower inocula, thus reducing the time necessary for skin expansion. These membranes can be stored dried at room temperature, and they maintain their physical properties during *in vivo* manipulations for cell cultures.

Human keratinocytes seeded on hyaluronic acid membranes grow better than in standard conditions and the histological and ultrastructural characteristics show an important characteristic: haemidesmosoma-like structures. The presence of a junctional organization and the fact that the cytological architecture of this cell layer resembles that present *in vivo* suggest that the basal cells are in a situation preceding the formation of a true dermo-epidermal junction. This is not the case for keratinocytes grown in standard conditions.

Our results are interesting considering their clinical application. The clinical results obtained with hyaluronic acid perforated membranes as carriers are particularly interesting; the early growth in the holes of basal keratinocytes and their tendency to bud below the membranes suggest the possibility of using these perforated membranes as carriers of active proliferating units of epidermal cells, which could migrate below the membranes after their application on the wound.

The factors that determine graft take in burn patients and the strategies that have led to improvement of graft performance need to be discussed. Multiple factors were thought to be responsible for graft loss, including epidermal fragility, heavy microbial density and some types of immune phenomena [17]. Early tangential excision resulting in clean, well-vascularized wound beds shows better graft take than non-excised, chronic granulating wounds grafted at a later stage. Heavy microbial contamination of chronic granulating wounds may contribute to late graft take. It is therefore important to perform microbiological monitoring of burn wounds every 3 days by repeated antibiograms and topograms[18]. Graft take was highest when applied to the face, anterior trunk, legs and arms. It was not so high on posterior surfaces or areas subject to mechanical shearing or pressure forces, although the use of air-fluidized support systems improved take on these surfaces.

Hyaluronic ester membrane can therefore be used as a carrier for keratinocytes in burn patient treatment, in order to favour complete cutaneous reconstruction. The use of these perforated membranes as carriers of human keratinocytes for grafting offers a number of advantages. First of all, the culture can be grafted without enzyme treatment which often damages the cells; secondly, they can be used earlier than standard cultures; thirdly the composite laminae make the graft less vulnerable to external agents. This research is a further step towards production of a 'total' skin consisting of human keratinocyte and artificial or semiartificial dermis, for autografting purposes.

The major cause of graft failure appeared to be infection; and the major questions still to be resolved regard the proper preparation of the wound bed and the development of adequate antiseptics which can be used with cultured keratinocytes.

REFERENCES

1. Rheinwald, J. G., Green, H. (1975). Serial cultivation of strains of human epidermal keratinocytes: the formation of keratinizing colonies from single cells. *Cell*, **6**, 331–344
2. Rheinwald, J. G., Green, H. (1977). Epidermal growth factor and multiplication of cultured human epidermal keratinocytes. *Nature*, **265**, 421–424
3. Pittelkow, M. R. (1989). Cultured epidermal cells for skin replacement. Perspective. *Plast. Surg.*, **3**, 101–105
4. Pittelkow, M. R., Scott, R. E. (1986). New techniques for the *in vitro* culture of human skin keratinocytes and perspective on their use for grafting of patients with extensive burns. *Mayo Clin. Proc.*, **61**, 771–775
5. Compton, C. C., Gill, J. M., Bradford, D. A., Ragauer, S., Gallico, G. G., O'Connor, N. E. (1989). Skin regenerated from cultured epithelial autografts on full-thickness burn wounds from 6 days to 5 years after grafting. A light, electron microscopic and immunohistochemical study. *Lab. Invest.*, **60**, 600–612
6. Rue L. W., Cioffi W. G., McManus W. F., Pruitt B. A. (1993). Wound closure and outcome in extensively burned patients treated with cultured autologous keratinocytes. *J. Trauma*, **34**, 662–668
7. Trabucchi, E., Andreassi, L., Malcovati, M., Tenchinin, M. L., Donati, L., Marazzi, M., Radaelli, E., *et al.* (1991). Ultramicroscopic observations of cultured epithelial sheets before and after grafting for human major burns. *Wounds*, **3**, 83–88

8. Andreassi, L., Casini, L., Trabucchi, E., Diamantini, S., Rastelli, A., Donati, L., Tenchini, M. L., Malcovati, M. (1991). Human keratinocytes cultured on membranes composed of benzyl ester of hyaluronic acid. *Wounds*, **3**, 116–126
9. Odessey, R. (1992). Addendum: multicenter experience with cultured epidermal autograft for treatment of burns. *J. Burn Care Rehab.*, **13**, 174–180
10. Philips, T. J. (1988). Cultured skin graft. *Arch. Dermatol.*, **124**, 1035–1038
11. Philips, T. J. (1988). Cultured skin grafts. Past, present and future. *Arch. Dermatol.*, **124**, 1035–1038
12. Cuono, C. B., Langdon, R., McGuire, J. (1986). Use of cultured epidermal autografts and dermal allografts as replacement after burn injury. *Lancet*, **1**, 1123–1124
13. Cuono, C. B., Langdon, R., Birchall, N., Brittelbort, S., McGuire, J. (1987). Composite autologous allogenic skin replacement and clinical application. *Plast. Reconstr. Surg.*, **80**, 626–635
14. Gallico, G. G. (1990). Biologic skin substitutes. *Clin. Plast. Surg.*, **17**, 519–526
15. Hansbrough, J. F. *Wound coverage with biological dressing and cultured skin substitutes.* Austin: R. G. Landers Co
16. Heck, E., Bergstresser, P., Baxter, C. (1985). Composite skin graft: frozen dermal allografts support engraftment and expansion of autologous epidermis. *J. Trauma*, **25**, 106–112
17. Donati L. (1992). The growth and clinical use of cultured keratinocytes. *Burns*, **18** (Suppl 1)
18. Boyce, S. T., Holder, I. A. (1993). Selection of topical antimicrobial agents for cultured skin for burns: combined assessment of cellular cytotoxicity and antimicrobial activity. *Plastic Reconstr. Surg.*, **92**, 493–500

Teepe, R. G. C. (1993). *Cultured keratinocytes grafting: implication for wound healing.* Den Haag: Pasmans Offestdrukkerij B. V

Woodley, D. T. (1989). Covering wounds with cultured keratinocytes. *JAMA*, **262**, 2140–2141

64
Controlled trial on donor sites: Biocol versus Jelonet

J. EBBEHOJ, B. K. GAVRILYUK*, V. A. MENZUL**, E. L. PAKLIN† and YU. A. ROCHEV†
*Hvidovre, Denmark; *Biocol Ltd., Moscow; **Moscow Regional Children's Burns Center, Lyubertsy, Moscow; †Institute of Theoretical & Experimental Biophysics, Puschino, Moscow, Russia.*

INTRODUCTION

Early and complete healing of donor sites is important for two reasons: the faster they heal, the better the cosmetic result and the earlier they can be reharvested for further transplantation.

This means that rapid healing will shorten the patient's stay in hospital, and sometimes determine survival for patients with extensive burns which require repeated reharvesting from the few available donor sites.

A great variety of dressings, ranging from no dressing at all to complicated multilayered synthetic or biological materials, have been proposed and tested. No universally accepted, ideal material to substitute the epidermis has yet been found.

This chapter presents an early trial of a new material, Biocol, tested against a commonly used and accepted dressing material, tulle gras in the form of Jelonet.

MATERIALS AND METHODS

Biocol (supplied by the manufacturer, Biocol, Puschino, Moscow) is a 0.15 mm thick transparent elastic membrane consisting of synthetic latex incorporated with polysaccharides. It is permeable to water vapour and oxygen. It is sterilized by γ-irradiation. Jelonet (kindly supplied by Smith & Nephew) is a wide-mesh cotton gauze soaked in paraffin, sterilized by γ-irradiation and permeable to water and air.

Skin was taken from experimental sites of almost symmetrical location consecutively by the same surgeon with the same dermatome in the same setting. The donor sites were photographed together with the patient's registration chart. Supplementary donor sites were created if necessary, some distance away in an attempt to allow for discrimination of pain in the experimental sites.

Reharvested donor sites were not included, and no reharvesting was performed in the experimental donor sites.

After application of adrenalin-saline soaked compresses for haemostasis and absorption of the initial exudate, the randomized allocation code was broken and the experimental donor sites were covered with Biocol or Jelonet as indicated, the donor sites were then rephotographed. Supplementary donor sites were covered with dry gauze in seven layers. All donor sites were covered with compresses of gauze or polyethylene foam and bandaged with circular gauze for compression.

After 1–2 days the compression and loose material was removed. None of the dressings was changed, except one by mistake. Seven days after the operation the field was photographed, after which removal the bandage was tried daily. On the day when this was achieved, the healed wound was again photographed and the day was regarded as the day of healing. When the second dressing was removed the patient was again photographed.

To eliminate the possible bias of accumulated discomfort from one donor site to the other we always attempted to remove the Jelonet before any attempt was made to remove the Biocol. All photographs were marked by date.

The dressings on the supplementary donor sites were peeled off layer by layer, and after each peeling the remaining dressing was moistened with a 10% solution of potassium permanganate. In addition to healing time we tried to evaluate if there was any difference in pain and discomfort.

As it had been decided to compare the cosmetic results of the two treatments, no reharvesting was performed in the experimental sites. Before commencement of the experiment it was decided to interrupt the intake of patients if and when sequential analysis (2α: 0.1) showed a result or when 50 patients had entered. A difference in healing time of 24 h was considered relevant.

RESULTS

Fifteen patients were studied, 10 boys and 5 girls, aged from 13 months to 13 years and with burns covering 2–40% of total body area. The donor sites ranged from 30 to 80 cm^2, mainly located on the anterior or lateral aspects of the thighs, with some on the lower legs or the abdomen. The results are shown in Table 1.

One patient, heavily infected when entering the hospital, had severe infection in the donor site, and was excluded from the trial. No signs of

Table 1.

Patient No.	Age (years) sex	Diagnosis	TBSA %	Healing day Biocol	Healing day Jelonet	J-B	3 month cosmetic results
1	7 F	burn	20	10	13	3	B = J
2	11 M	burn	25	10	13	3	B = J
3	4 F	burn	20	12	13	1	B = J
4	1 M	burn	2	11	11	0	0
5	6 M	plastic surgery		15	15	0	B = J
6	12 M	burn	10	13	14	1	J > B
7	4 M	burn	25	11	12	1	0
8	12 M	burn	13	10	11	1	0
9	13 M	burn	12	8	11	3	B = J
10	4,5F	burn	5	12	12	0	B = J
11	5 F	burn	25	9	12	3	0
12	13 M	burn	16	9	13	4	B = J
13	12 M	burn	40			excluded	
14	2,5F	burn	8	8	9	1	B = J
15	5 M	burn	20	8	9	1	B > J

infection were seen in the remaining donor sites, whether experimental or supplementary.

In patient 2 the Biocol dressing on the compressive bandage was mistakenly removed. It was replaced by a new sheet of Biocol with minimal pain to the patient.

The results regarding pain are too unreliable to be published. Seven of the patients were < 5 years of age, and answered in relation to the way the questions were put to them, while most of the remaining patients had supplementary donor sites too close for reliable discrimination when one was more uncomfortable. None of the patients was restricted by the donor sites in normal daily activities.

Three months after healing there was no difference in eight of 10 cases. In one case the Biocol treated area was better and in another case the Jelonet treated area. Owing to travel difficulties around Moscow we were unable to follow up the remaining five patients.

DISCUSSION

The policy of the Moscow Regional Children's Burns Centre is early tangential necrectomy 3–5 days post-burn, down to normally bleeding tissue. This is performed by a rotary dermatome.

The wounds are covered by autografts, expanded up to 1:4. No more than 30% of the total body area is excised in any one session, the patients being operated on repeatedly, with new necroses excised in 3–5 days.

This method necessitates repeated reharvesting from the available donor sites. It can therefore be of critical importance that the donor sites heal quickly.

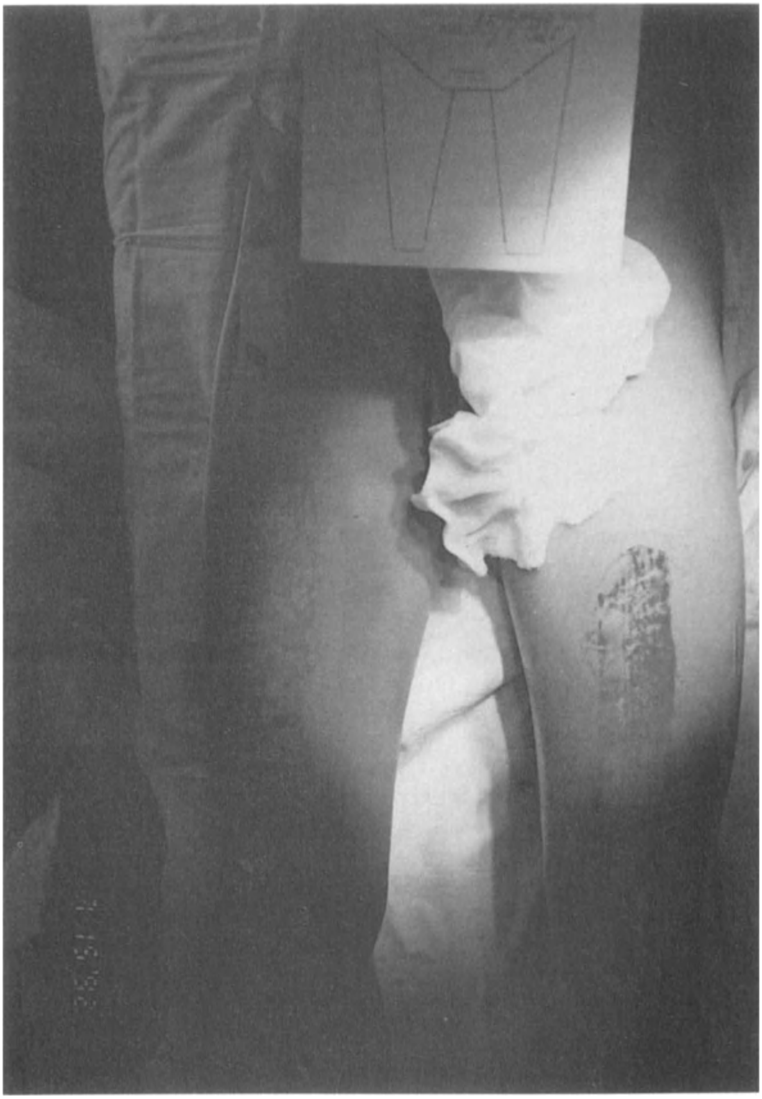


Figure 1. The experimental donor sites of patient 12 immediately after removal of the autografts, 15 July 1992.

It is commonly accepted that a sterile and moist ambience is ideal for healing of partial-thickness wounds (Winter, 1962; Davies, 1984; Hermans and Hermans, 1986) and that occlusion enhances collagen formation (Alvarez *et al.*, 1983). It has not been explained why a rich formation of collagen should accelerate the growth of the keratinocytes needed to cover the collagen of the wound, and some experiments

Figure 2. The experimental donor sites of patient 12 after dressing with Biocol and Jelonet, before harvesting of the supplementary donor sites.

indeed suggest that this is not so (Paulsen *et al.*, 1991). These considerations have not yet produced a wound dressing with a shorter healing time than tulle gras, and the search for the ideal cheap and speedy cover still goes on.

The ideal cover should not provoke pain, and not necessitate changing of dressings, as changing is painful and costly. It should not restrict the

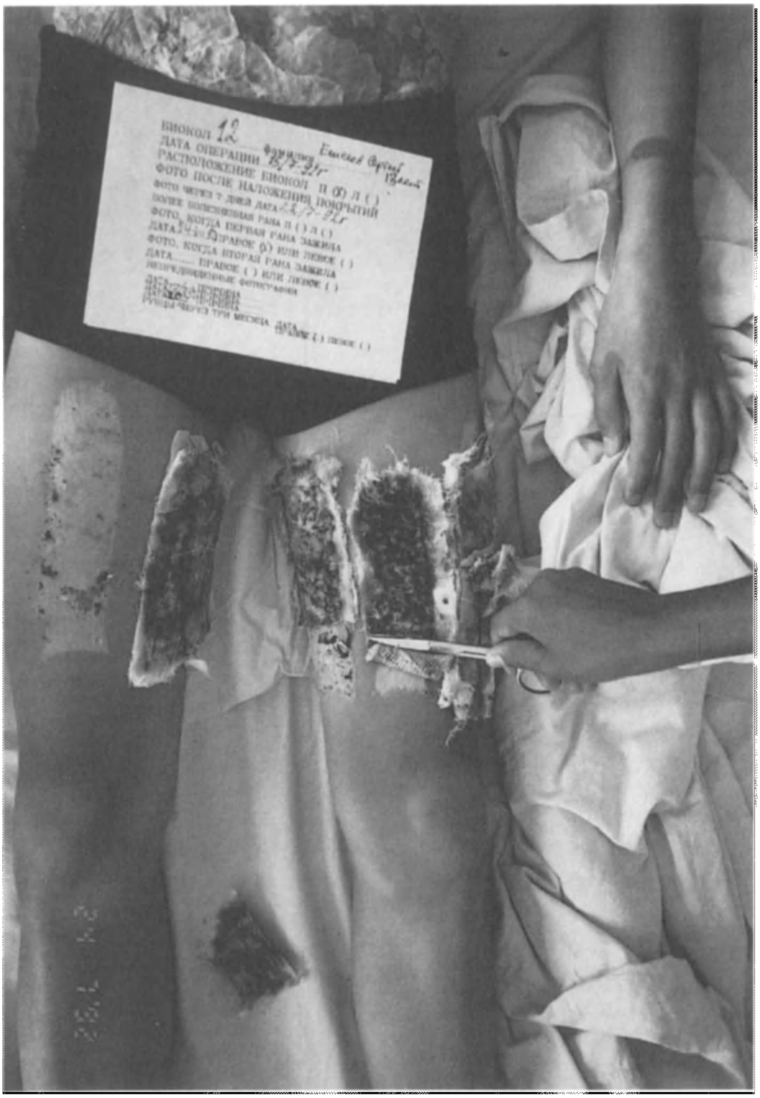


Figure 3. Healing day of the first experimental donor site (Biocol), 24 July 1992.

patients' activity by being bulky or stiff. Toxic and allergenic side-effects are prohibitive. It should clearly give the fastest possible healing.

The differences between Biocol and Jelonet are as follows: Biocol has a very smooth surface, the pores are very small (diameter 3–10 polysaccharide molecules), it is not invaded by the newly formed cells, and thus does not adhere to the cells. It is transparent so that the wound is fully visible through it.

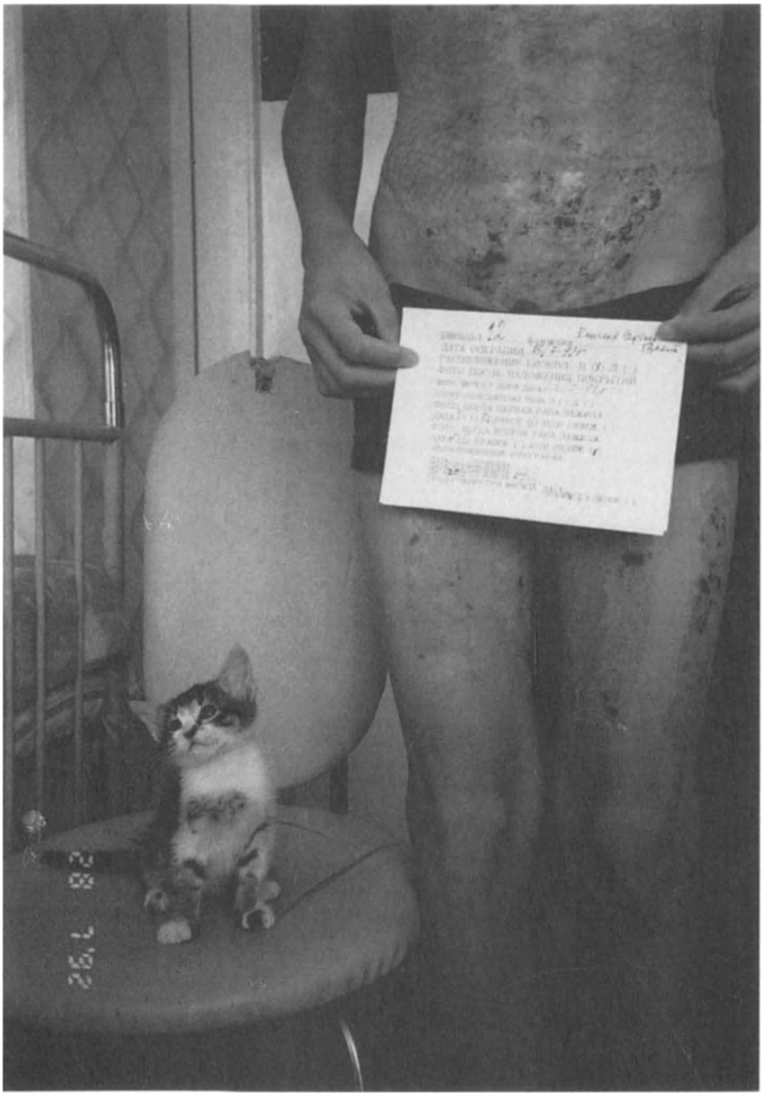


Figure 4. Healing day of the last experimental donor site (Jelonet), 28 July 1992.

Jelonet is a coarse gauze mesh to which cells and granulation tissue may well adhere. Biocol is permeable to water vapour and air. Jelonet is permeable to water and air.

At present price comparison has no meaning, since the two products come from two economically completely different worlds. But with today's exchange rates Biocol is cheaper by a factor of 5–10.

CONCLUSION

A controlled clinical trial showed that a new semisynthetic dressing gave a slightly shorter healing time in donor sites in 14 patients than the conventional treatment with Jelonet. No conclusion was possible with regard to pain. The cosmetic results after 3 months were identical, and the cost was somewhat cheaper.

REFERENCES

Alvarez, O. M., Mertz, P. M., Eaglestein, W. H. (1983). The effect of occlusive dressing on collagen synthesis and reepithelialization in superficial wounds. *J. Surg. Res.*, **35**, 142–148

Davies, J. W. L. (1984). Synthetic materials for covering burn wounds. Progress towards perfection. Part I. Short term materials. *Burns*, **10**, 94–103

Hermans, M. H. E., Hermans, R. P. (1986). Duoderm, an alternative dressing for smaller burns. *Burns*, **12**, 214

Poulsen, T. D. *et al.* (1991). Polyurethane film (Opsite) vs. impregnated gauze (Jelonet) in the treatment of outpatient burns: a prospective, randomized study. *Burns*, **17**, 59–61

Winter, G. D. (1962). Formation of the scab and the rate of epithelialization of superficial wounds of the skin of the young domestic pig. *Nature*, **193**, 293–294

Section XI

Burn scar management

65
The regeneration of skin sensitivity after extensive burns

M. STELLA, G. MAGLIACANI, M. CALCAGNI, G. C. PANZICA and G. RAMIERI
Divisione Chirurgia Plastica e Centro Grandi Ustionati, Ospedale C.T.O., Turin, Italy

INTRODUCTION

Extensive burns affect the nervous system at all levels. Lesions of the central nervous system, although they may jeopardize the patient's life, will not be considered here. However lesions in the peripheral nervous system may occur in various forms, in all cases accompanied by degeneration and regeneration.

In the rehabilitation phase extensively burned patients frequently complain not only of their scarring but also of poor discriminative sensitivity, dysaesthesia and/or paraesthesia accompanied by peripheral circulatory deficit and dyshydrosis. The localization of the lesions responsible for these symptoms can vary considerably, creating a variety of physiopathological situations when a main nerve trunk, the peripheral plexus or the receptors are involved. The nerve may be damaged directly, as in the case of electrocution or full-thickness burns, when the nerve is subcutaneous (e.g. the sural). The surface plexus is involved when the thermal trauma affects the dermis (second-degree deep and third-degree burns). Receptors may not only be directly damaged by the burn but they may also be affected by scarring processes, which alter their functional characteristics.

The surgeon must therefore carefully analyse the methods for the recovery of sensitivity and evaluate its qualities.

MATERIALS AND METHODS

For this study 15 patients were selected with dermo-epidermic grafts of at least 6 months' standing, together with eight patients with spontaneous burn scarring sequelae. These were studied aesthesiologically by standard tests integrated with the Weber test and the Dellon test. Fourteen patients subjected to reconstructive plastic surgery for other pathologies involving the sacrifice of healthy skin acted as controls for the study.

Skin biopsies were performed and fixed in Zamboni liquid (4% paraformaldehyde and 0.2% picric acid in 0.1 M phosphate buffer) for 12 h at 4°C, washed in phosphate buffer (PBS) and 15% saccharose for 3 days, and then frozen.

The next step was the preparation of 15–30 μm sections processed according to Sternberger's peroxidase-antiperoxidase method (1979). After deactivation of the endogenous peroxidases the sections were incubated overnight with anti-protein gene product 9.5 serum (PGP 9.5, Ultraclone, Cambridge, UK), diluted 1:3200 in PBS. Anti-IgG and PAP complex (Dako) were used (1:50) in PBS for 1 h at room temperature. The peroxidase reaction was developed in TRIS 0.05 M buffer containing 0.02% diaminobenzidine and 0.01% (H_2O_2) per 10 m^3. The immunocytochemical controls were performed: i) by replacing the primary antiserum with normal non-immune rabbit serum, and ii) by omitting the anti-rabbit IgG or the PAP complex.

RESULTS

Normal skin

A large number of nerve structures were seen in normal skin by means of the anti-PGP 9.5 antibody. It is possible to observe a rich subpapillary plexus from which fibres branch out, cross the dermo-epidermal junction and penetrate the epidermis, where their route becomes variable.

Other fibres, at papillary level, form capsulate structures such as Merkel's complexes, Meissner's corpuscles, or simple ball-shaped complexes. Occasionally these structures are in pairs, innervated by ramifications of the same fibre.

Immunoreactive structures were also observed around vases, glands and hair bulbs.

Dermo-epidermal grafts

Examination of grafts of at least 6 months' standing showed a well-established subcutaneous plexus with fasciae running among the dermal papillae in a direction parallel to the dermo-epidermic junction. From this plexus varicose fibres run straight into the epidermis.

Two types of receptors were observed: 1) free dermic endings, and 2) free intra-epithelial endings. The latter, less numerous than the dermic receptors, were situated among the keratinocytes as far as the most superficial strata. In rare cases, immunoreactive structures were observed around the vessels. Capsulate structures were not observed at all.

Scars

The anti-PGP 9.5 antiserum showed in scars the presence, below the dermal papillae, of a plexus with fasciae running parallel to the surface, from which varicose fibres branch off, giving rise to structures of variable complexity; other fibres cross the dermo-epidermal junction and form free endings in the epithelium.

Three types of receptors were observed: 1) free intraepithelial endings, 2) free dermic endings, and 3) Merkel's complexes. The free endings were located among the keratinocytes as far as the most superficial layers.

The Merkel complexes consisted of groups of round and ovoid cells in contact with specialized expansions of a single nerve fibre. The complexes were mostly situated in the basal stratum of the epidermis. No Meissner corpuscles were observed in any case. Immunoreactive structures were also observed around the vessels.

DISCUSSION

Classical histological techniques (in particular silver impregnation) made it possible to carry out the first studies on the nervous system, but they are non-specific and repetitive and unable to resolve certain doubts on the morphology and classification of fibres and receptors. In recent years technical advances in chromatography and electrophoresis have permitted the isolation and study of increasingly purer protein fractions, including the protein gene products. Used as an immunohistochemical marker, PGP 9.5 has proved to be particularly useful for the study of the peripheral nervous system, both in the normal state (Wang, 1990) and when regenerating (Stella, 1990).

Histologically, it is possible to observe that the subpapillary plexus is always well represented in scars and grafts, even though its density does not reach that in normal skin.

Unlike other authors (Dalsgaard, 1989; Wang, 1990) we found some superficial structures, i.e. dermic and intraepithelial fibres. With regard to the receptors we noted the constant presence of free endings both in the dermis and in the epithelium. There were no capsulated receptors either in the grafts or in the scars, but in the latter we observed some rare Merkel's complexes.

CONCLUSIONS

Classical aesthesiology recognized the recovery of sensitivity in the scar, often characterized by dysaesthesia and/or paraesthesia. The present work provides histological confirmation of the presence of superficial sensitive structures.

Regarding grafts, the clinical data to be found in the literature indicated poor recovery of sensitivity, with a protective component described as being like 'feeling through a glove', while the histological data suggested the total absence of superficial structures (Dalsgaard, 1989; Wang, 1990). The present work highlights the presence, in grafts, of fibres and superficial receptors, even if of lower density than in normal skin. Quantitatively speaking, the relative distribution of the structures regenerated in the various anatomical regions is almost equal to normal, although the absolute number may be considerably less.

A study is currently in progress aimed at the correlation of the clinical data and experimental observations.

BIBLIOGRAPHY

Dalsgaard, C. J., Rydh, M., Haegerstrand, A. (1989). Cutaneous innervation in man visualized with protein gene product 9.5 (PGP 9.5) antibodies. *Histochemistry*, **92**, 385

Stella M., Ramieri, G., Anselmetti, G. C., Baracchi, F., Calcagni, M., Panzica, G. C., Teich-Alasia, S. (1990). Dimostrazione di fibre nervose rigeneranti nella cute cicatriziale e trapiantata mediante un anticorpo contro la PGP 9.5. *Riv It. Chir. Plast.*, **22**, 125

Sternberger L. A. (1979). The unlabelled antibody peroxidase-antiperoxidase (PAP) method. In: Sternberger L. A. (ed.) *Immunocytochemistry*, New York; Wiley, p. 104

Wang, L., Hilliges, M., Wiegleb-Edstrom, D., Johansson, O. (1990). Protein gene product 9.5 – immunoreactive nerve fibers and cells in human skin. *Cell Tissue Res.*, **261**, 25

66

Treatment of hypertrophic scars with topical silicone gel

W. W. MONAFO
Washington University School of Medicine, Department of Surgery, St. Louis, MO, USA

INTRODUCTION

Hypertrophic scar (HS) frequently occurs after cutaneous trauma of any cause that extends to or beyond the deep, reticular layer of the dermis. Burn wounds are particularly prone to HS formation, which arguably now constitutes the single most important and most frequent complication of thermal injury. Although partial resolution of HS may take place after a variable period of 6–12 months following trauma, complete or near-complete resolution of HS to a cosmetically satisfactory endpoint in burn patients is infrequent. A variety of treatments of HS exist, but none is consistently effective and some are impractical for use in the widespread HS that is common in burn patients; these include meticulous surgical wound closure, early skin grafting of burns, scar massage, intraluminal corticosteroid injection and radiotherapy. During the last 25 years, custom-fitted elastic compression garments have come into widespread use for the treatment of HS in burn patients (Larson, 1979). These garments, which are unsightly, uncomfortable in hot weather or during exercise and expensive, must be worn near-continuously in order to be effective. A prospective randomized trial of the efficacy of elastic compression garments has not been published, although a recent preliminary report of such a trial (now long overdue) indicated that their use did not influence the rate of burn scar maturation (Chang, 1994).

During the past several years, we have prospectively evaluated the use of silicone gel sheeting as topical therapy, both for the prevention of HS in surgical scars and for the treatment of established HS. We used adjacent or mirror image scar of similar severity as a control site in all patients. The results of these investigations, which were done in collaboration with Drs S. T. Ahn and T. Mustoe, have been published in detail previously (Ahn, 1989; 1991). What follows is a summary of the methods used and the results obtained. Briefly stated, we observed that silicone gel sheeting is effective in a clear majority of patients, both for the prevention and treatment of HS.

METHODS

The study protocols were approved by the Human Studies Committee, Washington University, St. Louis, Missouri. Informed consent was obtained from 29 patients, age 12–44 years who had recently undergone elective surgical procedures and were therefore at risk of developing HS, and from 19 patients with established hypertrophic scars, whose age ranged from 3 to 78 years, 16 of whom had HS caused by burns.

Surgical incisions

Thirty-two scar pairs were originally entered into the study, but 10 patients (11 scar pairs) failed to complete treatment and could not be assessed. This left 21 scar pairs in 19 patients that were assessable. There were 17 women and all patients but two were younger than 40 years of age. There were two Blacks and one Hispanic. The patients were instructed to wear a 0.35 cm thick silicone gel sheet (Dow Corning Silastic Gel, Dow Corning Corporation, Midland, Michigan) on the test area of the scar, which was at least 2 cm in length, for at least 12 h each day, preferably for 24 h, removing it only briefly to clean the scar and wash the gel sheet at least once daily. The gel was held in place by a single strip of adhesive tape. No treatment or dressing was used on the control portion of the incisions. In addition to clinical observations and photographs, the volume of these scars was measured at study entry and after 1 and 2 months, respectively using vinyl polysiloxane to make duplicate negative impressions of the scar. Thirty minutes or more after the polysiloxane paste had set, the impressions were filled with a mixture of 5 g of dental stone and 2 ml of water. One hour later, the resultant positive scar impressions were removed and dried to a constant weight for at least 24 h. The impressions were then scraped to the level of the normal, adjacent skin using a scalpel and the impressions re-weighed. The average weight of each scar site was then computed and converted to scar volume using the previously determined volume/weight ratio of the dried dental stone (0.51 mm^3/mg). All steps in the measurements of scar volume were performed by a blinded observer.

Established hypertrophic scar

These patients also were instructed to wear the gel bandage for at least 12 h daily, preferably removing it only once or twice daily for washing and cleansing. The treatment was continued for at least 2 months. In addition to photographs and clinical observations, a previously described instrument – the elastometer – was used to measure the elasticity of the scar (Bartell, 1989). Six elastometric measurements were taken of each scar and averaged. The measurements were made at study entry and at monthly intervals subsequently. Normal human skin displays between 30–42% stretch, with a standard deviation of 7%. However, when six measurements are made and averaged on each site in a single patient, the results are highly reproducible with a standard deviation of less than 2%.

STATISTICAL ANALYSIS

The data were analysed with the assistance of the Department of Biostatistics, using the SAS system as implemented on a mainframe IBM computer (SAS Institute, 1985). A repeated measures analysis of variance was used to compare baseline values with those at subsequent times. The sign-rank test was used to compare the differences in volume between control and test pairs, as these data were non-parametric.

RESULTS

Patients with surgical incisions

At study entry, test and control scar volumes, as anticipated, were the same ($p = 0.26$). After 1 month of silicone gel treatment, however, control scar volumes were already proportionately larger than test scar volumes ($p = 0.03$). After 2 months, control scar volumes were also greater than the scar volumes in gel-treated patients, but at a considerably higher level of statistical significance than at 1 month ($p = 0.003$). The repeated-measures analysis of variance also showed a treatment-time effect on gel-treated scar volume ($p = 0.03$). Control scars were between 25% and 75% larger in volume than the gel-treated ones at the end of the 2 month treatment period. In absolute terms, the volume of control scars ranged between 4.6 mm^3 and 82.4 mm^3 larger than those treated with silicone gel sheets. Transient minor contact dermatitis was the only complication noted. It promptly resolved with more careful hygienic measures.

Established hypertrophic scar

Gel-treated test and control sites were equally elastic at study entry ($p = 0.89$). No significant increase in the elasticity of the untreated control scars was observed during the remainder of the study. It contrast, however, the elasticity of silicone gel-treated scars improved progressively. After 2 months of treatment, the treated scars were clearly more elastic than the untreated control scars ($p = 0.001$). Clinically, the appearance of treated scars was also improved, as assessed by both the patients

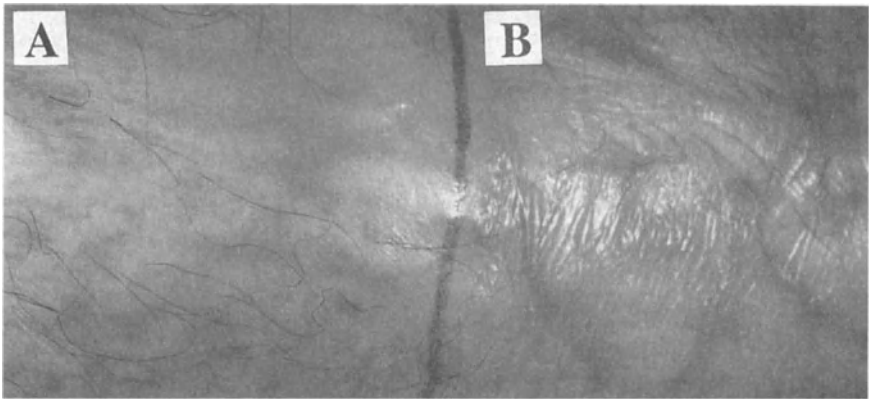


Figure 1. The appearance of an hypertrophic burn scar on the upper limb after treatment with topical silicone gel (A). The adjacent control site is shown in B

and the investigator (Figure 1). In six patients, who had completed the 2 months study period, treatment was stopped for 1 month and then resumed for several months more; subsequent changes in scar elasticity were not observed, however, suggesting that a wearing time of 2 months is sufficient and that recurrence of the hypertrophy when the gel treatment is withdrawn is infrequent.

DISCUSSION

These data show that topical silicone gel has measurable efficacy, both in minimizing the severity of subsequent HS in patients with surgical incisions (and presumably as well in burn patients who have not yet developed HS), and in promoting the resolution of HS in patients in whom HS has already developed. In this study, most of the subjects with established HS had originally sustained burn injury.

The mechanism of action of silicone gel is not known. It does not appear, however, that a pressure effect is operative as the pressure exerted by these light-weight sheets is less than a few mmHg (Quinn, 1987). In fact, two patients in this study who previously had failed to respond to protracted therapy with compression garments (which exert about 30 mmHg pressure) responded to the silicone gel. Changes in scar water content, which could reduce scar volume, have not been directly measured to our knowledge, nor has transcutaneous absorption of silicone been demonstrated. However, the possibility that a chemical reaction takes place in the scar has not been completely excluded. The side effects we observed were minimal. Careful attention to hygiene essentially eliminated the contact dermatitis, which in any event was mild. We recognize that our studies involved only small areas and that the practicality of this treatment on extensive areas on HS has not yet been established.

There was a trend for the response of established HS to be greater in those patients in whom the interval between the original injury and the onset of the therapy was the shortest. This observation requires additional study, however.

BIBLIOGRAPHY

Ahn, S. T., Monafo, W. W., Mustoe, T. A. (1989). Topical silicone gel: A new treatment for hypertrophic scars. *Surgery*, **106**, 731–787

Ahn, S. T., Monafo, W. W., Mustoe, T. A. (1991). Topical silicone gel for the prevention and treatment of hypertrophic scar. *Arch. Surg.* **126**, 499–504

Bartell, T. H., Monafo, W. W., Mustoe, T. A. (1989). A new instrument for serial measurements of elasticity in hypertrophic scar. *J. Burn Care Rehab.*, **9**, 657–660

Chang, P., Laubenthal, K. N., Lewis, R. W., *et al.* (1994). Prospective, randomized study of the efficacy of pressure garment therapy in burn patients. *Proc. Am. Burn. Assoc.*, **26**, 39

Larson, D. L., Huang, T., Linares, H. A., *et al.* (1979). Prevention and treatment of scar contracture. In: Artz, C. P., Moncrief, J. A., Pruitt, B. A. (eds.) *Burns – A Team Approach.* Philadelphia: Saunders, pp. 466–491

SAS Institute Inc. (1985). *SAS User's Guide: Statistics.* 5th edn., Cary, NC: SAS Institute, p. 956

Quinn, K. J. (1987). Silicone gel in scar treatment. *Burns*, **13**, 933–940

67

Burn scars: prevention and treatment with elastic compression

P. DE SANTIS, P. VERRIENTI and A. SAVOIA
Ospedale Regionale, A. Di Summa, Brindisi, Italy

INTRODUCTION

Hypertrophic scars and contraction are frequently encountered sequelae in the recovery phase of deep burns. There is a histomorphological correlation between granulation tissue and the evolution of scars. The absence of elastic fibres is a characteristic of the developing hypertrophic scar. When they begin to appear the scar begins its involutive phase, characterized by the progressive orientation of the collagenous fibres parallel to the skin surface, by the lengthening of the nodules and spirals, and by the reduction of fibrovascular activity. The developing hypertrophic scar presents features that make it comparable to fibrocellular hyperplasias and non-specific inflammatory processes.

The true cause of burn-related hypertrophic scars is not yet well understood, but a number of factors are probably involved. For unknown reasons, the biochemical reactions following collagen production and the chemicophysical reactions due to the accumulation of collagen in a burn in the cicatricial phase are usually exaggerated in burn patients. As well as the chemical anomalies, hypertrophic scars appear to be partly due to a chronic inflammatory reaction. The number of bacteria, which is always high in an open burn lesion, is rapidly reduced by application of skin grafts and falls practically to zero within a few hours.

When reconstructive operations are performed in the thick hypertrophic scar phase it is possible to isolate viable bacteria from the deepest part of the scar tissue even after a period of some weeks. This would suggest that some hypertrophic scars are caused by the continued presence of bacteria which are not eliminated for several weeks.

MATERIALS AND METHODS

Correct surgical treatment, the degree of graft take and continuous elastic pressure are important factors for preventing hypertrophic scars.

ELASTIC COMPRESSION

In the 2-year period 1990–91 we treated 180 patients with deep burns to 30% of the body surface area using the technique of continuous elastic compression; in one group treatment began on day 10 after healing and in another group on day 40 (Tables 1 and 2).

Depending on the condition, the treatment of scarring can be either non-surgical (pressure garments, splints, silicone gel, steroid therapy in small keloids, physiotherapy) or surgical (Z-plasty, flap transposition, skin expansion, free grafts) (Figures 1–8).

Table 1. Patients treated with elastic pressure

No. patients	70	110
Treatment initiated (mean day)	10	40

Table 2. Results obtained (%)

Excellent	70	30
Good	10	40
Poor	20	30

DISCUSSION

Analysis of case histories indicates that the fundamental factors necessary for good results are the following:

1. Early application of pressure, i.e. as soon as the skin grafts have taken and before the scar is organized. The results obtained in established hypertrophies are different from the results in scars still in the organization phase; there is a direct relationship between results and the time of application. Continuous elastic compression was applied to hypertrophic scars using specially made-to-measure garments worn 24 h a day for at least 6–8 months and then 12 h a day for another 4–6 months until the scar appeared to be mature. When this technique was delayed until hypertrophy was already well developed and in the evolutive phase, the results were less satisfactory because the structures were partially organized. Application also had to be prolonged for as long as 18 months.
2. Correct application. Elastic compression is effective only if it reaches a mean pressure of 60 mmHg. There is a direct relationship between pressure and results. Slight hypertrophic scars are occasionally observed in the dead spaces – the interscapular, supraclavicular or lumbar zone and the nasogenial fold, where the underying bone structures prevent the garments from adhering properly.

Figure 1. Deep burn caused by molten iron

Figure 2. Result after topical therapy and elastic compression for 7 months

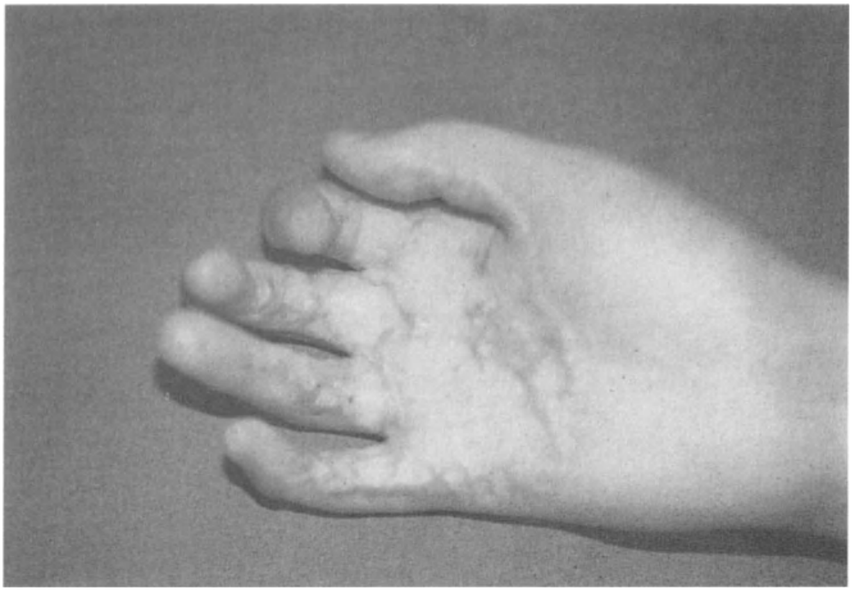


Figure 3. Scar contracture after free graft

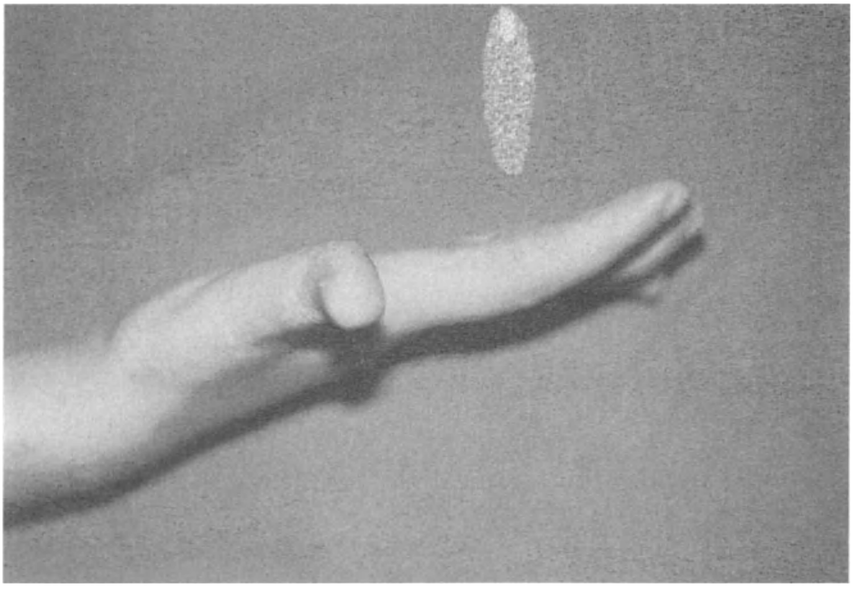


Figure 4. Result after multiple Z-plasty surgical therapy and orthopaedic splint for 12 months

Figure 5. Severe left mammary areola scar contracture following burn

Figure 6. Repositioning of areola in situ

Figure 7. Contracting scar in right submandibular region (use of skin expander)

Figure 8. Excision of scar contracture and free movement of flap

3. Patient compliance is central to success of the therapy. The physician has to persuade the patients, slowly and gradually, that pressure garments are not simply a shield covering their scars but a therapeutic instrument which will decide the functional and aesthetic results. Early compression prevents the formation of nodules and spirals and it immediately orients the collagenous fibres parallel to the skin surface, causing artificial ageing of the scar.

Surgical therapy will be necessary to complete treatment in cases which for various reasons have not been resolved by non-surgical methods.

BIBLIOGRAPHY

Bruster, J. M., Pullium, G. (1983). Gradient pressure. *Am. J. Occup. Ther.*, **37**, 485

Deitch, E. A., Wheelahan, T. M., Rose M. P. *et al.* (1983). Hypertrophic burn scars: analysis of variables. *J. Trauma*, **23**, 895

Harries, C. A., Pegg, S. P. (1989). Measuring pressure under burns pressure garments using the Oxford pressure monitor. *Burns*, **15**, 187

Leung, P. C., Ng, M. (1980). Pressure treatment for hypertrophic scars resulting from burns. *Burns*, **6**, 244

Leung, K. S. *et al.* (1984). Complications of pressure therapy for post burns hypertrophic scars. *Burns*, **10**, 434

Reid, W. H., Evans, J. H., Naismith, R. S. *et al.* (1987). Hypertrophic scarring and pressure therapy. *Burns*, **13**, 329

Robertson, J. C., Bruett J. E., Hodgson B. *et al.* (1980). Pressure therapy for hypertrophic scarring: preliminary communication. *J. R. Soc. Med.*, **73**, 348

Rose, M. P., Deitch, E.A. (1985). The clinical use of tubular compression bandage. *Burns*, **12**, 58

Wachtel, T. L., Frank, D. H. (1984). *Burns of the Head and Neck*, 1st edn. Philadelphia: W. B. Saunders

68
The extended deep inferior epigastric flap: a spearhead to charge into the most resistant sites

M. KADRY, A. A. NOURELDIN and I. G. KHALIFA
Plastic Surgery Unit, Faculty of Medicine, Cairo University, Egypt

INTRODUCTION

The epigastric vascular arcade supplies a wide area of the anterior abdominal wall and exhibits a strategic location providing a highly versatile multicomponent flap that can bridge defects from chest to knees (Brown *et al.*, 1975). The vascular tree of this part of the body is a link between the subclavian vessels (via internal mammary and superior epigastric vessels), external iliac vessels (via inferior epigastric vessels) and intercostals (via costomarginal vessels) (Boyd *et al.*, 1984).

These excellent communications between such sizeable vessels ensure a highly vascular territory and hence construction of a safe transfer of various tissue (Corlett and Taylor, 1980). One of the best uses of this vascular arcade is the extended inferior epigastric flap (EIEF) (Boyd *et al.*, 1984) which is a multicomponent transfer formed of axial component (inferior epigastric vessels), muscular component (rectus abdominis muscle), fasciocutaneous component (of vessel dispositions and locations), and a bony component (9th or 10th rib). The resulting flap is long (nearly 1/4 of body height), narrow based (trunk of inferior epigastric vessels), and reaches as far as chest, breast, anterior trunk, perineum, posterior trunk, flank,. groin and thigh down to ipsilateral knee (Mixter *et al.*, 1989).

MATERIALS AND METHODS

Thirty patients with various defects were treated using the EIEF during the period 1989–1992 in the Kasr-El-Aini and Al-Salam Hospitals, Egypt.

Twelve cases were groin defects, 10 of which were contracted scars treated by release and/or excision, one case was epithelioma of the vulva and groin fold treated by radical vulvectomy, and the last was a histiocytoma of the groin excised with a safety margin. All defects were covered using the EIEF and donor site closed primarily.

Five cases of bed sores affecting the trochanteric, iliac crest, and sacral regions were treated by bursectomy, debridement and covered EIEF. One of these was an axial flap based on skeletonized inferior epigastric vessels to enable 120° rotation of the flap to cover a trochanteric ulcer.

Four cases of infected traumatic wounds of the femoral triangle were cleaned and covered by EIEF to save the limbs from risk of secondary haemorrhage.

One case of haemangioendothelioma of the lateral aspect of the thigh, which was excised leaving a large defect, was successfully closed using the EIEF.

Three cases of lacerated wounds around the elbow, with various extents of soft tissue loss and exposure of nerves and vessels and parts of bones, were treated by debridement and primary neurovascular repair and covered by the fasciocutaneous element of the flap only, which was detached 3 weeks later.

Two cases of degloved injury of the forearm were also treated by the same technique.

Two flaps were used simultaneously to cover both hands and distal forearms of a post-burn contracted scar (PBCS) in a 5-year-old child.

One case of above-knee amputation, with exposure of distal end femur, was covered by the EIEF.

RESULTS

In this study 30 flaps were performed to demonstrate the clinical applications and versatility of the EIEF. The flap was successfully used to cover defects of different aetiology and location. One case however developed severe venous congestion and gangrene, while another suffered loss of the distal 5 cm of the fasciocutaneous component (Table 1).

DISCUSSION

It has always been the dream of the plastic surgeon to find an ideal flap that is highly versatile, safe, with a wide arc of rotation, able to reach a distant destination, with rich blood supply, easy design, rapid raising and not bulky. The EIEF seems to top the list of flaps achieving the above criteria (Boyd *et al.*, 1984).

The anatomical study of Taylor *et al.* (1984) showed that the EIEF is nourished by the deep epigastric system that forms the abdominal portion of a vascular railroad which links the subclavian and iliac vessels and provides reliable perforators that permit the raising of several flaps.

Table 1

Site of defect	*No. of cases*	*Aetiology*	*Type of flap*	*Results*
Groin	12	10 PBCS	Pedicled EIEF	Complete survival
		2 malignant tumours	Pedicled EIEF	Venous gangrene (one case)
Gr. Troch	1	Bed sore	Pedicled EIEF	Complete survival
I. crest	2	Bed sore	Pedicled EIEF	Complete survival
Sacrum	2	Bed sore	Pedicled EIEF	Complete survival
Fem. triangle	4	Infected wound	Pedicled EIEF	Complete survival
Lat. thigh	1	Malignant tumours	Pedicled EIEF	Complete survival
Elbow	3	Trauma	Pedicled EIEF	Tip necrosis (one case)
Distal UL	4	2 degloved ing.	Pedicled EIEF	Complete survival
		2 PBCS	Pedicled EIEF	Complete survival
Amp. knee stump	1	Pressure sore	Pedicled EIEF	Complete survival

In our work we found that a skin flap of large dimensions can be raised in one stage. The largest was 36 cm. This was extended to the scapular line, although we lost the distal 5 cm of this flap, i.e. nearly up to the post-axillary line. We also succeeded in raising two other flaps safely to the post-axillary line without any ill effects. The longest flap created by Taylor *et al.* (1983) reached only as far as the mid-axillary line.

The disc in the anterior rectus sheath, necessary to capture the cutaneous perforators, was narrowed by carefully approaching the vessels from both medial and lateral directions. In this way the skin island mobility is increased and hence its arc of rotation. The narrowing of the disc until it carries two perforators is optimum for flap survival, although Taylor *et al.* (1984) harvested only one perforator and luckily the flap survived.

This flap is advantageous in that it has a wide arc of rotation which reaches almost to the ipsilateral knee and contralateral mid-thigh (Gottlieb *et al.*, 1986). In our work we were able to cover a defect following soft tissue sarcoma immediately above the knee on the same side (as done by Gottlieb *et al.*, 1986), to cover a defect over the medial condyle femur following liposarcoma excision.

Lewis *et al.* (1980) described the use of a non-delayed thoraco-epigastric flap for a defect of the upper extremity.

In our work we used the fasciocutaneous element of the EIEF alone to cover the forearm and hand of a child with a defect following excision and release of a PBCS, with preservation of most of the integrity of the anterior abdominal wall. The fasciocutaneous element of the flap proved to be supple, soft, not bulky and is equal to the Chinese flap in many aspects and even superior in having less donor site morbidity.

The versatility of the flap was demonstrated by Taylor *et al.* (1984) in 18 patients, when they used it as a free flap in 15 cases and as a pedicle in three.

Figure 1. (**A**) Trochanteric bed sore

Figure 1. (**B**) Post-operative, 3 weeks

In our work we demonstrated the versatility of the flap as a pedicled flap to cover large defects in the groin, trochanters, forearm and hands, and to reconstruct the vulva and perineum.

Out of 30 cases we had two complications, one with venous congestion and gangrene, most probably due to too much bending of the flap, the other with distal 5 cm flap necrosis due to too much extension of the flap to the scapular line.

The donor defect was successfully closed primarily in all cases without the need to mesh, and no hernia developed in any of our cases, which were followed up for between some months and two years post-

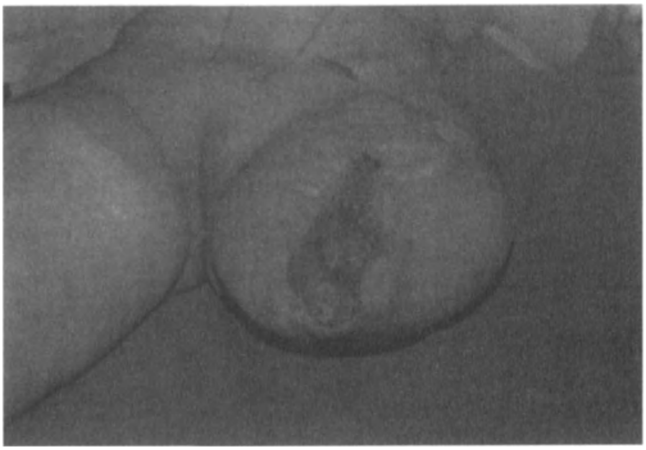


Figure 2. (A) Raw area – amputation stump

Figure 2.(B) Post-operative, 6 weeks

operatively. They all have an accepted scar. In one case we used the two sides to provide two flaps simultaneously to cover post-burn defects in both upper limbs and we closed the donor defects primarily by utilizing the ample tissue reserve provided by the anterior abdominal wall, thus saving the patient much suffering by avoiding a multistaged procedure such as the classical jump flap or some other technique.

With our experience in 30 cases we are convinced that this procedure is safe, speedy and reliable, and that it fulfils almost all the criteria sought by every reconstructive surgeon.

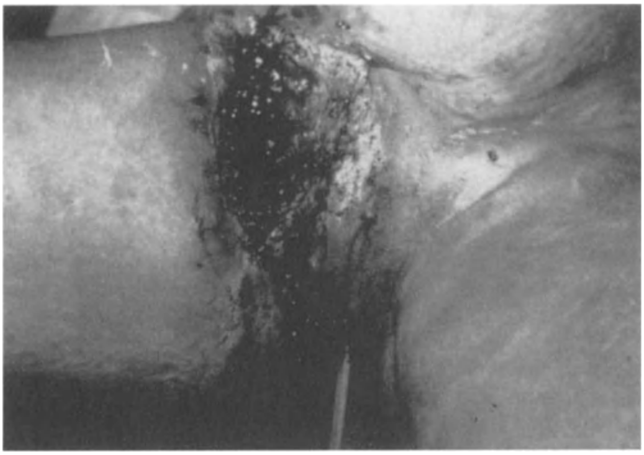


Figure 3. (**A**) Carcinoma of the vulva

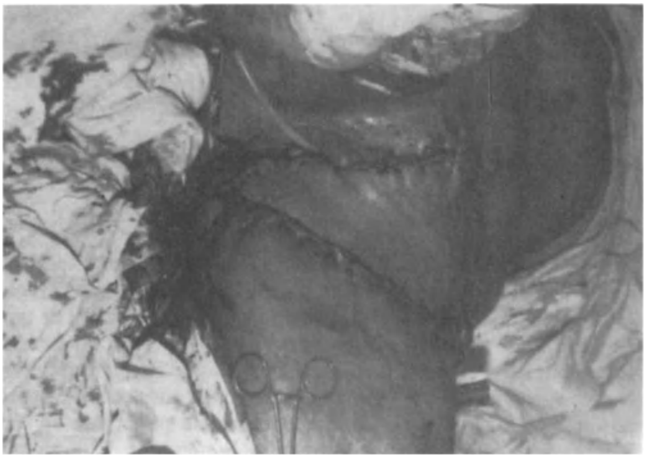


Figure 3. (**B**) Flap in place after excision of the tumour with safety margin and lymphadenectomy

BIBLIOGRAPHY

Boyd J. B., Taylor G. I., Corlett R. J. (1984). The vascular territories of the superior epigastric and the deep inferior epigastric systems. *Plast. Reconstr. Surg.*, **73**, 1

Brown R. G., Vasconez L. O., Jurkiewicz M. J. (1975). Transverse abdominal flaps and the deep epigastric arcade. *Plast. Reconstr. Surg.*, **55**, 416

Corlett R. J., Taylor G. I. (1980). The angiotomes of the body and their relation to local and distant tissue transfer. Paper presented at the British Association of Plastic Surgeons Summer Meeting, July 1980

Gottlieb M. E. *et al.* (1986). Clinical applications of the extended deep inferior epigastric flap. *Plast. Reconstr. Surg.*, **78**, 782

Figure 4. Flap in place after release of a large post-burn contracted scar, right groin

Lewis V. L., Cook J. Q. (1980). The nondelayed thoracoepigastric flap: coverage of an extensive electric burn defect of the upper extremity. *Plast. Reconstr. Surg.*, **65**, 492

Mixter R. C., Wood W. A., Dibbell D. G. (1990). Retroperitoneal transposition of rectus abdominis myocutaneous flaps to the perineum and back. *Plast. Reconstr. Surg.*, **65**, 437

Taylor G. I. *et al.* (1983). The extended deep inferior epigastric flap: a clinical technique. *Plast. Reconstr. Surg.*, **72**, 751

Taylor G. I. *et al.* (1984) The versatile deep inferior epigastric (inferior rectus abdominis) flap. *Br. Plast. Surg.*, **37**, 330

69
The treatment of burn scars in the cervico-facial region with bipedicled expanded flap of the scalp

G. VELLA and G. PASQUINI
Divisione di Chirurgia Plastica, Spedali Civili, Brescia, Italy

INTRODUCTION

In severe extensive burn injures of anterior cervical, jaw and chin regions an important problem is presented by the resulting scar and/or keloid retractions even if very early splints (Cronin, 1964) or pressure garments can now be used. The surgical treatment of large scars comprises several techniques, the most successful of which are cutaneous and fasciocutaneous flaps from cervical, achromial and pectoral surfaces (in this site also myocutaneous), as well as free flaps (Harri, 1974).

In the adult male the anatomical regions mentioned above carry the beard and for this reason the most suitable flaps are those which correct the scar and also provide hairy skin to simulate bearded skin. In burned male patients admitted to our Division with hypertrophic and retracting scars of the chin, jaw and neck, we use skin expansion, inserting expanders beneath the scalp according to Dufourmentel's technique (1959).

METHOD

This flap, cut in the frontal and parietal surfaces of the scalp, extends from one auriculo-temporal region to the other and offers typical arterial flap characteristics as the vascular bundles arise from the superficial and posterior auricular arteries: the flap therefore has good supply, viability and resistance, and also, central to our purpose, hair covering. We therefore used skin expanders which, inserted beneath the scalp in selected sites, increase the surface of the flap without obstructing vascularization. This gives a longer flap and permits direct suture of 80% of the donor site. These features of increased length and surface, by rotation like a viser, make it possible to reach distant regions such as those mentioned above, particularly in dolichocephalic subjects (see case 2). Further corrections can eliminate two small triangular surfaces of alopecia in the temporo-parietal regions covered by graft.

CASE HISTORIES

Case 1

A.S., 19 years old; admitted in June 1986 for hypertrophic scars of the chin. We decided to perform an autonomous scalp flap pedicled on the temporal areas. Two 400 cm^3 skin expanders were inserted between the galea aponeurotica and the periosteum. After 45 days, having achieved highest expansion, we transferred the flap (30 cm × 9 cm) after scar exeresis. Two triangular surfaces in the temporal areas were covered by a graft. After another 20 days the pedicles were detached and returned to their natural sites.

Case 2

A.P., 28 years old; admitted in January 1989 for severe scars of the neck and face. First treatment was the insertion of a 400 cm^3 skin expander between the galea and the periosteum. After 60 days a scalp flap (25 cm × 8 cm) was cut. At the same time the left pedicle was cut to transfer the flap to cover the raw areas of the face and chin. After 30 days the flap was modelled and the right pedicle was returned to the temporal site (Figure 1).

Case 3

H.A., 21 years old; admitted for severe and extensive scars in face and neck. In April 1990 we created a scalp flap (27 cm × 7 cm) and positioned two 400 cm^3 skin expanders. After 30 days we removed the expanders, rotated the bipedicled flap and covered the chin and mandibular areas; the temporal regions were grafted and the vertex sutured. In January 1991 we performed a new expansion of the scalp in the chin area with a 150 cm^3 prosthesis to restore the upper lip and also the hypertrophic scar site; this last operation was performed after 50 days (Figure 2).

COMMENTS

This technique involves a great commitment both by the surgeon and particularly by the patient who will be subjected to at least two

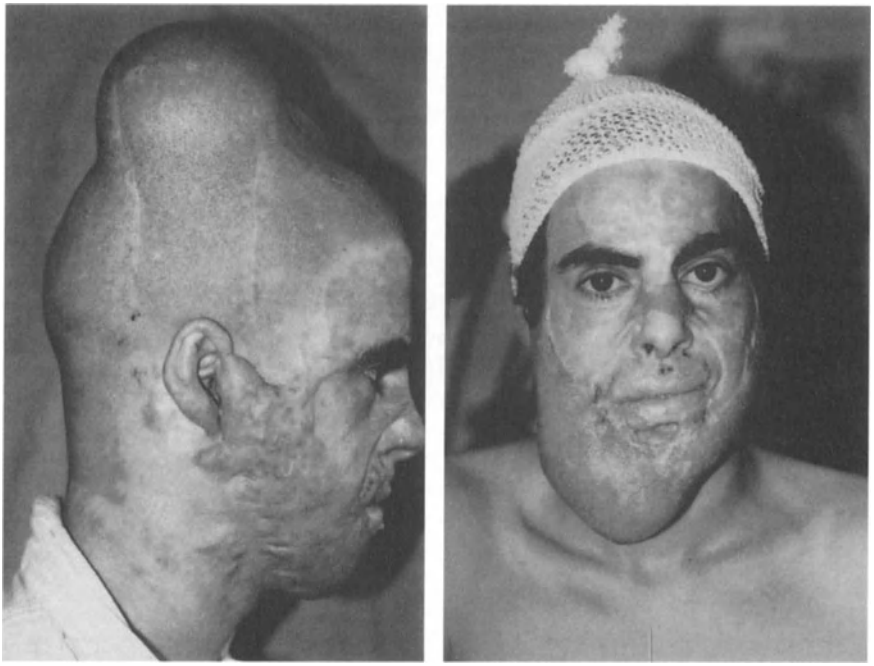


Figure 1. Steps in restoration of upper lip and chin

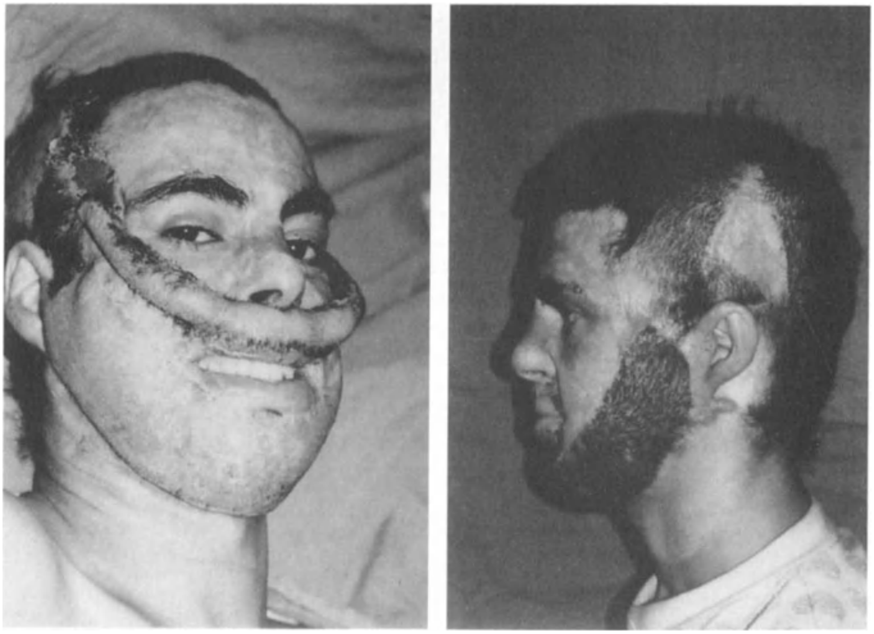


Figure 2. Steps in restoration of face, chin and neck

operations (implant of prosthesis and excision of scar with immediate repair), and to the long period, approximately 45 days, between the two operations, during which time he will be subjected to progressive expansion and therefore have to modify his social relations because of the increased volume of the cephalic extremity and surgical considerations.

BIBLIOGRAPHY

Cronin, T. D. (1964). Deformities of the cervical region. In: Converse, J. M. (ed) *Reconstructive Plastic Surgery, Vol. 3*. Philadelphia: Saunders, pp. 1175–96

Dufourmentel, C., Mouly, R. (1959). *La Chirurgie Plastique*. Paris: Flammarion

Harri, K. *et al.* (1974) Hair transplantation with free scalp flap. *Plast. Reconstr. Surg.*, **53**, 419

70
Tissue expansion in the rehabilitation of head and neck burn sequelae

J. C. CASTEDE and A. BALLANGER
Centre des Brûlés, CHU Pellegrin, Bordeaux, France

Burn scars in the cervicocephalic extremity are clearly visible, often dyschromic, and of irregular texture. Contractures give the appearance of a fixed expression without lines or wrinkles; and the lower part of the face and the neck often presents a hypertrophic aspect or keloids.

However, certain particularities related to the structure and the specialized nature of the skin covering cause some specific aspects:

- cicatricial alopecia;
- destruction of certain structures of great symbolic importance for the human race (pinna of the ear, nose);
- peri-orificial damage, where contracture results in mutilating functional and aesthetic modifications.

Burns have serious sequelae including functional (microstomia, eyelid modifications), aesthetic (the face and neck are always visible and difficult to conceal), psychological (patients who no longer recognize themselves in the mirror modify their identity) and social (due to reactions of family or work colleagues expressed in varying levels of surprise, pity, rejection or morbid interest).

GENERAL PRINCIPLES OF REHABILITATION

Head and neck burn sequelae are in all cases characterized by a skin deficit related to the appearance, localization and surface of the scars and to scar contracture. This deficit can be overcome by coverage with healthy skin of appearance and texture similar to the normal structure of the areas requiring repair. This is particularly evident in the scalp where a natural hair implant has to be performed. It is also necessary to avoid any excess tension that might result in deformation of orifices or other normal structures.

Skin expansion is the best procedure we now have for increasing the availability of skin starting from healthy neighbouring residual areas.

PATIENTS AND METHODS

Patients

We used the skin expansion technique in 42 patients. Sixty-seven prostheses were applied for the reconstruction of head and neck burn sequelae, which represented 35% of all prostheses implanted, with an average of 1.5 prostheses per patient. The patients were equally divided as regard sex (21 males, 21 females), with an average age of 16 years.

Indications (Table 1)

Skin expansion is especially indicated in the treatment of scars and alopecia. Half the patients presented face and neck scars, and over a third had alopecia, while in four patients skin expansion made more complex reconstruction possible (otoplasty in three cases and rhinopoiesis in one).

Table 1. Indications of head and neck skin expansion

	No. patients	*Prostheses*	
		No.	*%*
Alopecia	16	24	35.8
Scars	22	39	58.2
Face	7	14	
Neck	15	25	
Otoplasty	3	3	4.5
Rhinopoiesis	1	1	1.5

Localization of the prostheses

The localization of the protheses is indicated in Table 2.

Analysis of Table 2 shows that the majority of prostheses (32.8%) were placed in the scalp. Face prostheses were placed mainly in the broad surfaces (forehead, cheeks, retroauricular area), while expansion in the upper thoracic and prescapular region (14 prostheses) allowed reconstruction of the cervical region. When expansion was performed on the neck (11 prostheses: 16.4%) the prostheses were placed in front of the platysma cervicalis muscle. There were no functional signs despite their position in relation to the jugular-carotid axis.

In one case, a prosthesis implanted at distance in the iliac fossa made possible an extensive full-thickness skin graft for resurfacing of the face.

Table 2. Localization of prostheses

Scalp	22	32.8%
Face	16	23.9%
Forehead	8	
Cheeks	6	
Chin	2	
Auricular region	3	4.5%
Neck	11	16.4%
Prescapular region and upper thorax	14	20.9%
Abdomen	1	1.5%

Choice of prostheses (Figure 1)

All the prostheses were standard models with implanted distance valve. The majority were rectangular or oval ('waterdrop') in shape (45% and 35%, respectively). The volume of the implanted prostheses ranged from 3.5 to 500 ml, with a mean of 210 ml. Small protheses (< 100 ml; 19 prostheses: 28%) were mainly used in more reduced areas, particularly in the face. Medium-size protheses (100–200 ml; 17 protheses: 25%) were used in larger face areas, i.e. auricular site, cheeks and forehead. Large-volume prostheses (> 200 ml; 31 prostheses: 47%) were used in the scalp and neck.

It is necessary to use the largest prosthesis possible in order to achieve maximum skin gain, as the objective of scar reconstruction is to cover not only the visible surface of the scar but also the skin deficit masked by contracture, which can represent up to 30% additional surface.

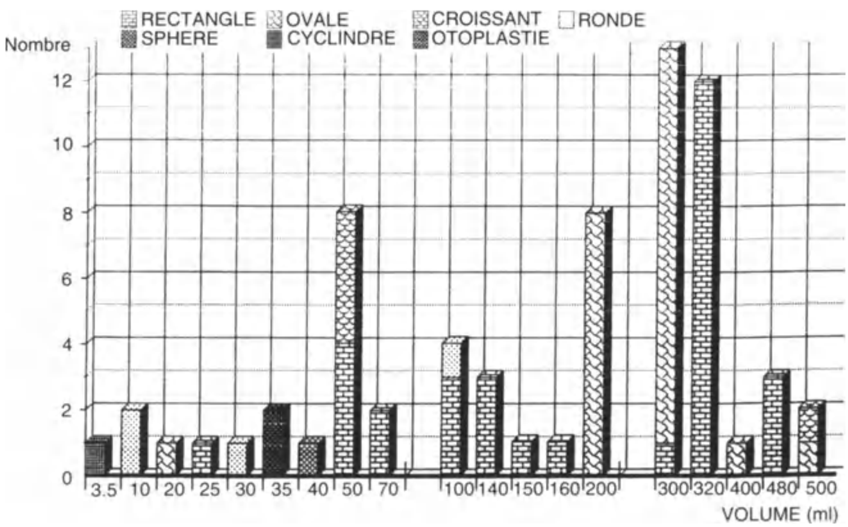


Figure 1. Distribution of prostheses by form and volume

OPERATIVE TECHNIQUE

The operative technique is now well codified and only a few particular points require special mention.

1. The choice of the implant site must be carefully made in relation to the objectives of the planned reconstruction, always bearing in mind the imperatives of plastic surgery.
2. Aspiration drainage is indispensable (generally for 48 h) to prevent the formation of haematomas that may cause detachments and infection.
3. The inflation protocol is classic. It starts 10–15 days after implantation and continues at the rate of two sessions a week for 6 weeks, on average. The operative cycle thus lasts about 2 months.

Overinflation must always be watched for, and at the end of the cycle it is important to pay special attention to the risk of localized ischaemias which are a source of suspended and limited necroses. During this period there is considerable aesthetic and social embarrassment, especially as regards the face, and the patient must be fully informed in advance.

RESULTS

Complications are rare. At the beginning of our experience we had a failure with a prosthesis placed in the prescapular area intended for neck resurfacing. Haematomas (three cases), caused by faulty drainage and the difficulty of checking the site where the prosthesis is lodged, can be prevented by a compressive and haemostatic packing prior to implantation and by initial inflation of the prosthesis to 10–20% of its full volume in order to achieve slight tension without affecting the short or distant route of access.

Minor detachments (six cases) may occasionally occur at the level of the access or at the valve as well as at the level of the salient angles of the prosthesis. However, they are more often due to limited and suspended necrosis secondary to localized ischaemia towards the end of the expansion protocol in skin that has become fragile.

The results are generally consistent with expectations. A few points relative to the technique should however be made.

1. It is rarely possible to achieve an adequate healthy skin gain in just one procedure; several skin expansions are usually necessary to eliminate extensive scars and important contractures.
2. Mobilization of the flaps is facilitated by resection of the periprosthetic capsule on the deep face of the lodge and on the hinge of the flap. This is possible at the latter level because of the divergence between the capsule and the cutaneous vascular network.
3. The flap skin often shows signs of erythrosis. This condition may last for some weeks before it gradually disappears, while the

lamination of the subcutaneous fatty layer caused by expansion appears as tenuity or depression;
4. The scars are often difficult to mask and they sometimes undergo an initial inflammatory process which has to be prevented and treated by pressure therapy.

CONCLUSION

The reconstruction of burn sequelae in the cervicocephalic region by means of skin expansion has proved to be very positive and extremely useful. Skin expansion is a reliable technique but it requires a long operative cycle lasting about 20 months, during which there may be aesthetic and social embarrassment. It is therefore necessary to have the close cooperation and good understanding of the patient. The results are favourable and beneficial in the long term and generally give the patient lasting satisfaction.

BIBLIOGRAPHY

Adamson, J. E. (1988). Nasal reconstruction with the expanded forehead flap. *Plast. Reconstr. Surg.*, **81**, 12–20

Baux, S. (1990). La place de l'expansion cutanée dans les séquelles de brûlures. *Ann. Medit. Burns Club*, **3**, 5–7

Caleffi, E., Bocchi A., Toschi, S., Montacchini, G. and Papadia, F. (1990). Tissue expansion in the treatment of burn scars. *Ann. Medit. Burns Club*, **3**, 177–180.

Cohen, M., Marschall, M. A. and Schaffer, M. E. (1988). Tissue expansion for the reconstruction of burn defects. *J. Trauma*, **28**, 158–163

Cohen, M., Marschall, M. A. and Tsutsos, D. A. (1992). Reconstruction of secondary burn defects of the head and neck with controlled tissue expansion. *Ann. Medit. Burns Club*, **5**, 165–168

Foyatier, J. L., Comparin, J. P., Latarjet, J., Delay, E., Spitalier, P. and Masson, C. L. (1993). Réparation des séquelles de brûlures de la face par expansion cutanée cervicale. *Ann. Chir. Plast. Esthét.*, **38**, 27–33

Hallock, G. G.: Maximum overinflation of tissue expanders. *Plast. Reconstr. Surg.*, **80**, 567–569

Leighton, W. D., Johnson, M. L. and Friedland, J. A. (1986). Use of the temporary soft-tissue expander in posttraumatic alopecia. *Plast. Reconstr. Surg.*, **77**, 737–743

Radovan, C. (1984). Tissue expansion in soft-tissue reconstruction. *Plast. Reconstr. Surg.*, **74**, 482–490

Rougé, D., Grolleau, J. L., Bodi, H., Chavoin, J. P. and Costagliola, M. (1990). Expansion du cuir chevelu dans les séquelles de brûlures de la voûte cranienne: expérience toulousaine. (1990). *Ann. Medit. Burns Club*, **3**, 241–251

Sasaki, G. H. (1990). Tissue expansion. In Jurkiewicz, M. J. *et al.* (eds.) *Plastic Surgery*, vol. 2, New York: C.V. Mosby, pp. 1609–1634

Section XII

Electrical burns

71
Electrical burn injury

M. HABERAL and N. UÇAR
Turkish Transplantation and Burn Foundation Hospital, Ankara, Turkey

INTRODUCTION

The discovery and development of electricity significantly improved the quality of human life and the general socioeconomic structure. However, improper use of electricity causes accidents resulting in a very severe health problem: electrical burn injury, with its severe and sometimes fatal complications. This is an ever present problem that threatens human life in the developing countries. Previous reports from Turkey showed that electrical burns covered a relatively larger part of burns requiring hospital treatment than in other countries (Haberal, 1985; Haberal *et al.*, 1988, 1989; Panayotou *et al.*, 1991). We have in fact had to treat a large number of patients, making up one of the largest series of electrical burn injuries, in the last 13 years, since the establishment of our burn unit. The present study was carried out in order to investigate the epidemiological pattern of patients suffering from electrical burns admitted to the burn unit of the Hacettepe University Hospital in Ankara.

PATIENTS AND METHODS

Between 1 January 1979 and 31 December 1991 1005 patients were admitted to our burn centre. Of these, 208 (20.70%) had electrical burns. All patients were treated according to a multidisciplinary treatment protocol (Haberal, 1985). Following assessment of the extent of the burns, general resuscitatory measures were taken. Intravenous fluid resuscitation was initiated, with the administration of isotonic saline or saline with dextrose solution until the blood electrolyte measurement was carried out, and continued with Ringer's lactate solution, provided that the potassium level was normal. The administration rate was adjusted according to a urine output of at least 50 ml/h. If the patient became oliguric and acidotic, despite appropriate fluid resuscitation, 20–40 g of mannitol and 40–100 mg of furosemide were given and the bicarbonate deficit was restored. If oliguria persisted and potassium, BUN and creatinine levels were rising, haemodialysis following insertion of a double-lumen subclavian catheter (Gambro SCK-102 20 cm, Lund, Sweden) or peritoneal dialysis was performed. This catheter was found to be very convenient also for parenteral hyperalimentation.

Following initial stabilization, the patients were reassessed in the operation room in the burn unit. If necessary, debridement, escharotomy and fasciotomy were performed. Wounds were cleansed and closed using a topical chemotherapeutic agent, such as silver sulphadiazine, mafenide acetate or silver nitrate incorporated amniotic membrane. In severely injured patients, debridement was repeated vigorously until all nonviable tissues were removed. Amputation was performed when salvage of the extremity was impossible. Skin grafts and flaps were used as needed. Psychological and physical rehabilitation was initiated when patients were vitally stabilized, and continued after discharge as necessary (Haberal *et al.*, 1988).

RESULTS

Between 1 January 1979 and 31 December 1991 1005 patients were admitted to the burn unit at the Hacettepe University Hospital, Ankara. Of these patients 208 (20.0%) were suffering from electrical burn injury (Figure 1). Of these 208 patients 146 (70.2%) were over 16 years of age, 51 (24.5%) were between 7 and 15 years and 11 (5.3%) were under 6 years (Figure 2). One hundred and eighty-six (89.4%) of the patients were male and 22 (10.6%) female (Figure 3). The most important complications were amputation and acute renal failure. Fifty-two (25.0%) patients required at least one partial or total amputation of the injured extremity. Thirty (14.4%) patients presented acute renal failure on admission or during treatment. One patient had paraplegia due to T3-T4 fracture. One patient had sustained a femur fracture and three patients a head fracture. Thirty-five patients had fallen as a result of a stroke and 18 patients had cerebral complications. Two patients had cardiac arrhythmia.

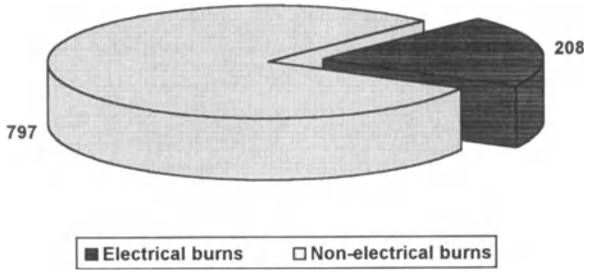


Figure 1. Total number of hospitalized patients (1005)

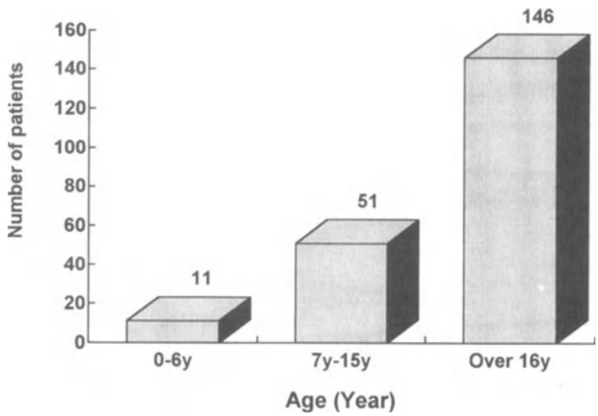


Figure 2. Distribution of patients by age

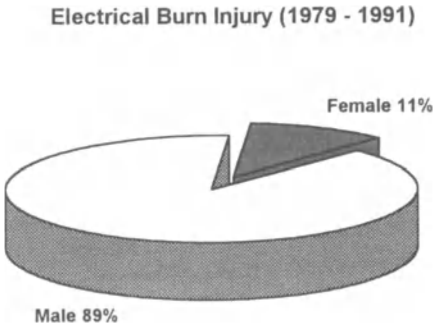


Figure 3. Distribution of patients by sex

Of the 208 patients 45 died of electrical burn injury. Of these 45 patients 26 (57.8%) developed multiple organ failure, including acute renal failure. In 11 patients (24.4%) sepsis was the cause of death. Eight patients (17.8%) died of severe cerebral trauma.

DISCUSSION

Electrical burn injury constituted 20% of the burns admitted on an in-patient basis at our hospital. This rate was very high compared with that reported by authors from other countries (Panayotou *et al.*, 1991; El Danaf *et al.*, 1991; Papp, 1984). This may reflect the higher incidence of electrical burn injury in Turkey (Haberal *et al.*, 1989). The high rate may however be aggravated to some extent because our burn unit is one of the most important referral units for electrical burn injury in Turkey. Also, the country's electricity regulations are poor.

Although most of the patients were over 16 years of age, the number of younger patients was also remarkable, when compared with other series (Panayotou *et al.*, 1991; El Danaf *et al.*, 1991; Papp, 1984). This may be attributed to the lack of parental supervision, since these injuries were usually caused by activities such as riding on top of a train, climbing an electrical pole, coming into contact with a live wire or electrical outlet or cutting the flex of an iron with a pair of scissors. In the over 15-year-old group, environmental factors caused electrical burn injury as well as individual personality factors, such as misuse, inattentiveness and ignorance. Exposed wires and poles placed close to buildings, TV aerials and inadequate safety controls by electrical manufacturing companies were the most important environmental factors contributing to electrical burn injuries (Haberal, 1985).

Musculoskeletal complications and acute renal insufficiency were the most common complications in this series. Musculoskeletal complications led to amputation in one-quarter of the patients because early surgical decompression and sequential wound debridement was not carried out as early as possible owing to the late admission of the patients to our centre. Acute renal failure, the second most frequent cause of death, was found in 14.4% of the patients, even when haemodialysis was performed in emergency conditions when needed. The late admission of the patients also delayed treatment of fluid and electrolyte imbalances as well as the management of acute tubular necrosis due to accumulation of myoglobulin secondary to muscular necrosis. The high incidence and mortality rate of electrical injuries treated in our burn unit, which is one of the leading centres for electrical injury in Turkey, stress the importance of this public health problem in our country. Prevention of electrical injuries requires a coordinated approach on the part of health-care officials and physicians, and of electricity company experts in order to guarantee strict safety measures and to enforce the application of high standards in consumer and industrial products as also in residential and industrial building design.

REFERENCES

El Danaf, A., Alshlash, S., Filibbos, P., Rasmi, M., Salem, S. (1991). Analysis of 105 patients admitted over a 2-year period to a modern burn unit in Saudi Arabia. *Burns*, **17**, 62

Haberal, M. (1985). Electrical burns: A five year experience: 1985 Evans Lecture. *J. Trauma*, **26**, 103

Haberal, M., Öner, Z., Gülay, H., Bayraktar, U., Bilgin, N. (1988). Severe electrical injury and rehabilitation. *Ann. Medit. Burns Club*, **1**, 121

Haberal, M., Kaynaroğlu, V., Öner, Z., Gülay, H., Bayraktar, U., Bilgin, N. (1989). Epidemiology of electrical burns in our center. *Ann. Medit. Burns Club*, **2**, 14–16

Panayotou, P., Alexakis, D., Strigilis, Ch., Ioannovich, J. (1991). Epidemiological data on burn injuries in Greece: a statistical evaluation. *Burns*, **17**, 47

Papp, T. (1984). Electrical burn with complications. *Bull. Clin. Rev. Burn Injury*, **1**, 13

72
Epidemiology, clinical treatment and therapy in electrically burned children

B. NAPOLI, N. D'ARPA, S. GULLO and M. MASELLIS
Divisione di Chirurgia Plastica e Terapia delle Ustioni, Ospedale Civico e Benfratelli, USL 58, Palermo, Italy

---

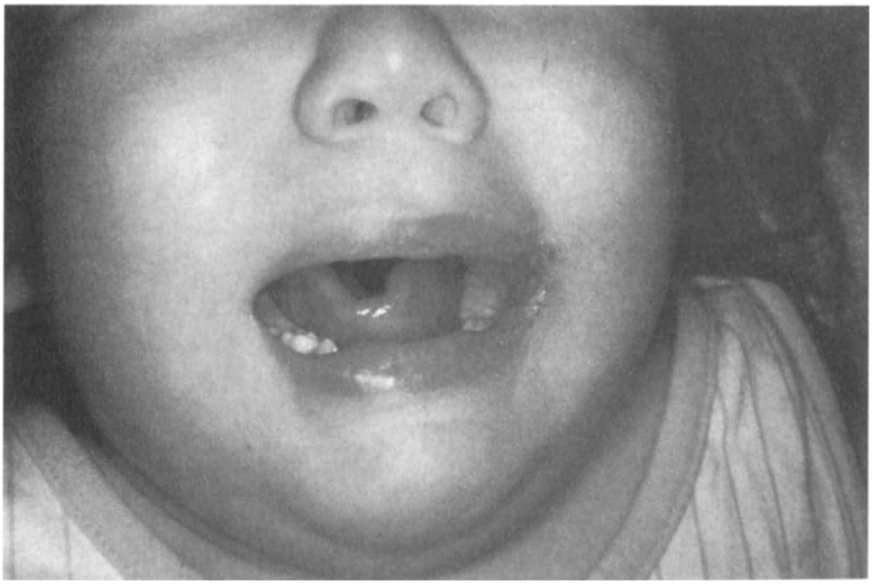
In the period 1975–1991, 132 children suffering from electrical burns were admitted to our burns unit. Boys (73.5%) outnumbered girls (26.5%) with a male/female ratio of 2.7:1. The highest concentration of cases (82, i.e. 62.1%) was in the 0–3 year age group (Table 1). Burns caused by low voltage in the home environment were the most frequent (93.3%). Play activities, such as the recovery of kites or birds' nests on power pylons, caused some high-voltage burns in older children (3.52%; Table 2). The list of causative agents, mainly exposed electric wires (36.3%), power points (33.9%) and electric plugs (8.9%) – all in the home environment – indicates the dangers posed by contact with these electrical agents (Table 3).

Contact generally occurs by direct handling: when electrified objects come into contact with the mouth, the saliva – which is rich in electrolytes – completes the circuit, transmitting the current through body tissues where resistance is lower.

In 103 cases (78%) the lesion was in the hands, in 15 cases (11%) in the mouth, in six cases (5%) in the forearm and wrist, and in eight cases (6%) in other parts of the body (Table 4). Hand burns involved the first and second fingers in 55 cases (53.4%). The percentage of body surface area burned was very limited in all patients but two (1.5%), in whom contact with high-voltage cables caused the ignition of clothing, resulting not only in electrocution of the forearm and wrist but also an extensive fire burn to 20% BSA in one case and 15% in the other. In all cases burns were third degree or associated second and third degree.

A total of 78 (59.1%) patients received exclusively medical treatment, while 54 (40.9%) were treated surgically (Table 5). Forty of the surgically treated patients (74.1%) underwent early surgery (within 20 days post-burn) while the other 14 (25.9%) had late surgical treatment. Seventy-eight non-definitive surgical procedures (escharectomy, escharectomy

Figure 1. G.G., age 1, girl
(**a**) necrosis due to electrocution of tongue and left labial commissure



(**b**) lesion in advanced state of cure after conservative treatment

Table 1 Distribution by age and sex

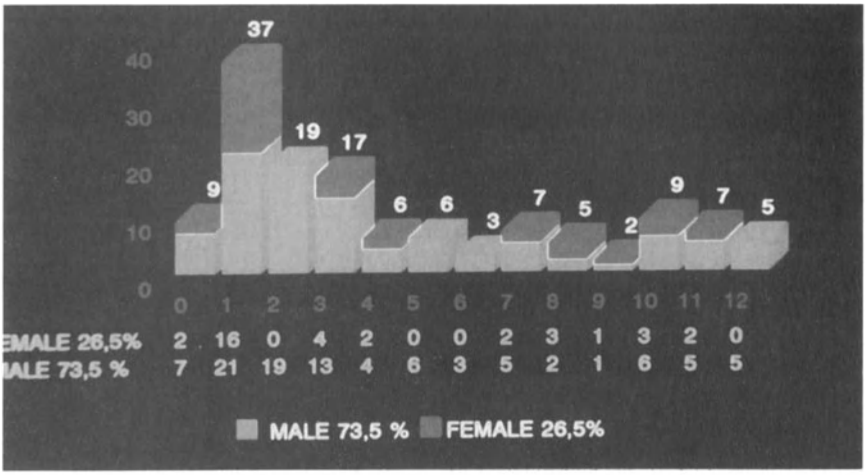


Figure 2. G.G., age 11, boy
(**a**) necrosis due to electrocution of scalp

Figure 2 (**b**) exposure, after escharectomy, of cranium; design of rotation flap performed on day 15

Figure 3. V.G., age 8, girl
(**a**) electrocution of first finger of left hand with exposure of long flexor tendon

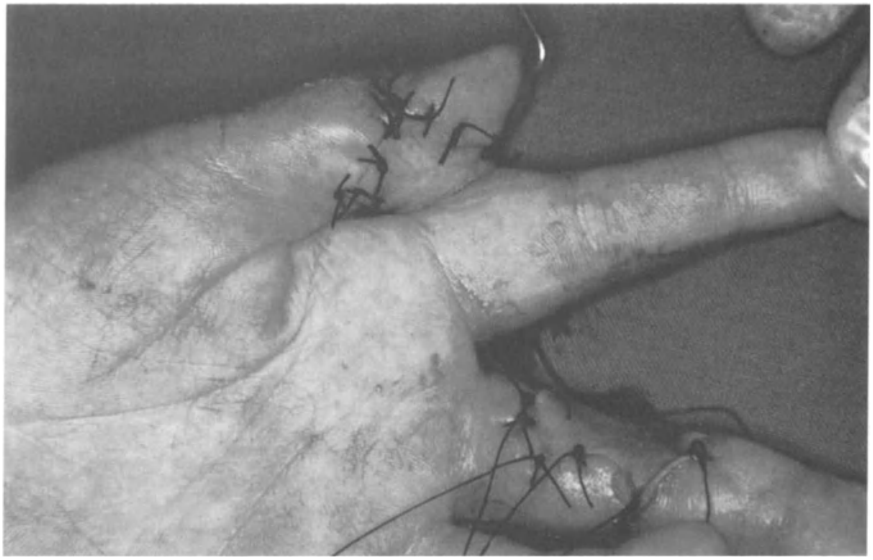
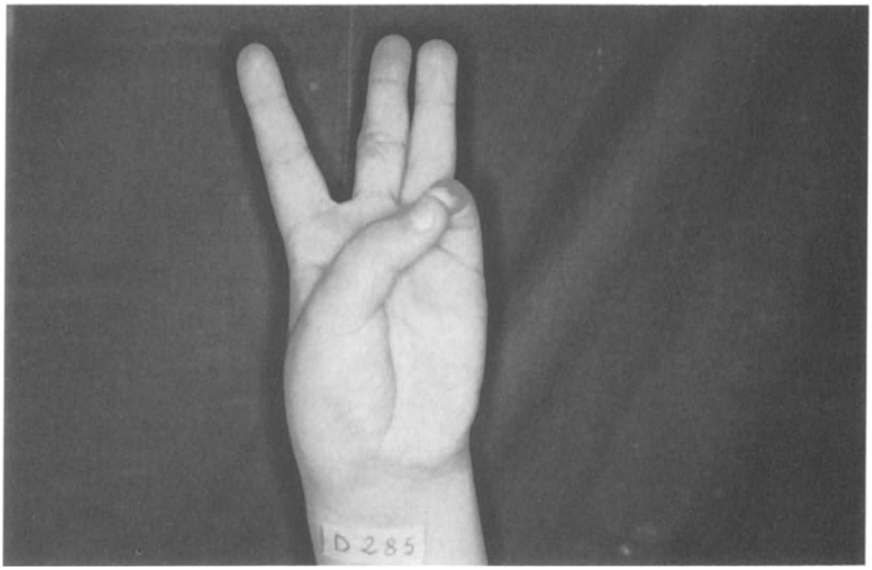


Figure 3 (**b**) cross-finger with second finger performed on day 22



(c) long-term functional recovery

Table 2. Distribution by current voltage

Voltage	*Cases*	*%*
Domestic voltage	124	93.3
High voltage	5	3.52
Not stated	3	2.8

Table 3. Subdivision according to causes

Cause	*Cases*	*%*
Bare electric wires	45	36.3
Power point	42	33.9
Electric plug	11	8.9
Bulb socket	3	2.4
Electric toys	2	1.6
Hairdryer	1	0.6
Not stated	20	16.1

Table 4 Distribution by site of lesion

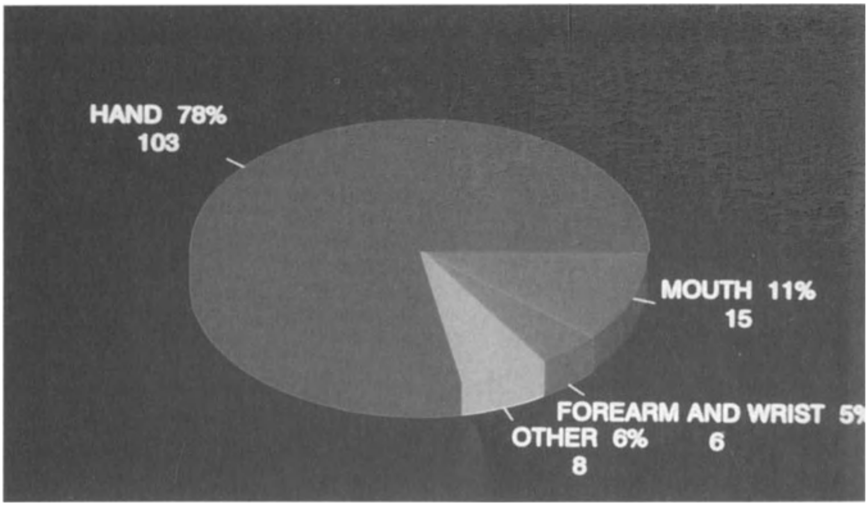
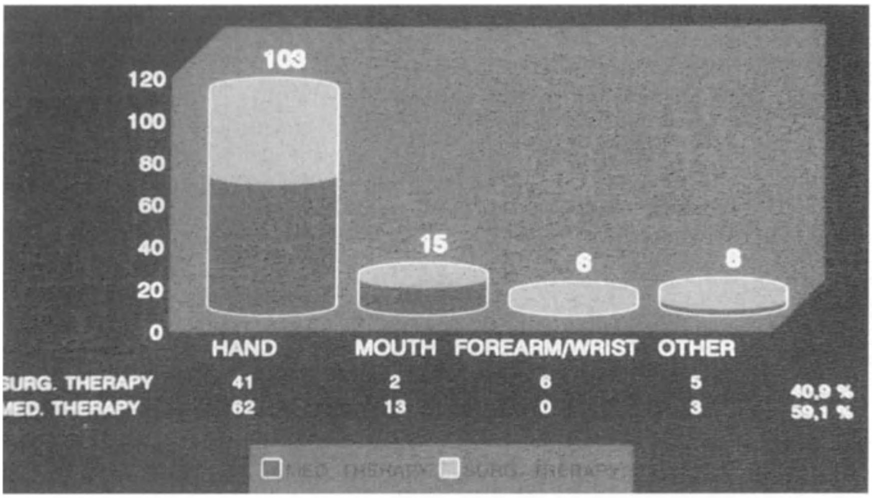


Table 6. Distribution by surgical therapy

Operation	*Hand*	*Mouth*	*Forearm and wrist*	*Other*	*Total*
Suture	0	2	0	0	2
Graft	24	0	1	4	29
Flap	14	0	3	1	18
Minor amputation	3	0	0	0	3
Major amputation	0	0	2	0	2
Total	41	2	6	5	54

Table 5 Distribution by site and therapy



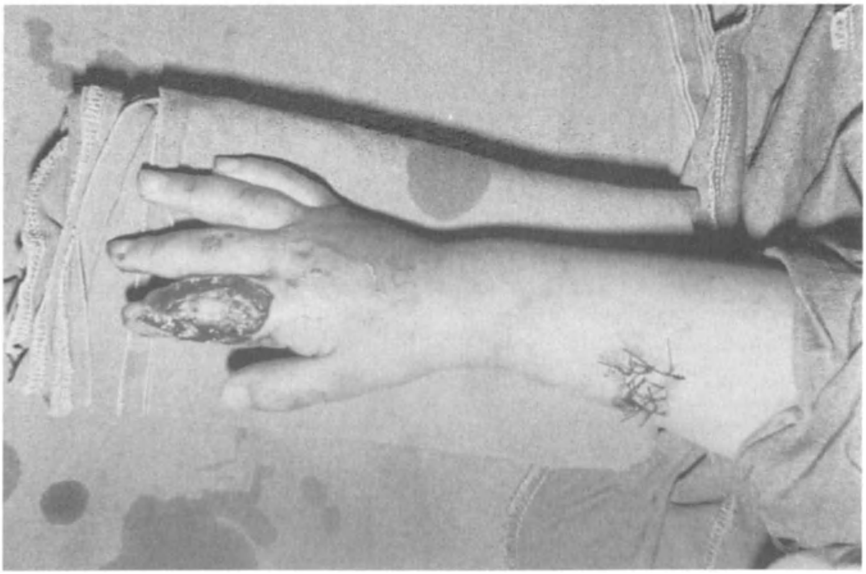


Figure 4. B.M., age 1, boy
(a) destruction of extensor apparatus and articular capsule of proximal interphalangeal articulation of second finger of left hand reconstructed with DERMIS graft from ipsilateral forearm

Figure 4 (b) abdominal pouching on day 12

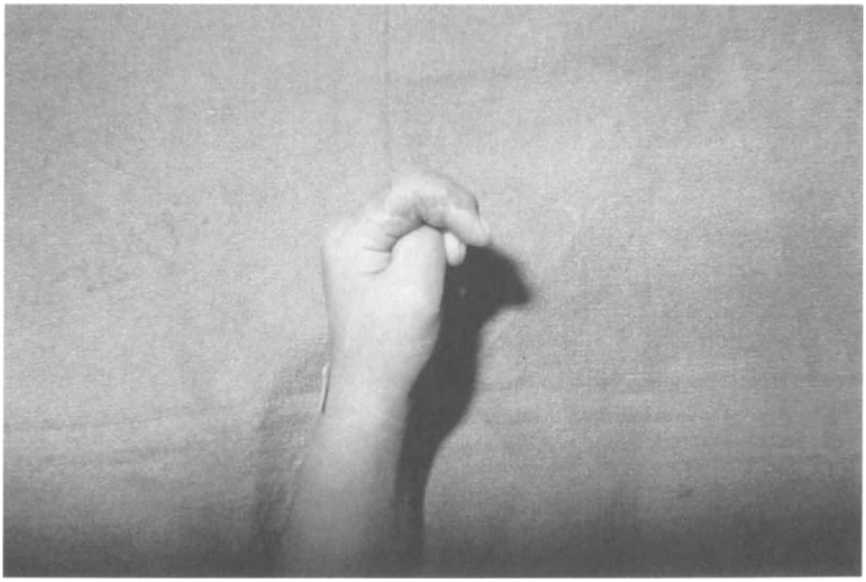


Figure 4 (c) long-term functional recovery

Figure 5. A.C., age 1, girl
(**a**) serious electrocution of first and second finger of right hand with complete destruction of soft tissues subjected to surgical debridement on day 11

(**b**) coverage with groin flap on day 16 after further debridement

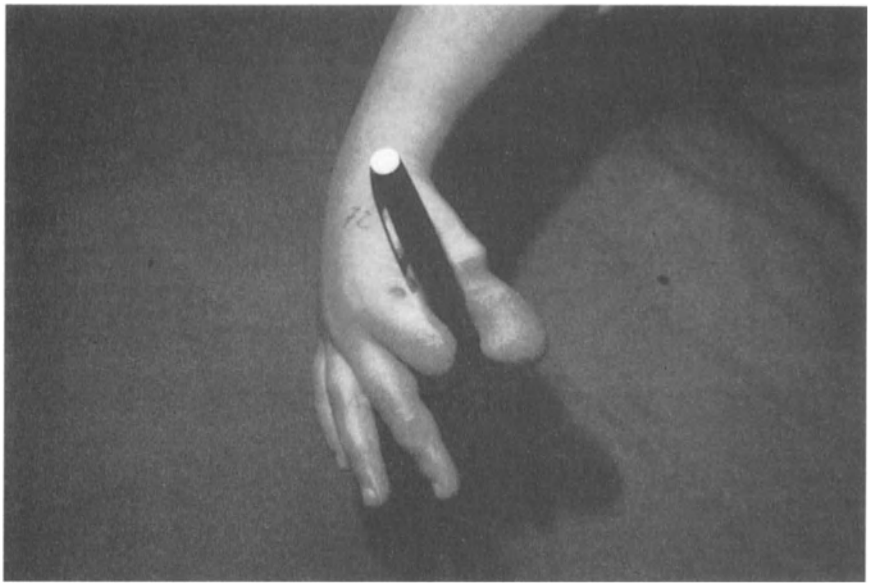


Figure 5 (c) functional recovery

and temporary coverage with free skin graft) and multiple stage operations (flaps) were performed, equivalent to 1.4 per patient.

DISCUSSION

The distribution by age and sex in our patients is consistent with that reported by other authors (Rodrigues *et al.*, 1988). This is also true of the aetiopathogenetic aspects which, considering that we are dealing with children, may be considered typical (contact in the home with objects in a state of low voltage). Also typical, in relation to the aetiopathogenetic aspects, are the site and the characteristics of the lesions, which were mainly in the hands and mouth and, although localized and limited in extension, generally deep (Rodrigues *et al.*, 1988; Kazanjian, 1988; Nahas and Nahas, 1990).

Most of the burns were treated medically: in addition to non-serious lesions many others generally required conservative treatment due to their localization. This is the case of electrical burns to the mouth, especially at commissure level, which can if necessary be treated with secondary reconstructive procedures if functional sequelae develop (Kazanjian, 1988; Feldman, 1990). No surgical procedures were performed in the first post-trauma hours, although this is recommended by some other authors (Luce, 1990; Neale, 1990). However, compared to patients operated late, more patients were subjected to surgery before day 20, when the lesion was considered to be stable.

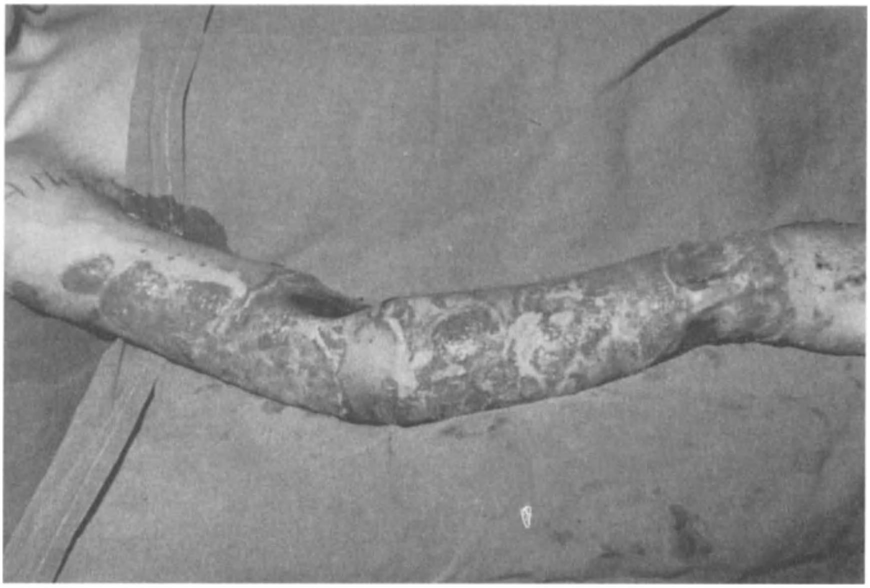
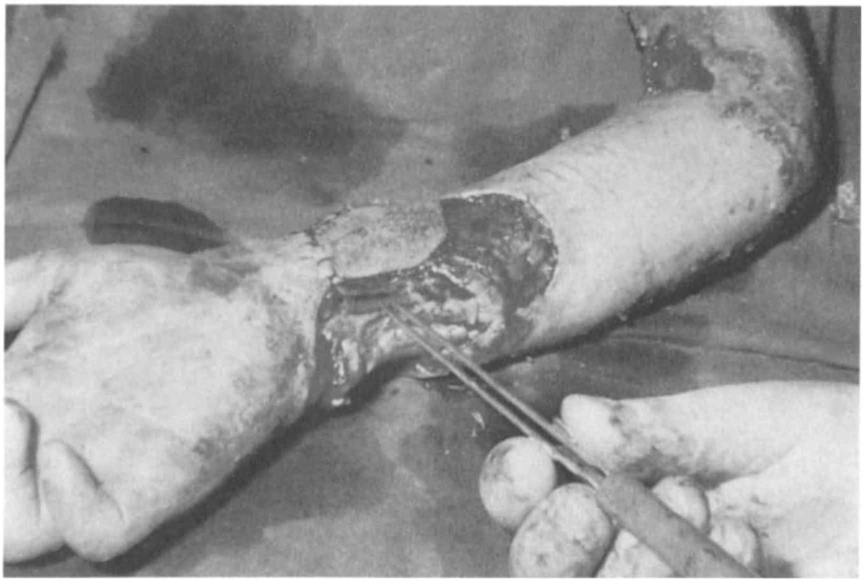
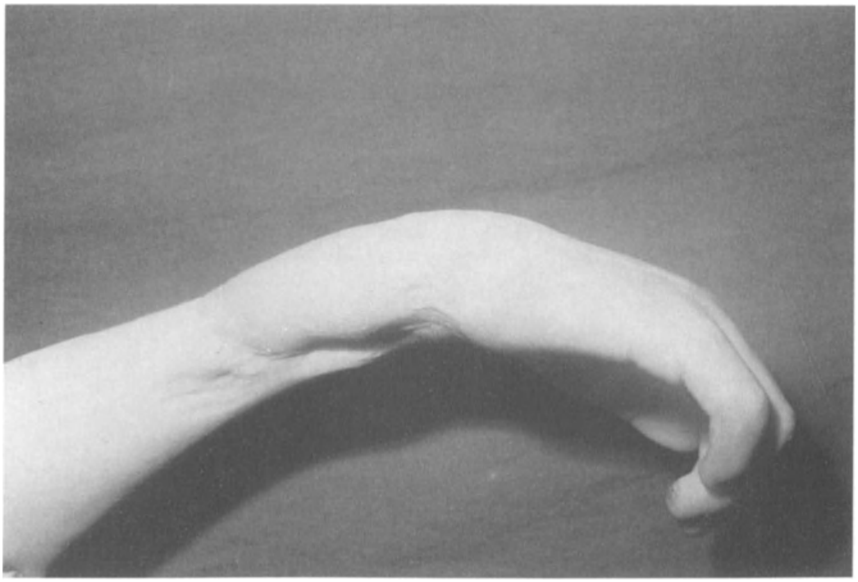


Figure 6. D.I., age 10, boy
(**a**) high voltage double electric arc in right wrist and elbow



(**b**) exposure of ulnar vasculonervous bundle after escharectomy on day 15. Temporary coverage with skin graft

Figure 6 (**c**) exposure of ulna after further escharectomy



(**d**) after reconstruction with abdominal flap performed on day 30

The definitive reconstructive techniques used are summarized in Table 6. The procedures followed were debridement, décollement and juxtaposition of the edges, and suturing in one case, and wedge excision and layered suturing in the other case, because of haemorrhagic complications secondary to electrical burn of the lower lip. In accordance with the principle of greater simplicity we used dermoepidermal grafts whenever possible. We used flap coverage when structures such as nerves, tendons, vessels, articulations or bones were exposed.

Non-viable segments of limbs were amputated as soon as possible in order to prevent possibly life-endangering complications (sepsis, kidney failure) (Neale, 1990; Garriba *et al.*, 1983; Masellis *et al.*, 1982).

CONCLUSION

The age distribution and aetiopathogenesis of the lesions show that the prevention of electrical accidents in children is possible, and is based on careful surveillance of younger children by adults; elimination of risk factors in the home environment and preventive education in older children and the population as a whole (Cabanes, 1991).

Regarding the treatment of lesions caused by electric current, what may at first sight appear to be a serious and extensive injury will in some cases heal with minimal sequelae. However, damage to the vessel intima may cause thrombosis even weeks after the trauma. A lesion due to electric current is thus a lesion in evolution (Feldman, 1990; Garriba *et al.*, 1983); it is therefore of fundamental importance to make the right choice between conservative and aggressive treatment and, if surgery is necessary, to choose the right moment for reconstruction, i.e. either soon after the trauma or subsequently, when the lesion has stabilized.

The site of the trauma may determine the choice of the type of treatment; as to the choice of the right moment for surgical procedures, our previous considerations would recommend a prudent and watchful period of waiting. The reconstruction techniques are conditioned by clinical objectivity and by the normal functions performed by the affected area; in children, reconstruction using flaps involves an age-related risk factor due to their natural unawareness and restlessness.

REFERENCES

Cabanes J. (1991). Prevention des brûlures électriques. *Ann. Medit. Burns Club*, **1**, 38–40

Garriba R., Tanzarella M., Colesanto A. D., Pascone M. (1983). Problemi di trattamento nelle gravi folgorazioni del polso. *Riv. Ital. Chir. Plast.*, **15**, 377–383

Feldman J. J. (1990). Facial burns. In: McCarthy (ed.), *Plastic surgery*, vol. 3, chap. 1. Philadelphia: Saunders

Kazanjian, C. (1988). *Il trattemento chirurgico dei traumi facciali*, vol. 2, chap. 29. Padova: Piccin

Luce E. A. (1990). Electrical injuries. In: McCarthy (ed.), *Plastic surgery*, vol. 1, chap. 24. Philadelphia: Saunders

Masellis M., Conte F., Fortezza G. S. (1982). Use of dermis to reconstruct hand joint capsules. *Ann. Plast. Surg.*, **9**, 72–80

Nahas L. F., Nahas R. A. (1990). Quemaduras electricas de los labios y comisura bucal. *Cir. Plast. Iber. Latinoam.*, **2**, 129–134

Neale H. W. (1990). Electrical injuries of the hand and upper extremity. In: McCarthy (ed.), *Plastic surgery*, vol. 8, chap. 130. Philadelphia: Saunders

Rodrigues Menes H., Rigo Aguada A., Del Pino Paredes V. (1988). Epidemiologia, prevención y tratamiento de las quemaduras electricas infantiles. *Cir. Plast. Iber. Latinoam.*, **14**, 265–271

73
Shoulder disarticulation after high-tension electrical burns: technical problems

G. BELBA, K. ZHUKA, X. OSMANI and I. GEDESHI
Clinic of Plastic Surgery and Burns, U.C.H.T., Tirana, Albania

INTRODUCTION

The passage through the body of high-tension electricity of ≥ 1000 V causes irreversible injuries in the extremities. The anatomical formations are very sensitive, being readily affected even at a distance from the point of entry of the electric current. The technical evaluation of major anatomical elements (muscles, vessels, nerves, etc.) is the main task of the medical team. The degree of their destruction will determine the survival of the patient and the complete or reduced function of the injured extremity.

The more frequent destruction of the upper extremities than the lower ones (for different reasons) leads to even more technical problems (Luce *et al.*, 1978). All authors speak about early operations such as necrectomy, fasciotomy and decompression of the muscle compartments in order to avoid muscle ischaemia, vascular thrombosis and neurological complications (Escudera-Najs *et al.*, 1990; Halperin *et al.*, 1983; Lochaitis *et al.*, 1991).

Re-exploration is sometimes necessary, but this should not delay the decision to undertake a radical operation. Amputation is well tolerated without compromising the general condition, even on the first day of hospitalization (Philip *et al.*, 1985).

These patients are in a septic condition and at this dangerous period they are also threatened by delayed acute haemorrhage, due to the destruction of the great vessels (Nicosia and Petro, 1983).

During shoulder disarticulation, the ligation of the axillary artery and vein is of great importance. When these show signs of damage and the peripheral tissues are necrotic, ligation at a distance from the subclavian artery and vein is recommended (Yang *et al.*, 1982). Of great importance are those cases in which no such injury is suspected but which becomes evident after development of a massive haemorrhage stimulated also by the septic condition.

We use the term 'development of haemorrhage' because before it becomes massive (2–3 days later), it causes micro-haemorrhage, from the micro-vessels over the ligation points in the axillary artery and vein. In this chapter we present our experience in 7 cases in which shoulder disarticulation was indicated.

MATERIALS AND RESULTS

An analysis of patients with high-tension electrical burns admitted during the period July 1990–July 1992 to the Clinic of Plastic Surgery and Burns in Tirana shows a total of 43 cases. The most typical localization was in the upper extremities, with 30 cases (Table 1). An examination of the distribution of amputation levels indicated that in 17 of these patients (56.6%) 18 amputations (Table 2) were performed. Shoulder disarticulation was frequent, with seven cases or 38.8% of the total number of amputations – this being a higher number than in other reports (Escudero-Nafs *et al.*, 1990). These seven patients had severe burns of considerable extent varying from 10% to 25% BSA (mean 16.6%). In addition to shoulder disarticulation other operations were performed in some patients (an average of 3.1%), such as necrectomy, fasciotomy and skin grafts, in order to treat the various injuries.

In four patients we performed shoulder disarticulation with ligations of the axillary artery and vein. From this group we excluded one patient who was taken urgently to the operation room 12 days after disarticulation with acute haemorrhage at the point of ligation of the artery and vein. The operation consisted in ligation of the subclavian artery and vein with a separate incision at a distance.

Table 1. Location of electrical burns

Upper extremities	30
Lower extremities	4
Head and neck	6
Trunk and shoulder	3
Total	43

Table 2. Amputation at the upper extremities

Level	*No.*
Fingers	5
Antebrachia	4
Brachia	2
Shoulder disarticulation	7
Total	18

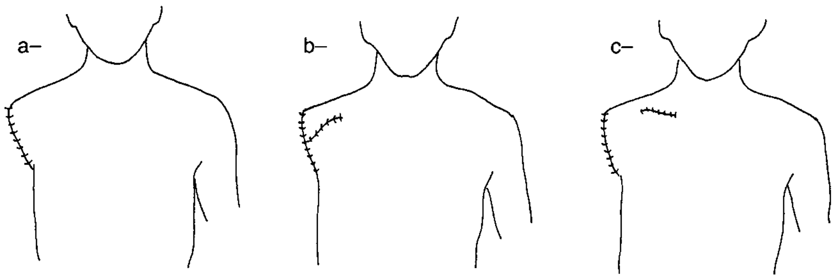


Figure 1. Ligation of subclavian artery and vein near to bifurcation of the brachiocephalic trunk, to eliminate acute haemorrhage due to infection in the axillary wound. a – ligation of axillary artery and vein; b – ligation of axillary, subclavian arteries and veins with joint incision; c – ligation of subclavian artery and vein with separate incision, followed by shoulder disarticulation with ligation of axillary artery and vein.

In one patient we performed shoulder disarticulation, with ligation of the axillary, subclavian artery and vein, by means of two joining incisions. Also in this patient we were obliged to ligate the subclavian artery and vein urgently, near to the bifurcation of the brachiocephalic trunk, after an acute haemorrhage 10 days after the first operation (Figure 1).

In the other two cases, before shoulder disarticulation we ligated the subclavian artery and vein, with a separate incision, and then performed shoulder disarticulation. The two patients confronted sepsis without any vascular complications (Figure 2).

The hospitalization period of the patients subjected to shoulder disarticulation varied from 54 to 169 days, depending on the total injured surface, burn depth and the procedures applied. One patient died on the 20th day as a result of cerebral complications due to sepsis.

DISCUSSION

In the septic conditions caused by electrotrauma there is a real danger of acute haemorrhage at the level where the extremity is amputated. This delayed haemorrhage usually takes place in the second week, when autolysis reaches its peak. Even if the amputation is performed on completely healthy tissue, because of tissue renecrotization the many secretions and the microthrombi dissolving in the area can cause the release of the ligation of the arterial or venous stump.

If we divide the seven cases described above into sub-groups, this will allow us to discuss the technical intervention of shoulder disarticulation in order to eliminate acute delayed haemorrhage. Shoulder disarticulation with ligation of only the axillary artery and vein never excluded the danger of haemorrhage in these critical patients (Figure 1a).

Ligation at a distance from the subclavian artery and vein during the same operation stage, but with joint incision together with disarticulation, created a relatively safer condition (Figure 1b). This is due to the fact that a secondary infection in the disarticulation zone *per continui-*

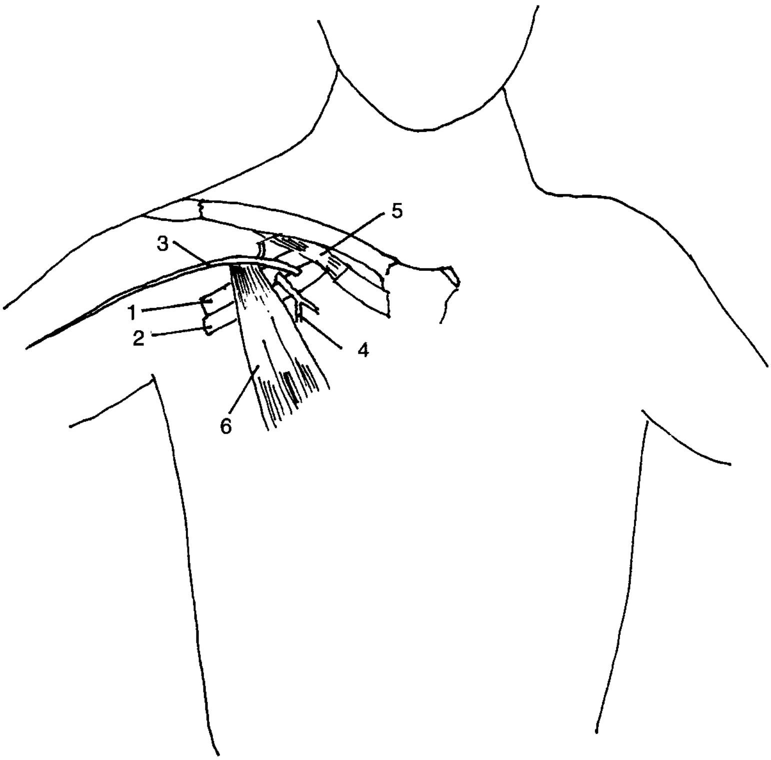


Figure 2. One patient in whom we first ligated the subclavian artery and vein with a separate incision and then performed shoulder disarticulation. 1. subclavian artery; 2. subclavian vein; 3. cephalic vein; 4. thoracoacromical artery; 5. subclavian muscle; 6. minor pectoralis muscle.

tatem will influence the ligation of the subclavian artery and vein, because the incisions and anatomical planes where the operation is performed are adjacent. We are of the opinion that the performance, from the beginning, of ligation of the subclavian artery and vein with a separate subclavian incision followed by shoulder disarticulation, with ligation of the axillary artery and vein, creates a safe post-operative situation (Figure 1c). The infection would not be life-threatening and would be well tolerated because the incisions and subclavian anatomical planes and those of disarticulation have no connection points.

In the four cases in which we performed ligation of the subclavian artery and vein, either as a secondary intervention in emergency or as a primary intervention during the same operation stage, we noticed a stability of the local condition and a normal course of the patient without any danger of haemorrhage. The operation technique of shoulder disarticulation with ligation at the beginning of the subclavian artery and vein has many general and specific aspects, from the incision lines which frequently are atypical to the angiological ligation of the vessels (Yang *et al.*, 1982).

We would underline the isolation moment of the subclavian artery and vein. The subclavicular incision involves the lateral third of the clavicle. The pectoralis major muscle is dissected, opening a window between the pectoralis minor muscle and the subclavian muscle. Thorough dissection will reveal at the beginning the subclavian vein and under this the subclavian artery. The ligation can be performed under the subclavian muscle at the level of the external side of the first rib, over the entry point of the cephalic vein and over the exit point of the thoracoacromial artery (Figure 2). Cutting of the clavicle with Gigli's wire saw is not necessary.

Lastly we would recommend that during shoulder disarticulation, the deltoid muscle should be protected as much as possible, because if it is uninjured it can ensure closing *per primam* of the wound.

BIBLIOGRAPHY

Escudero-Nafs, F. J., Leiva-Olivia, R. M., Collado-Aromir, F., Rabanal-Suarez, F., Demolina-Nunez, J. M. 1990. High-tension electrical burns. Primary treatment of seventy patients. *Ann. Medit. Burns Club*, **3**, 256–61

Halperin, D. S., Rougé, J. C. 1983 Accidents d'origine électrique chez l'enfant. *Annales de pédiatrie*, **30**, 5–13

Lochaitis, A., Parker, J., Stavropoulou, V., Panayotaki, D. 1991. Neurological disorders following electrical burn injuries. *Ann. Medit. Burns Club*, **4**, 84–9

Luce, E. A., Dowen, W. L., Su, C. T., Hooper, J. E. 1978. High tension electrical injury of the upper extremity. *Surg. Gynecol. Obstet.*, **147**, 38–42

Nicosia, J. E., Petro, J. A. 1983. *Manual of burn care*, 99–100, Raven Press, New York

Philip, F. P., James, K., Joseph, F. P., Peter, W. S., Stephen, H. M. 1985. Aggressive approach to the extremity damaged by electric current. *Am. J. Surg.*, **150**, 68–72

Yang, Ch., Hsu, W., Shih, T. 1982. *Treatment of burns*, 210–11, Shanghai Scientific and Technical Publishers, Shanghai

Section XIII
Hand burns

74
Hand burns in children

G. JANJIĆ, Z. GOLUBOVIĆ, D. PARABUCKI and B. ILLIČIĆ
Department of Plastic Surgery and Burns, University Children's Hospital, Belgrade, Yugoslavia

INTRODUCTION

In children, hand burns are more frequent than burns in any other site, and they also disturb the normal routine of children's life, because of their localization. We refer here to hand burns that do not cover a large percentage of the body and therefore do not provoke the disorders caused by extensive burns.

The pattern of injury seen in paediatric hand burns differs from that of adults. Paediatric hand burns are usually the result of curiosity, ignorance or inattention. The most common cause of paediatric burns is contact with very hot liquids, especially water. The second most common cause is contact with burning objects, while burns due to electricity are rare. Burns due to chemical contact are even rarer.

PATIENTS AND METHODS

In the treatment of hand burns the localization, whether palmar or dorsal, is irrelevant, as treatment depends primarily on the depth of the affected tissue region. In the diagnostic and therapeutic protocol it is therefore necessary to determine the depth of injury as soon as possible and then decide on treatment. In all situations the main goal is to prevent damage to healthy tissue.

In our hospital, in the treatment of burns, we use the method of primary tangential excision developed by Janžekovič. In essence the procedure converts the burn injury into an ordinary surgical wound, after which grafting is performed. The benefit of this procedure is that the burn heals faster and practically without contracture, which would require further corrective surgery and physical therapy. Good prognosis is therefore based on a fundamentally sound evaluation of the burn. Precise evaluation of the non-viable tissue is difficult and the decision has to be based on the surgeon's experience.

For superficial burns we use occlusive dressings. For dermal and subdermal burns we use a surgical technique which entails excision of non-viable tissue followed by grafting of the wound site. We use a tourniquet during surgery. In cases of split-thickness transplant, to maintain its viability we use a bulky dressing with gauze for bandaging.

In treating very small children with palmar burns from very hot objects (i.e. a hot iron), we place the hand in palmar hyperextension when bandaging the wound and maintain it extended until scarring is complete. Physical therapy rehabilitation can then be initiated.

RESULTS

In the last 3 years at the Belgrade University Children's Hospital, in the Department of Plastic Surgery and Burns, 115 patients were treated for hand burns (Table 1). Seventy-three children were treated conservatively as out-patients, as their burns were superficial and there was no necessity for surgical intervention nor for any frequent dressing daily changes.

Table 1. Hand burns in children treated during a 3-year period

	Conservative	*Operative*	*Total treated*
Out-patients	73	0	73
In-patients	28	14	42
Total	101	14	115

Forty-two children were hospitalized. Of these, five had burns in both hands. We operated on 14 hands, in 10 patients. The data include patients with extensive surface burns, including hand burns. A significant number of burned children were not given primary treatment at our hospital. On average, these children were brought to us after 12 days. In these children it was evident that pronounced granulation was already present as well as incipient contractures. At this stage it was clear that the burns were very deep and that spontaneous epithelialization would take a long time. This clearly shows the effects of incorrect diagnosis at the critical time.

CONCLUSION

Comparing the results of surgically treated children to those treated conservatively, we can say that the results in those treated surgically were much better as regards aesthetic appearance, functionality and length of hospitalization (Figures 1 and 2). The period of epithelialization is not as important as the period of cicatrization without complications (contractures).

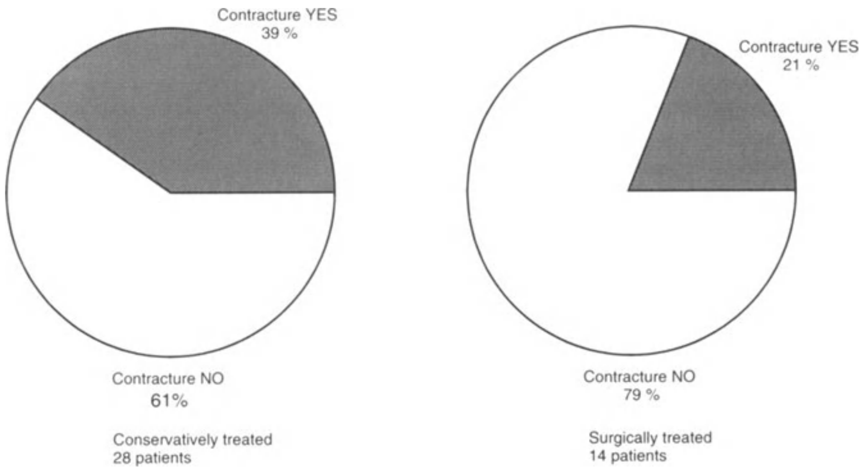


Figure 1. Contractures in post-operative and post-conservative treatment

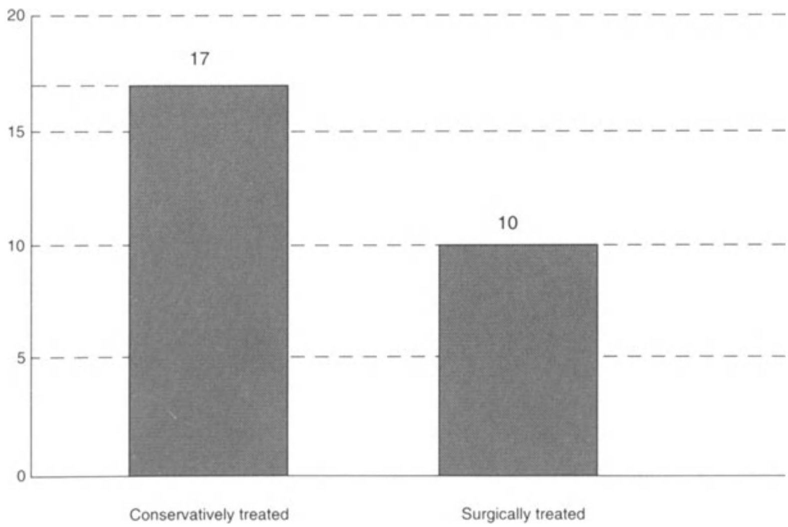


Figure 2. Length of hospital stay

We have considered children, not adults, because we feel that their problems are more complex. For normal psychological development and a childhood with minimal trauma, it is necessary to return the child as soon as possible to his family, his friends and toys. As doctors we must therefore keep in mind during treatment and therapy that the child after our intervention should remain only a child and never a chronic patient.

BIBLIOGRAPHY

Clarke, H. M., Wittpenn, G. P., McLeod, A. M., Candlish, S. E., Guernsey, C. J., Weleff, D. K., Zuker, R. M. (1990). Acute management of pediatric hand burns. *Hand Clin.*, **6**, 221–232

Dado, D. V., Angelats, J. (1990). Management of burns of the hands in children. *Hand Clin.*, **6**, 711–721

Hanumadass, M., Kagan, R., Matsuda, T. (1987). Early coverage of deep hand burns with groin flaps. *J. Trauma*, **27**, 109–114

Sherif, M. M., Sato, R. M. (1989). Severe thermal hand burns – factors affecting prognosis. *Burns*, **15**, 42–46

Shugerman, R., Rivara, F., Parish, R. A., Heimbach, D. (1987). Contact burns of the hand. *Pediatrics*, **80**, 18–21

Strachan, R. D., McCombe, A. W., Sutherland, A. B. E. (1989). The long-term results of electric fire hand burns in children. *Br. J. Plast. Surg.*, **42**, 468–472

75
Deep hand burns: the importance of rehabilitation in the acute phase for surgical preparation

A. DI LONARDO, E. BRIENZA, M. FERRANTE, G. MAGGIO, G. GIANCASPERO and D. DIOGUARDI
Cattedra di Chirurgia Plastica Ricostruttiva, Università degli Studi di Bari, Italy

---

The treatment of hand burns in the acute phase requires a precise therapeutic strategy. Our experience is that this strategy should be realized in the early phase of the evolution of the lesion.

The therapeutic programme followed at the Bari Burns Centre provides for physiotherapy in the immediate post-trauma period. The treatment is performed in the pre-operative phase (i.e. the acute phase) and is an optimal preparation of the lesion for the surgical operation, affecting its subsequent evolution in terms of the prevention or invalidating scar sequelae. Surgical reconstruction, performed within 7–10 days of presentation, still however remains the elective therapeutic procedure in intermediate-deep and deep burns, promoting rapid healing of the lesion and ensuring early and effective functional recovery.

This therapeutic approach may be modified by some factors of a general nature affecting the final result. These include marked systemic involvement (related to burn extent), age, secondary immunodeficiency, peripheral vasculopathies, and haematological conditions. All of these may considerably slow down the biological phenomena that participate in the repair of injured tissue.

MATERIAL AND METHODS

Eighty-seven per cent of patients admitted to the Bari Policlinic Burns Centre have hand burns. The treatment protocol in the acute phase provides for mobilization by means of application of an Opsite glove, hydrotherapy, orthotic immobilization and early surgical reconstruction.

Our experience is that very early mobilization is of fundamental importance not only in spontaneously healing lesions but also in those requiring surgery. The advantages of this approach are numerous:

- reduction of the typical oedema of the burned hand, through activation of the venous circulation;
- reduction of the cleansing phase, because of increased vascularization and tissue oxygenation;
- reduction of reactive inflammatory processes (myositis, tendinitis, post-trauma arthritis);
- reduction of muscular hypotrophy and articular block due to the pathological postural immobilization of the burned hand (hook hand);
- prevention of contracting scar sequelae, due to the mechanics of the newly formed scar tissue in the initial phases of the scarring process.

A glove made from Opsite, a synthetic skin substitute made of transparent sheets that can be modelled to the hand with a Spencer applicator, is optimal treatment for deep burns in the acute phase. The glove is applied after surgical cleansing and replaced every 2–3 days. It provides a sterile, practical and easy-to-apply dressing that can be used to wrap fingers individually. The Opsite glove facilitates – both for the patient and the physiotherapist – continuous mobilization of every area of the hand, rapidly establishing the optimal anatomical and functional conditions necessary prior to surgical procedures.

Hydrokinesitherapy at a temperature of 30–35°C in baths containing diluted disinfectants offers excellent mobilization of the hand and favours cleansing of the lesion. The treatment is applied twice daily for 15–30 min. Kinesitherapy is however not the only physical treatment available.

Our experience and that found in the literature indicate that correct orthotic positioning offers considerable advantages for the prevention of invalidating scar sequelae. Immobilization is achieved by means of restraining devices made of thermoplastic material. This method is not however an alternative to dynamic treatment, and is justified only when dynamic treatment is impossible. Static treatment (night splinting) is thus indicated during the night.

Orthotic devices are modelled individually in relation to the lesions. By extending the burn area they reduce scar contraction and give the scar greater elasticity.

DISCUSSION

The physical methods we have described are indispensable rehabilitation techniques in a therapeutic strategy aimed at the prevention and reduction of invalidating scar sequelae.

Although early surgical reconstruction is not a method of rehabilitation, it is in our opinion the only treatment offering optimal rehabilitation of deep hand burns. It is essential that the surgical operation should be early. Reduction of the pre-operative period interrupts the biological phenomena characteristic of the scarring process that always result in scar contractures. Pre-operative physical therapy favours cleansing and vascularization of the lesion and promotes trophism of perilesional tissues, improving the results of surgery and graft take.

CONCLUSION

In order to reduce healing time and favour early functional recovery, treatment of the burned hand in the acute phase must be performed to a precise time schedule, incorporating immediate physiokinesitherapy and early surgical reconstruction (day 7–10).

BIBLIOGRAPHY

Bache, J. (1988). Clinical evaluation of the use of Opsite gloves for the treatment of partial-thickness burns of the hand. *Burns*, **14**, 413–416

Brienza, E. *et al.* (1980). La clinica chirurgica del Nord America. *Simposio sulle ustioni*, vol. 2 (Italy: Piccin)

Durafourg, M. *et al.* (1983). Orthèses statiques et orthèses dynamiques d'extension de la main et des doigts. *Ann. Kinesither.*, **10**, 221–229

Hunt, J. L. *et al.* (1987). Face burn reconstruction – does early excision and autografting improve aesthetic appearance? *Burns*, **13**, 39–44

Matarrese, V., Brienza, E. *et al.* (1989). Possibilità dell'intervento preventivo e riabilitativo sulla cicatrice da ustione. *Atti del Congresso Simposio Naz. of the Int. Soc. for Burn Injuries*

Ninneman, J. L. *et al.* (1982). Immunologic defenses against infection: alteration following thermal injury. *J. Burn Cure Rehabil.*, **3**, 355–366

Spencer, D. S. *et al.* (1987). The Spencer Opsite applicator, a new technique for treating the burned hand. *Burns*, **13**, 330–333

76
Tactics for operative treatment of postburn hand contractures in children

V. K. GUSAK, I. I. SPERANSKIJ and N. N. ZAGORUJKO
Donetsk medical institute, Donetsk, Russia

Hand burns are the most common thermal trauma in children. In 35–40% of cases they lead to the formation of various contractures, even after correct and early treatment. This causes various deformations and transforms patients into invalids. Failing prophylaxis and timely overall treatment, stable arthrogenic and myogenic changes are added to the initial dermatogenic component that children already have. These changes appear quickly, because of the rapidity of children's growth, and make hand deformations stable. Application of traditional methods of skin plastic surgery when exposing vascular-nerve bundles, tendons, bones and joints, as also long-term conservative treatment, leads to the development of hypergranulation and collagen tissue. This leads to irrevocable loss of function in the damaged hand. Physicians are therefore looking for new methods of treatment. This chapter reports on the development of guidelines for selection of rational periods and methods in the operative treatment of burns and postburn contractures in children with various hand traumas. We surveyed the results of the treatment of 451 children aged 7 months to 14 years who received treatment in the Donetsk Burn Center in 1982–1992. The clinical histories and late results were studied over a 2–5 year period. These data enabled us to formulate the following guidelines for the treatment of patients with hand burns.

First, from the moment of the trauma and administration of first aid it is absolutely necessary to immobilize the hand in the position of hypercorrection with respect to the potential form of contracture. Immobilization should be maintained until complete healing of the wounds, and for a further 2–3 months during the night.

Second, it is necessary to perform early drying of the burned surface and to achieve scab formation in order to prevent suppuration of the wound and development of hypergranulation. This leads to hypertrophic cicatrices, which deform the hand. For this purpose we use ATY-3, ATY-5, apparatuses, ordinary hairdriers, clinitron-beds, and drying with incandescent and infrared lamps.

Third, we perform early operative treatment and substitution of a burned surface of the hand and fingers with a split, but full thickness flap (no thinner than 0.35–0.40 mm), and when joints and tendons are exposed, with non-free dermoplasty of cutaneous–subcutaneous–fascial flap, taken from the same hand or forearm or from the abdomen. We believe that operative treatment should be performed in the first 3–5 days, on formation of a dry burn scab without suppuration. When functionally active surfaces are affected it is preferable to use a cutaneous–subcutaneous flap, because covering the wound with a thin flap leads to retraction and tightening of the fist, which presents further contractures.

Fourth, in cases of delayed admission of the patient or of suppuration of the burn wound we use various methods: bandages (changed daily, when necessary, every 2–3 days); and rubber or polyethylene gloves filled with liniments in a water-dissolved base such as Levosin, Levomekol, Dioksikol, or 5% liniment of mafenate acetate. It is important to remember that some allergic reactions and maceration of skin may occur; this is due to the high sensitivity of affected bone to antibiotics after local application.

The efficiency of the various methods used should be assessed by means of bacteriological and cytological methods, of examining the external appearance of the wound, the return of hand function, and the periods of hospitalization.

Use of 24 h hypercorrection until complete wound healing is of paramount importance in the post-operative period in the hand and fingers, plus the use of various methods of physiotherapy later on. Movement of the fingers, even during hand immobilization, must begin 3–5 days after surgery, when pain and tissue oedema are reduced, and the lips and the base of wounds adhere with transplanted flap.

In the prophylaxis of hypertrophic cicatrices and postburn contractures, special attention must be devoted to physical methods of treatment. Starting on the first day post-trauma UV radiation therapy should be used. This promotes drying of the burn wound and scab formation, and the healing of the affected section. After the wound has healed or the hand contracture operation has been performed we apply phonophoresis of hydrocortisone or colicin according to a method we have developed, electrophoresis of terrilitin, a 5% solution of zistein, or a 4% solution of aminocaproic acid. This slows down the formation of collagen tissue, of hypertrophic scars and the resolution of earlier formed cicatrices. Compression therapy using elastic bandaging or elastic fibre gloves is also of great help.

Patients with severe hand burns, following reconstructive surgery, must be followed up for a period of 3–5 years for signs of development of scar tightening and the formation of contractures, deformations, cosmetic deterioration or functional inadequacy, and also in order to plan remedial measures. The patient should be followed up by the same physician from the moment of initial treatment until total recovery. This will promote better long-term results and more rapid recovery of hand function and prevent mistakes and complications.

If there are no inflammatory processes in the hand, the operative treatment of post-burn scars should be performed earlier, in the first 3–4 months, as arthrogenic changes add to the dermato–desmoid formations. The earlier the excision of all scar tissue, including the elimination of any skin defects, the better the immediate and long-term results.

In reconstructive operations, if there are bend-unbend contractures and syndactyly, it is necessary to perform one-off elimination of defects, because the staged elimination of contractures and syndactylies increases the number of operations but reduces long-term results.

It is necessary to eliminate arthrogenic contractures by means of distractive apparatuses and to reduce diastasis in the affected joint to no more than 5 mm. Immobilization in this position should last one month, after which a reconstructive operation on the affected joint is needed. Immobilization in the post-operative period is extended to 3 months in this case.

In patients with severe hand burns psychosocial rehabilitation in hospital is of particular importance. They must receive all the attention and care of physicians and family, and must not develop any sense of inferiority either in the first period or when their wounds have healed. From day one they must try to look after themselves, take their food, and perform their toilet. Should patients have any mental disorders because of their hand mutilation, they must be followed by a psychologist.

The above methods of treatment of severe hand burns in children decrease the percentage of postburn contractures and their complications and reduce the number of operations while the children are still growing. We have had positive results in 65.7% of children with severe hand defects, plus good and satisfactory long-term results in 77.7% of cases.

77
Rehabilitation in severe burned hand sequelae

M. AMICO, V. GERACI, R. BRANCATO and M. MASELLIS
Divisione di Chirurgia Plastica e Terapia delle Ustioni, Ospedale Civico, Palermo, Italy

The hand is the part of the body with the greatest capacity of movement and is essential both for personal autonomy and in the field of social relations and work. Loss of use of the hand causes serious psychological and physical problems.

Deep burns can cause severe invalidating sequelae to the complex anatomical and functional structure of the hand. Maximum functional recovery is obtained by appropriate preventive measures. The therapeutic approach has three main parts: surgery, rehabilitation and correction of residual sequelae. The surgical procedure consists of early tangential excision of the necrotic area and coverage with full medium-thickness free grafts of autologous skin.

Rehabilitation must start early. It must be constant, long-term, personalized, conducted in concert with other parallel practices and be appropriate to the various phases of the burn disease. In the acute phase, rehabilitation consists essentially of correct positioning of the hand, with the limb in the discharge position, and in passive physiotherapy. This favours reduction of oedema which otherwise would cause fibrin deposits in the periarticular tissues with consequent rigidity. Physiotherapy is effective and not painful if undertaken in conjunction with balneotherapy. During the post-acute phase of rehabilitation positional splints are used. These are generally made of thermoplastic material and modelled according to need. The palmar resting splint is used in patients with burns to the back of the hand not involving the wrist. The wrist is placed in extension, the metacarpophalangeal (MP) articulations in 70° flexion, the fingers in extension and the thumb in abduction. In isolated palm burns the splint is positioned for extension of the interphalangeal (IP) and MP articulations. In wrist burns the splint is positioned for extension or slight hyperextension of the wrist. Splints are removed during physiotherapy sessions, which have to be brief and repeated several times during the day. The exercises should be both passive and assisted active.

Rehabilitation continues in the phase of scar sequelae with the use of splints, which later may be used only at night. This is associated with:

- pressure therapy, using an increasing pressure gradient glove if persistent oedema arises due to discharge disturbances (e.g. in serious circumferential sequelae in the wrist or forearm);
- massage therapy, which is initiated when epithelialization is complete. This restores skin elasticity and movement of the skin over the subcutaneous planes;
- pressure therapy, using a made-to-measure constant pressure gradient elastic glove in order to limit hypertrophic scars. This may be associated with the use of adaptors or silicone gel if pressure alone proves inadequate.

Physiotherapy in this phase is almost exclusively of the active type. Occupational therapy, the purpose of which is to increase the patients' independence and personal autonomy and to facilitate their return to work, can be performed using the familiar objects that may be used in normal day-to-day activities.

Surgery may sometimes be necessary in order to complete rehabilitation treatment or when this has not otherwise been performed. The purpose of corrective surgery is to restore the hand's prehensile capacity and its thumb / index-finger pincer function. After removal of scar tissue it is necessary to reconstruct a cutaneous mantle which gives the skin elasticity and facilitates its movement over the underlying planes. This mantle is constructed using grafts or skin flaps (thin or medium-thickness grafts for the back of the hand, full thickness for the palm). Z-plasties can be performed if permitted by the surrounding tissues. Adjacent or distant flaps may be used when osteoarticular structures are exposed. In cases of profound loss of substance from the palm, pouching in the contralateral arm or the abdomen is indicated. In small losses on the volar surface of the fingers, the cross-finger technique is recommended.

Severe contractures caused by scars blocking the MP and IP articulations require capsulotomy and excision of the collateral ligament. This is the ideal procedure in hand burns. The collateral ligaments must however be excised only when the intrinsic muscles are functioning perfectly. The destroyed articular capsules can be reconstructed using dermis grafts which provide a good level of containment and favour early post-operative mobilization.

Destruction of the IP articulations poses considerable reconstruction problems. The elective operation is often arthrodesis in optimal position, performed after due evaluation of the condition. The operation is followed by the application of positional splints and early mobilization.

Section XIV
Rehabilitation

78

The burned hand: its consequences for the patients' psychological status and social readjustment

C. STRINGLIS, D. TSUTSOS, P. PANAYOTOU, M. PAPAGELIS and J. IOANNOVICH
Centre of Plastic Surgery and Microsurgery, General State Hospital of Athens, Greece

The burned hand has always been a challenging problem for the surgeon, not only because of its surgical difficulties but also because of the post-operative consequences for the patients' psychological status and social readjustment. These consequences are often severe and more troublesome to patients and surgeons than the initial injury itself.

The purpose of this study was to consider the effects the burned hand has on the patients' personality and rehabilitation to social life.

Seventy-four patients with burned hands, out of a total of 228 burn patients, were treated in the Burns Centre of the Athens General Hospital during the period 1990–91. The age and sex of the patients is shown in Figure 1. The distribution of patients with burned hands was very similar to that of patients with burns of other anatomical sites.

Treatment was either surgical (grafts, flaps, amputation) or conservative. The cause of the burn is important in the decision as to treatment. The majority of thermal burns (38) were treated surgically and the rest (22) conservatively. Electrical burns very rarely require exclusively conservative treatment, whereas chemical burns are usually treated conservatively.

A questionnaire was given to our patients after a follow-up period of 6–12 months in our out-patients department. The questionnaire focused mainly on the consequences of burned hands for the patient's psychological status and social readjustment. The post-burn physical condition of the hand was classified according to the degree of scarring on the patients' hands. Patients with no post-burn sequelae on their hands were classified as 'no scarring' (11 patients). Patients with some mild sequelae but no restriction in the range of movement (ROM) of their hands were

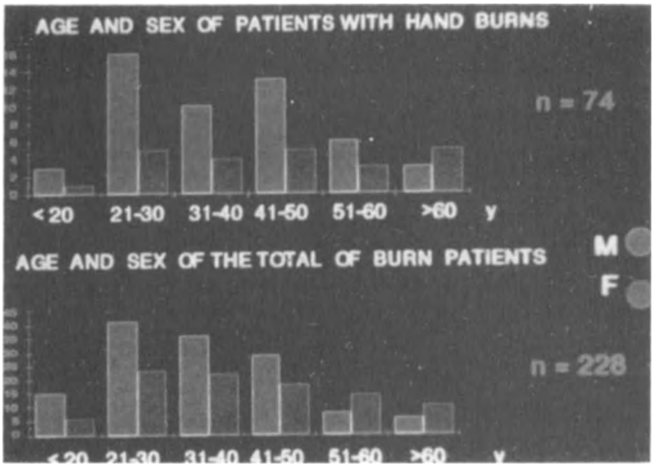


Figure 1. Age and sex of patients

classified as 'moderate scarring' (31 patients). Patients with contractures were classified according to the restrictions caused to ROM as with reduced ROM (27 patients) or significantly diminished ROM due to severe contractures (five patients).

Social adjustment was evaluated using several parameters.

Return to work

Patients with no scarring returned to work after 52 days, on average, while those with moderate scarring returned to work after 157 days, on average. Patients with contractures (reduced ROM) returned to work after 199 days, on average, and those with severe contractures (significantly diminished ROM) returned to work after 360 days, on average.

Productivity at work

All patients with no scarring had full work productivity compared with 83.8% of patients with moderate scarring, 9.6% of whom had reduced productivity and 6.6% had limited productivity. Among patients with contractures, 26.3% had full productivity, 57.9% had reduced productivity and 15.8% had diminished productivity (Figure 2). All patients with severe contractures had limited work productivity.

Post-hospitalization employment status

No patients with no scarring lost their job following treatment. Of those with moderate scarring, 83.8% were employed, 9.6% were partially

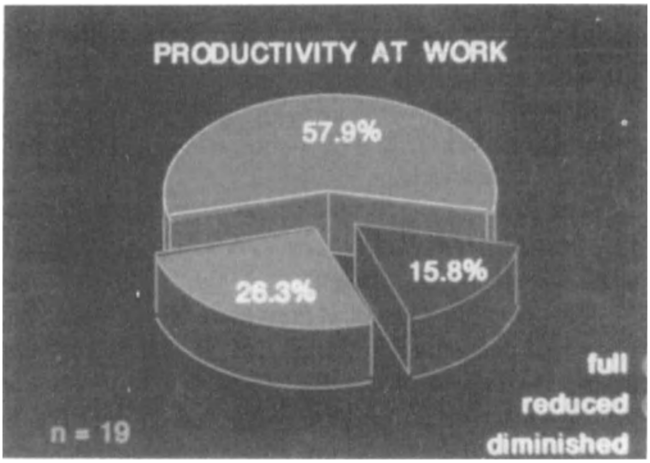


Figure 2.

employed and 6.6% were unemployed. Among patients with contractures, 25.9% had full employment, 48.2% were partially employed and 25.9% were unemployed (Figure 3). Sixty per cent of patients with severe contractures were on a pension and 40% were unemployed.

The consequences for family life and leisure

Patients with no scarring suffered no consequences in their family life and leisure time, as did 96% of those with moderate scarring, although

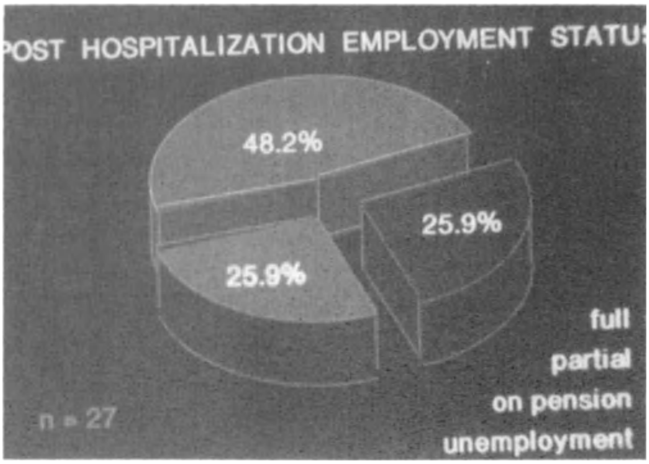


Figure 3.

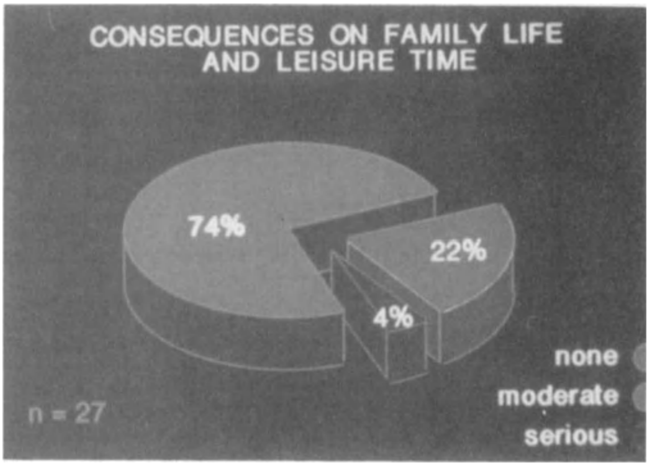


Figure 4.

4% of these had some consequences in their family life. Seventy-four per cent of patients with contractures suffered no consequences in their family life, 22% suffered some consequences, and 4% suffered serious consequences. Forty per cent of patients with severe contractures suffered moderate consequences and 60% suffered serious consequences (Figure 4).

Self-care ability was also evaluated as a parameter of social readjustment. Patients with no or moderate scarring had full self-care ability. Of those with contractures, 81.5% had full and 18.5% partial self-care ability, while only 20% of those with severe contractures had full ability. Forty per cent had partial and 40% reduced self-care ability (Figure 5).

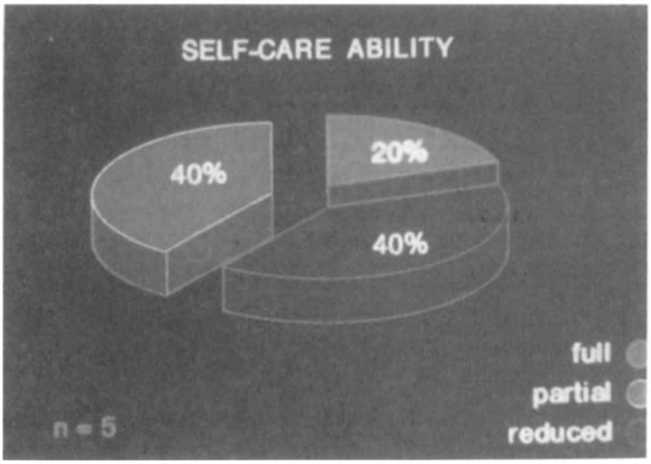


Figure 5.

The psychological status of the patients was evaluated in the form of appointments with a psychiatrist, use of relevant medication and need for in-patient psychiatric treatment.

Results revealed that the longer the hospitalization period the higher the incidence of the development of a psychological disorder (Figure 6).

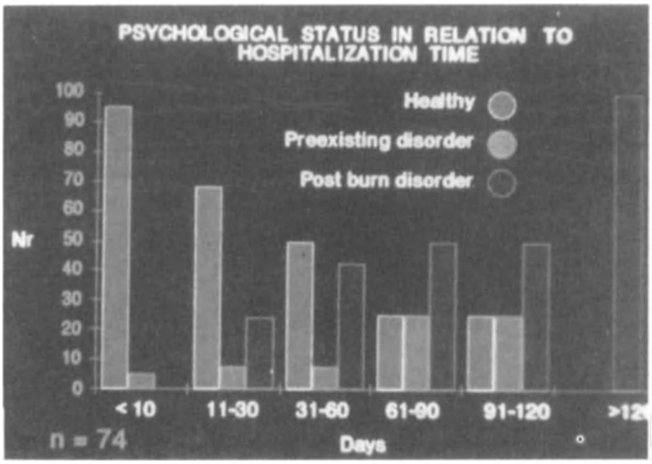


Figure 6.

In conclusion, patients with burned hands suffered serious consequences as regards their psychological status and social life. These consequences were related to the degree of post-burn sequelae and the physical condition of the hands. The surgeon should always bear in mind the importance of the hand for the burn victim's social readjustment and mental status, and he must not only aim at correct and early initial treatment but also consider the equally important follow-up and guidance after the patient's discharge from hospital.

Only in this way will the burn patient manage to readjust to social life and overcome the psychological impact of the burn disease.

79
Limb rehabilitation in the burned patient

I. GRECO*, G. LANDI*, E. DANTZER and C. ECHINARD****
**Centro Ustioni, Ospedale Bufalini, Cesena, Italy*
***Service des Brûlés, Hôpital Bernard, Hières, France*

Hypertrophic scars and skin contractions are two of the most severe sequelae in thermal lesions. On discharge from hospital the burned patient usually has a satisfactory appearance, but scar hypertrophy often develops rapidly, gradually leading to severe disfigurement. These sequelae are often passively accepted as an inevitable consequence of burn lesions, whereas in fact they are predictable and their evolution can be modified and controlled by special techniques. The use of adapted splints and made-to-measure anti-scar elastic supports, together with rehabilitative activity, has made it possible to achieve excellent results as regards contractions and hypertrophic scar formation. Rehabilitation of the burned patient has precise and important applications at every point during the course of the disease.

ACUTE PHASE

As soon as the burned patient is admitted to hospital, it is important to ensure correct postural alignment of the limbs by means of static and/or static-dynamic splints (Figures 1 and 2), active and passive kinesis and water therapy (Figures 3 and 4), use of the anti-pressure ulcer bed for elderly or debilitated patients or those with extensive burns, and respiratory exercises with Mesegue gymnastics (this is based on assisted deep breathing which is used as a motor for the gymnastic exercises–extension, flexion, pronation, supination, adduction and abduction).

Surgical necrectomy and grafting must be performed as soon as possible within one week post-burn, absolute priority being given to the limbs, and first of all the hands. When only the skin is damaged by the burn and the underlying tissues are intact, maximum skin capacity should be maintained as long as possible. When articular damage is also present, the skin becomes a secondary consideration; the articulation must be immobilized in the functional position.

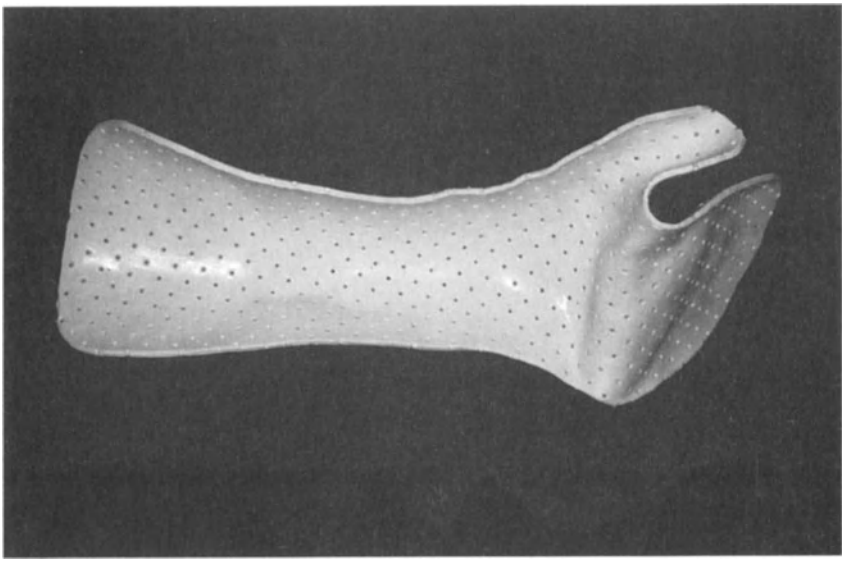


Figure 1.

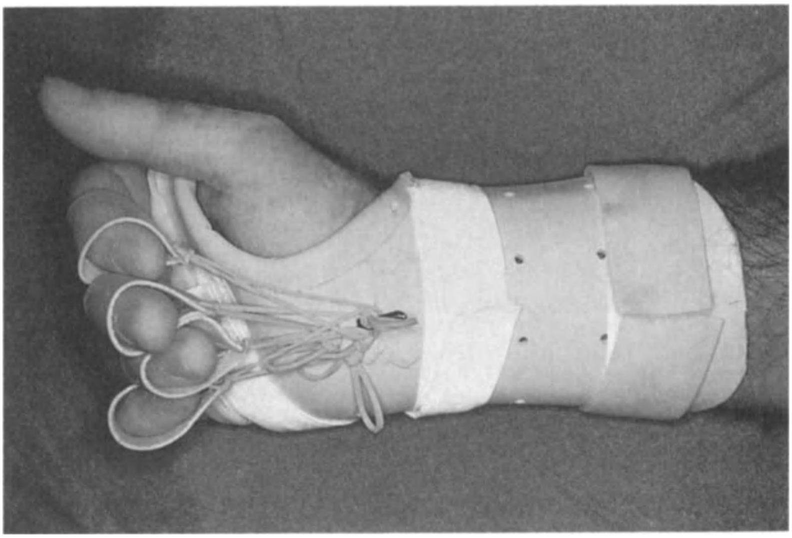


Figure 2.

Figure 3.

Figure 4.

Role of splints in the burned patient

Splints maintain the articulation in the functional position, permit cicatrization with maximum skin capacity, which is not always equal to functional capacity, limit hypertrophy by the creation of materials adhering perfectly to the skin, and have a static anti-contraction role or a corrective role when contraction is present. Dynamic splints are used in the treatment of contractions of flexor tendons, acting in association with, or as a replacement for, extensor tendons when these are damaged.

SUBACUTE PHASE

In the subacute phase global rehabilitative methods are used. These consist of massage, performed by pinching movements, usually with the fingertips, in order to detach cicatricial skin from the deep musculotendinous planes and to promote elasticity. One special technique is lymphatic massage, which is used in the event of oedema of the limb: slight pressure is exerted on the skin in a proximal direction (Figures 5 and 6). Physiotherapy and water therapy are continued for recovery of spatial movements, and pressure is initiated, usually with bielastic bandages. Personal autonomy and ambulation are promoted (Figures 7 and 8), and exercises are performed to facilitate the recovery of movements necessary for work activities (Figures 9 and 10).

LATE PHASE

In the final phase, definitive elastic pressure garments are used, if necessary in conjunction with dynamic splints. Follow-up checks will also be performed.

Figure 5.

Figure 6.

GENERAL PRINCIPLES OF ELASTIC PRESSURE

To be effective elastic pressure should be at least 20 mmHg, since capillary pressure is about 20 mmHg and this pressure blocks venous return.

The following principles are to be respected when applying elastic pressure:

1. The limbs should be covered entirely in order to avoid a tourniquet effect.
2. Elastic pressure garments should at first be worn in the presence of specialized medical staff in case circulatory complications develop.
3. Sponge materials added under the elastic bandage increase resistance and make it possible to fill concave lesions. Silicone is usually preferred because of its inhibitory action against hypertrophic scars.
4. The garments are to be worn day and night.
5. They may be associated with other therapies: massage, re-education, splints, warm water therapies.
6. It is advisable to have a double reserve quantity of elastic pressure material so that pressure therapy does not have to be interrupted in the event of breakage.
7. Elasticity is progressively lost especially after washing.
8. The garments must be worn for 6–12 months. They are removed when the scar tissue is no longer inflammatory. The appearance of small wrinkles on the hypertrophic surfaces indicates commencement of the regression phase.

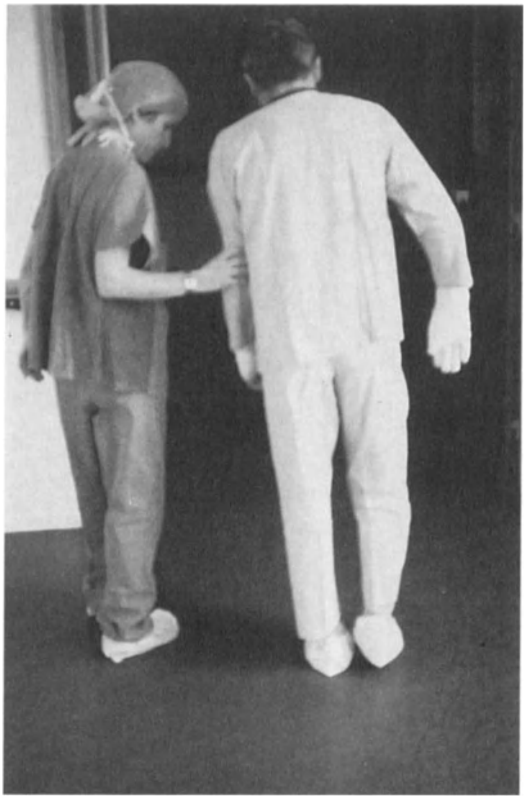


Figure 7.

Circumferential elastic compression interrupts the inflammatory state of the lesions, which become soft and white and less itchy. It also reduces scar contraction down to the normal extent of the articulations, which were previously maintained in flexion by contraction. Any newly formed ulcerations due to breakage of bridles have to be treated without interrupting the elastic pressure treatment.

The main purposes of these burn therapy devices are:

1. To combat malformations by increasing the articular angles which have been contracted by the patient for greater comfort.
2. To maintain maximum skin capacity (splints).
3. To maintain function position (splints).
4. To limit hypertrophy (elastic pressure garments, silicone, splints).

To all these must be added physical activity, physiotherapy and ergotherapy. These various techniques make it possible to eliminate sequelae due to the contracting tendency of scar tissue and to combat

Figure 8.

immobilization pathology, which is easier to prevent than to cure. We must also mention heat therapy, which may take the form of balneotherapy in radioactive water, if possible, at 37°C with hydromassage or in a bath. This permits better skin hydration and therefore greater facility for extension and physiotherapy. Filiform showers may also be taken in radioactive water, if possible, at 37°C in high-pressure filiform jets (12–18 mmHg/cm^2). This thermal therapy makes the skin pinker and more congested for 2–3 weeks. Subsequently, however, there is greater skin elasticity, with a reduction of contracting hypertrophic scars.

Finally, there is ultrasound therapy, which is performed in 10 cycles of 10-minute sessions, in water if possible. Ultrasound therapy should be low level (1 W) and pulsed (not continuous) in order to utilize the mechanical effect on the cell structures and not the thermal effect. Ultrasound is used in particular to combat interdigital hypertrophic formations. This treatment must not be used on cartilages that are still in the growing phase.

Figure 9.

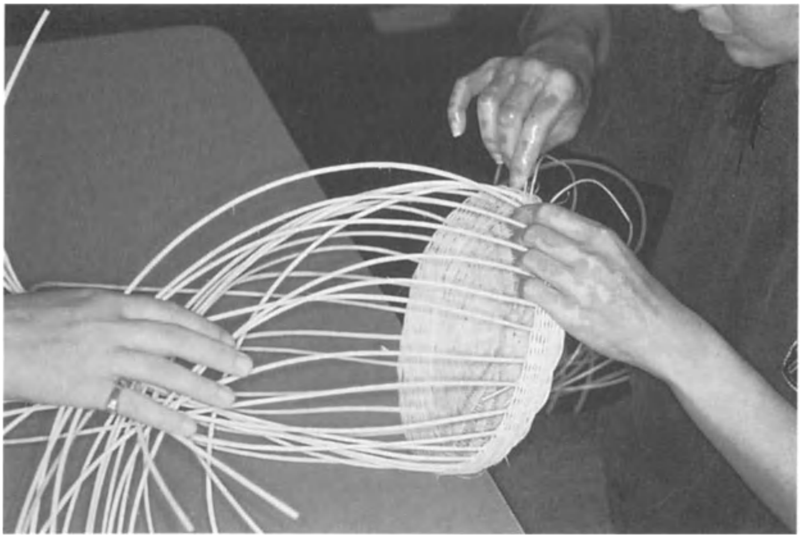


Figure 10.

CONCLUSIONS

The key treatments for correct rehabilitation of the burned limb are early surgery with absolute priority for articular zones, early functional re-education for all burned patients, and the use of close-fitting thermoplastic splints and continuous elastic pressure. These techniques have enabled us to obtain excellent results, without further surgery, in scar contractions and the formation of hypertrophic scars. Nothing can be achieved without the patients' cooperation, and it is important to remember the fundamental notion of the multidisciplinary team which works in perfect harmony in order to coordinate all persuasive strategies so that the overall treatment leads to the best possible social and professional rehabilitation.

BIBLIOGRAPHY

Bartlett, R. H. *et al.* (1978). Rehabilitation following burn injury. *Surg. Clin. N. Am.*, **58**, 1249–1262

Baux, S. (1980). Les séquelles des brûlures. *Rev. Prat. (Paris)*, **30**, 577–588

Casa, B., Caleffi, E., Bocchi, A., Ferraro, F., Delpiano, P. (1989). La riabilitazione del paziente ustionato. Parte prima: aspetti generali. *Acta Biomed. Ateneo Parmense*, **60**, 5–6

Casa, B., Caleffi, E., Bocchi, A., Ferraro, F., Delpiano, P. (1989). La riabilitazione del paziente ustionato. Parte seconda: l'esercizio terapeutico. *Acta Biomed. Ateneo Parmense*, **61**, 1–2

Casa, B., Costa, P., Ferraro, F., Delpiano, P., Gasparini, G. (1990). Le ortesi nella riabilitazionedel paziente ustionato. *G. Ital. Med. Riab.*, **4**, 22–27

Gaté, A., Debize, J., Clairac, C. (1978). Rôle du kinésithérapie dans le traitement des grands brûlés. *Encic. Méd. Chir.*, **4**, 1–10

Glicenstein, J., Tubiana, R. (1976). Problèmes posés par des brûlures des mains et leurs séquelles. *Concours Méd.*, **98**, 7181–7191

Hardy, P., Many, P. (1976). Traitement thermal des séquelles cicatricielles de brûlures à Saint-Gervais-les-Bains. *Entretiens Bichat (Ther.)* 85–88

Helm, P. A., Head, M. D., Pullium, G., O'Brien, M., Fred Cromes, G. (1978). Burn rehabilitation. A team approach. *Surg. Clin. N. Am.*, **58**, 1263–1278

Malick, H. M., Carr, A. J. (1982). *Manual on the management of the burn patient.* Pittsville: Harmarville Rehabilitation Centre.

Marra, M., Magnani, P., Zanetti, G., Aadori, A., Condello, S. (1987). Considerazioni sulla riabilitazione dell'ustionato. *Osp. Vita*, **14–2**, 31–35

Monteil, R., Guibauld, J., Cissay, M. (1979). La rééducation du brûlé. *Temp. Med.*, **40**, 21–32

O'Shaughnessy, E. Y., Heimbach, D. (1987). Trattamento e riabilitazione delle ustioni. In: Kottke, Stillwell, Lehmann (eds) *Trattato di terapia fisica e riabilitazione.* Rome: Verducci

Walter, C. (1987). *Splinting the burn patient.* Ramsco Publishing Co.

Zandonini, G., Giorgioni, C. (1988). Trattamento riabilitativo dell'ustionato. *Eur. Med. Phys.*, **24**, 53–58

80
Early and late results of physiotherapy in burns

I. PETRONIĆ, G. NIKOLIĆ, NAJDANOVIĆ and Z. GOLUBOVIĆ
Departments of Physical Medicine and Rehabilitation, and Plastic Surgery, Children's Hospital, Belgrade, Serbia

INTRODUCTION

The incidence of keloid formation after burns ranges from 6 to 9%. Numerous methods, e.g. atraumatic excision, irradiation (X-ray), local infiltration of corticosteroids with or without excision and cryosurgery, have been applied for the prevention and treatment of keloids with varying success, since the aetiopathogenesis remains obscure. The basic purpose of the application of certain agents of physical therapy is to prevent development of hypertrophic or keloid scar after treatment of the burn. Besides causing poor aesthetic appearance, keloid scars may endanger joint function. The main object of physiotherapy is therefore to make it possible to maintain the full range of movements and function in the affected joints.

MATERIAL AND METHODS

At the University Children's Hospital in Belgrade we treated 78 children with scars induced by burns, with combined electrokinesis or electrothermokinesis therapy. After completion of treatment of the burn, i.e. when epithelialization begins, we carefully examine the burned surface and investigate the functional state of the surrounding joints. At the first sign of compromised functioning or contraction of surrounding healthy tissue, we initiate physiatric therapy in order to interrupt formation of keloids and to promote regression of those already existing. Electrotherapy is applied by potassium-iodide electrophoresis, with 1% iodide solution as an active substance locally instilled by the biological effect of galvanic current. Electrophoresis is conducted in a series of courses of 15 consecutive applications with pauses of 2 weeks, repeated in several series if necessary. Beside electrophoresis, regular physiotherapy is also necessary.

Therapeutic exercises are used to prevent contractures, muscle atrophy, tendon coalescence, shortening of the joint capsule, and oedema, while circulation and lymph drainage are improved (Israel *et al.*, 1985). Physiotherapy is initiated by active exercises and continued by active supported and passive exercises. In all cases of scarred face, neck and joint surroundings, early active exercises are of great importance, and especially in cases of facial scarring, since the facial muscles are directly linked to the skin, and in addition to aesthetic defects there may also be facial changes (hypo- and amimic faces), with ectropion of the eyelids and anomalies in the nasal and oral apertures. Occupational therapy is also very important in children (Strasser and Obr, 1989).

Thermotherapy is somewhat less frequently used since heat influences long-term hyperaemia and perfusion, and may have an adverse effect, i.e. promotion of keloid growth. We applied the technique very carefully in patients with hand and finger burns, when fixed contractures had already developed. Thermotherapy, e.g. paraffin compresses, were used as an initial procedure.

We always use elastic bandaging of the scars since keloid can be reduced by permanently controlled pressure (Wright *et al.*, 1989; Kaufman *et al.*, 1989). In cases of involvement of articulations of the extremities, we apply corrective or plastic splints (Ward *et al.*, 1989a,b) which maintain or increase movement of the joint.

RESULTS AND CONCLUSIONS

We treated 153 children with scars induced by burns. Keloid scars were most commonly noted after full-thickness burns (84.21%), and deep second-degree burns (63.93%). Keloids develop more frequently in burns caused by flame, hot liquid and chemicals (Table 1). Keloid scars were commonly localized in the limbs, face and neck, because of greater exposure of these parts (Table 2). After physical therapy had been conducted, a significant number of immature scars (67.16%) were cured, in contrast to mature scars which had to be managed surgically (Table 3).

Surgical therapy was applied only in mature keloids since immature keloids are known to promote recurrence in 40–50% of cases. In immature keloids leading to extensive functional disorders, surgical therapy is initiated earlier in order to prevent degenerative processes around the joints.

Table 1. Occurrence of keloid scarring related to burn severity

Degree	*No. of cases*	*Keloid scars*	%
I	54	7	12.96
II	61	39	63.93
III	38	32	84.21

Table 2. The most common localization of burns and keloid scars in children

Localization	*No. of cases*
Face and neck	20
Arms	23
Abdominal region	10
Back and gluteal region	9
Legs	16
Total	78

Table 3. The outcome of physical therapy related to maturity of the keloids

Keloid maturity	*No. of cases*	*No. cured*	*Surgically treated*
Immature	67	45	22
Mature	11	2	9
Total	78	47	31

It should, however, be noted that favourable aesthetic results and full range of movements were achieved only in burns where physical therapy was applied simultaneously with wound epithelialization. Mature (older) keloids cannot be treated conservatively. In these cases surgery must be applied and followed by prolonged physical therapy.

REFERENCES

Israel, D. J., Heydon, K. M., Edlich, R. S., Pozos, R. S., Wittmers, L. E. (1955). Core temperature response to immersed bicycle ergometer exercise at water temperatures of 21°, 25° and 29° C. *J. Burn Care Rehab.*, **4**, 336–344

Kaufman, T., Nawman, R. A., Weinberg, A., Wexler, M. R. (1989). The Kerlix tongue-depressor splint for skin-grafted areas in burned children. *Innovat. Burn Care*, **5**, 462–463

Melhorn, J. M., Horner, R. L. (1987). Burns of the upper extremity in children: long term evaluation of function following treatment. *J. Pediat. Orthop.*, **7**, 563–567

Strasser, M., L., Otr, L. (1989). Creative use of metal rings in hand therapy. *J. Burn Care Rehab.*, **4**, 350–351

Ward, R. S., Schenbly, W-A., Krautz, M., Warden, G. D., Saffle, J. R. (1989a). Use of positive plaster impressions to facilitate measurement of anti-burn scar support gloves for severely burned hand. *J. Burn Care Rehab.*, **4**, 351–353

Ward, R. S., Schnebly, A., Kravitz, M., Warden, G. D., Saffle, J. R. (1989b). Have you tried the sandwich splint? *J. Burn Care Rehab.*, **1**, 83–85

Wright, M. R., Taddonio, T. E., Prasad, J. K., Thomson, P. D. (1989). The microbiology and cleaning of thermoplastic splints in burn care. *J. Burn Care Rehab.*, **1**, 79–82

Section XV

Burn centres

81
The burn unit – past, present and future

ANNE B. SUTHERLAND
Lothian Regional Plastic Surgery and Burns Unit, Edinburgh, UK

There is no doubt that improved burn care for the many has come from advances made in the treatment of those looked after in burn facilities.

PAST

In the remote past, separate facilities were requested for burned patients, mainly because surgeons in general surgical wards were reluctant to care for them, and felt they were a risk to other patients. For example, the minute of a meeting of the Board of Management of the Royal Infirmary of Edinburgh dated 13 March, 1843, records the following. 'The clerk stated that the Superintendent requested that it might be distinctly settled whether or not cases of accidents from burning were to be admitted to the Surgical Hospital because there seemed to be a disinclination to receive them ..... a house surgeon had informed the Surgeon of Police that his professor had indicated that such cases should not be admitted as they "stank" all the wards' (Simpson and Wallace, 1965). In the more immediate past, advances in care and the continuing problems with infection, have resulted in specialization and a demand for separate facilities. Burn units of varying design and complexity have been established throughout the world.

PRESENT

The larger units have made major contributions to research, both clinical and experimental, but little has been written about burn unit design and its influence, if any, on morbidity and mortality. Hundreds, perhaps thousands, of papers have been written or presented on infection, early versus delayed skin cover, and many other aspects of care, but seldom are the facilities in which the patients were treated described in any detail or criticized.

Feedback from staff is almost non-existent, yet those who work in a unit are surely those most able to criticize and suggest improvement in design. Such information is minimal, and any recommendations made appear to be based on theory only. The experience of those who have worked in established units should provide guidance, supported by fact, for those concerned with the provision of new facilities. In this cost-conscious age this information will be demanded when these are being planned.

FUTURE

In planning for the future several questions need answers.

What size of unit is necessary?

Many smaller injuries, while requiring specialist treatment, do not need sophisticated facilities. They do, however, play a part in relieving the emotional demands on staff, which the care of the major injury imposes. The population served will be a major factor in determining size, but a unit of less than six beds is probably not efficient, and is often no more than a prestige symbol for the hospital concerned. A unit admitting both adults and children requires special provision for the child patients. It may be better to make this provision in a Children's Hospital where staff, equipment, facilities and conditions are present for paediatric care.

What are the needs for air-conditioning and isolation?

Air-conditioning is expensive and its design for a burn unit complicated, a fact not always known or appreciated by air-conditioning engineers. It will be required in dressing stations and operating theatres, and climate may dictate a need throughout the unit. Elsewhere, adequate space in bed areas may be as important, and the lessons learned from those who treated infectious diseases in the past need to be re-learned if cross infection is to be prevented or at least reduced. Such discipline should be taught to and demanded of all staff.

Who looks after burned patients?

The development of intensive care units, usually with intensivists or anaesthetists in charge, is becoming the accepted pattern for the treatment of the severely injured or ill patient. It concentrates medical, nursing and paramedical staff in one place, avoiding duplication of both staff and of expensive equipment. Most intensive care units are not designed to deal with the equally important problem of the burn wound, and thus have poor facilities for total care. Lack of an adjacent dedicated operating theatre, dressing station and bathing areas, pose insuperable difficulties to the burn care staff. In addition the other patients in intensive care are likely to be at greater risk from infection, more especially when the burned patient with a major complication has to be returned to intensive care later in his course.

If such areas are to be shared, good forward planning is essential so that the special facilities required for the burned patient can be incorporated in the design.

What staff are required?

This will depend firstly on the size and admitting policy of the individual unit, but it is not always easy to recruit and retain staff – medical, nursing and paramedical. Now it is unusual to find surgical staff who are prepared to devote the whole of their professional life exclusively to the care of burned patients, although there are exceptions. Equally nursing staff are willing to gain experience on a burn unit, but their promotion tends to be away from direct patient care, so that really experienced staff are few. A unit without adequate numbers of dedicated and experienced staff has constant problems, both in the delivery of patient care, and in the results it achieves.

The ideal design will be different for differing needs and for individual countries, and often compromises have to be made, but wider honest discussion of this aspect of burn care requires greater attention.

REFERENCE

Simpson, D. C., Wallace, A. B. (1956). Edinburgh's first burn hospital. *J. R. Coll. Edinb.*, **2**, 134

82

The new burns centre in Messina, Italy (a sketch)

G. GERMANO, C. CARBONE, A. CARDILE
and G. CAUTERUCCIO
Divisione di Chirurgia Plastica, Ospedale Papardo, USL 41, Messina, Italy

The construction of burns centres has long been planned as part of the Sicilian Region health programme. About 10 years ago the need was felt for a third burns centre, in addition to those already existing in Palermo and Catania, in order to deal with emergencies in the Messina area and also from Calabria in mainland Italy. Because of its geographical position Messina should be able to provide services for a wide area of potential users, and it should also be able to collaborate with the other two Sicilian burns centres in the event of a major emergency.

The Messina Burns Centre is located in the country area of Papardo in a newly constructed multidisciplinary Hospital. It is already in part operative and will soon be completed. In the planning phase we collaborated with other Centres with several years of experience, who gave us valuable advice.

The Messina Burns Centre is divided into two sections: one for intensive therapy and the other for the post-acute phase. Particular attention was paid to the planning of paediatric care, as we wished to guarantee for younger patients a degree of comfort that could reduce the psychological stress of the burn injury. The children's area is isolated from other areas of patient care (see Figures 1 and 2).

Optimal efficiency is guaranteed by the Centre's functional layout, with internal and external access routes and sensible distribution of space. The Centre possesses all the equipment that is necessary for its efficient management. A helicopter landing station has been set up opposite the Burns Centre, which can thus be easily and rapidly reached by air. Every detail was studied in the planning of this hospital in order to make the admission of patients as rapid and comfortable as possible.

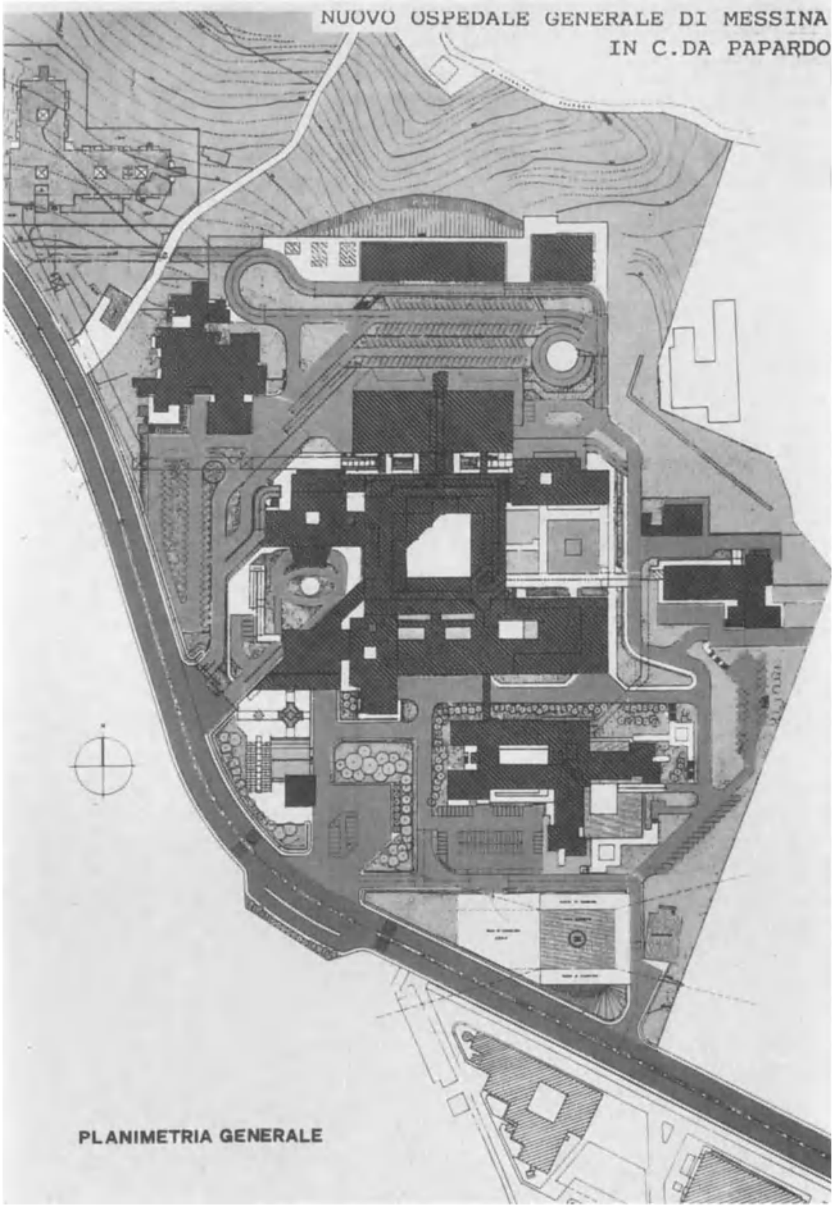


Figure 1. General plan of the Messina Hospital.

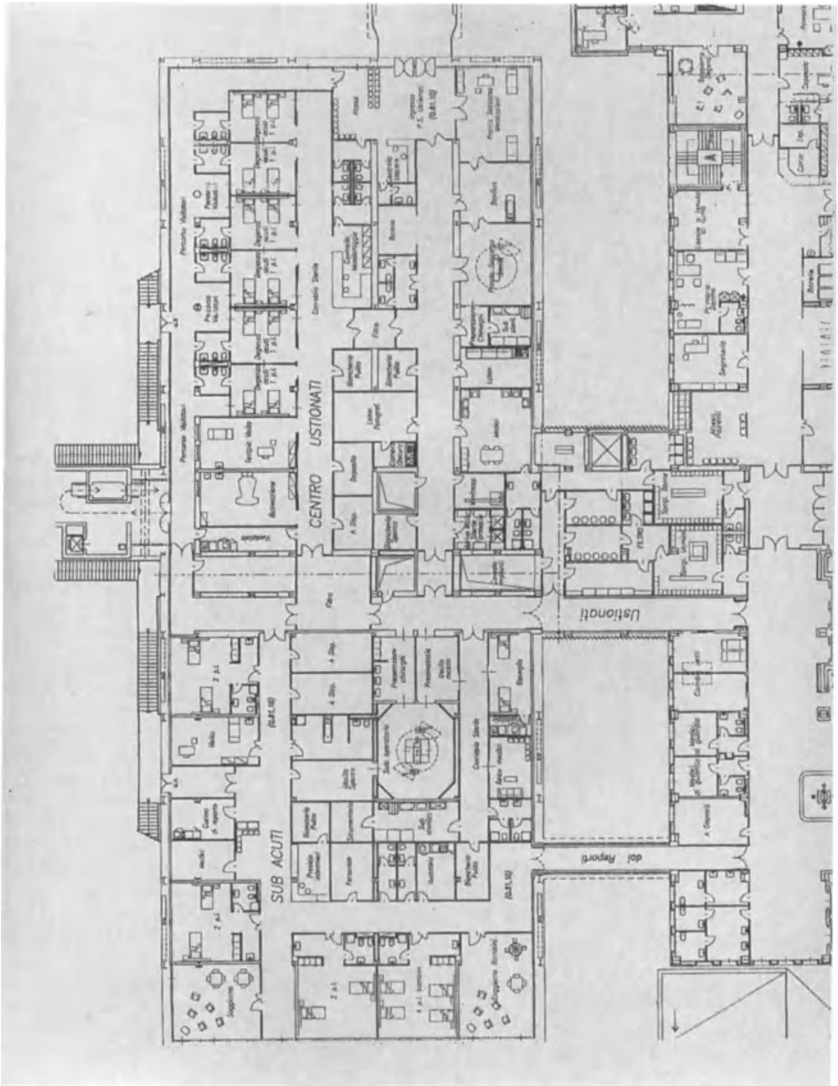


Figure 2. Detailed plan of the Messina Burns Centre

83
The new burns centre in Rome; a brief description

P. A. PALMISANO, V. PANTANO and G. PEDONE
Divisione Chirurgia Plastica e Centro Ustioni, Ospedale S. Eugenio, Rome, Italy

---

The new burns centre in Rome was opened in October 1990, and now, 2 years later, we would like to describe it in the light of the most recent constructive and functional criteria described in great detail in a recent work by Magliacani *et al.*

Various types and sizes of unit are proposed, ranging from small units for one or two patients attached to already existing departments (general surgery, resuscitation, plastic surgery) to burns departments for up to 10 patients, where a distinction is made between acute, non-acute and septic patients, and burns units, for up to 16 patients. A true burns centre should have space for up to 32 patients, be divided into sections that are as independent as possible of one another (acute, non-acute and septic patients) and have services providing adequate autonomy.

The ideal models that are proposed are more or less square in shape, with the services in the centre, an intermediate ring with the patient rooms, and an external corridor for visitors and non sterile traffic. There should be a single climatization system with a high air turnover rate, and filter zones between the various sections with a positive pressure gradient from the more sterile to the less sterile zones.

The Rome Burns Centre occupies an entire floor in the New Sant'Eugenio Hospital (Figure 1). It differs from the above ideal standards because of the Hospital's extremely elongated structure and in view of certain technical solutions that are possibly now outdated, particularly with regard to the climatization system and the filter zones, a consequence of the long time interval between the original planning of the Centre and its actual construction. The Centre is divided into two completely separate sections: intensive therapy and subintensive therapy. Subintensive therapy consists of services (reduced to a minimum because they are incorporated in the intensive section) and

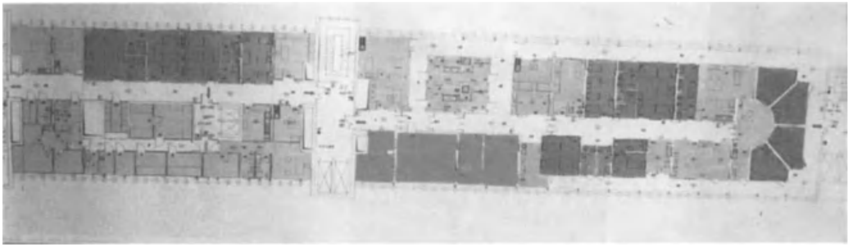


Figure 1. Plan of the Burns Centre at the New Sant'Eugenio Hospital

patient rooms with beds for eight adults and four children, plus an adjacent playroom. The structure is typical of many hospital departments, with a central corridor and rooms on either side. Intensive therapy consists of an admissions area with a medication room, a filter zone for the preparation of staff, and an operating theatre area with a preparation and recovery room.

The patient area contains 14 beds for adults and children, five in single rooms with incorporated bathroom and four equipped with respiratory units for resuscitation. This sector of the Centre comprises sterilization services, a pharmacy, a small laboratory and a balneotherapy room. The nurses have two work-stations, from one of which they can observe the four intensive therapy beds (by means of a small monitoring centre) and from the other the remaining beds. The services are halfway along the

Figure 2. Patient's bed in the Intensive Care Unit.

central corridor in order to reduce staff movements. The visitors' corridor runs along three sides of the patient room zone.

We would point out that although it has been necessary to adapt the Burns Centre to the long, narrow shape of the New Hospital, the technical solutions adopted have made it possible to create an efficient and functional facility. The fact that the operating theatre is located in the intensive care unit means that we have a functionally integrated unit used exclusively for burn patients. Medical and paramedical staff enter the intensive care unit by way of a filter zone where hands and forearms are sterilized and sterile clothing put on. Patients enter the area through a hatchway with a moving floor after careful washing in the acceptance area baths.

Although the ratio between intensive therapy and subintensive therapy beds is not optimal, we are able to manage patients during the whole cycle of the burn disease until discharge.

We are also fortunate to have the collaboration of the Second Rome University (Tor Vergata), which possesses on the same floor a cell typing and tissue culture laboratory, and it will thus soon be possible to use cultivated autologous skin.

84

After twenty years' experience, should the structures and standards of burns centres be reconsidered?

E. PALADINI, G. SICILIANO, A. GALLA, C. GOZZI, F. LONGATO, G. LOSASSO and M. BOLIANDI
Divisione di Chirurgia Plastica dell'Ospedale di Udine, Udine, Italy

In 20 years of activity the Udine Hospital Plastic Surgery Department has treated over 1000 burn patients. The statistical results of this activity are summarized in Tables 1 and 2. These results show that the average survival rates are similar to those of any national or foreign burns centre. The exceptional character of these results lies in the fact that they were not obtained in a specialist burns centre but in an ordinary hospital ward, built 50 years ago and employing the same personnel as normally found in general surgery.

Although its name is included in the national list of Italian burns centres, the Udine Plastic Surgery Department has neither the structures, the personnel nor the minimum technical support to offer burn patients care different from that offered to any other patient. The continuity with which the patients are treated depends on good internal organization and operative flexibility.

In contrast to the poverty of the structures, however, we have an adequate surgical armamentarium, expert anaesthetists and an excellent

Table 1. Absolute survival rates and percentages in a group of 1156 burn patients, subdivided into three groups on the basis of burn surface area (from 1973 to 1991)

	Percentage burn			
	0–25	*26–50*	*51–100*	*Total*
Number of burn patients	995	110	51	1156
Number of patients surviving	978 (98%)	92 (84%)	26 (51%)	1096 (95%)
Number of deaths	17	18	25	60

Table 2. Absolute survival rates and percentages in a group of 51 patients burned in over 50% body surface area, subdivided into three classes on the basis of burn surface area and with reference to age (from 1973 to 1991)

Class of burn (%)	*Patient*	*Age*	*% burn*	*Outcome*[a]	*Total*	*Percentage survival*
	T.P.	48	52	S		
	S.G.	60	54	S		
	P.S.	43	52	S		
	P.A.	22	52	S		
	C.D.	25	60	S		
	D.L.	2	52	S		
	D.L.	51	51	S		
	M.O.	49	51	S	15	
	T.A.	39	60	S		
	P.R.	37	60	S		
51–60	C.F.	18	55	S		68
	R.D.	18	60	S		
	G.R.	47	55	S		
	V.S.	26	52	S		
	V.E.	27	60	S		
	D.A.	84	52	D		
	C.G.	76	60	D		
	C.G.	26	55	D		
	C.C.	40	54	D	7	
	M.C.	87	60	D		
	L.G.	68	51	D		
	B.E.	57	60	D		
	D.P.	46	70	S		
	V.F.	19	64	S		
	P.C.	26	65	S	5	
61–70	Z.R.	41	62	S		55
	S.A.	51	63	S		
	V.A.	61	70	D		
	Z.A.	69	70	D		
	B.A.	76	65	D	4	
	R.M.	63	62	D		
	C.M.	28	72	S	1	
	F.E.	39	80	D		
71–80	T.E.	28	80	D	3	25
	B.G.	75	80	D		
	B.C.	33	90	S		
	B.R.	32	81	S	3	
	P.S.	41	84	S		
	B.G.	21	90	D		
81–90	G.M.	55	90	D		37
	S.G.	49	90	D	5	
	D.A.	53	90	D		
	V.E.	70	88	D		
	M.P.	25	92	S	1	
	C.M.	46	98	D		
	D.G.	39	98	D		
91–100	D.O.	51	95	D		12
	P.D.	16	92	D	7	
	R.I.	83	95	D		
	B.G.	70	95	D		
	C.G.	73	93	D		

[a] S, survived; D, died

qualitative and quantitative supply of blood, plasma and derivatives. The problem of post-transfusional hepatitis is practically non-existent among our burn patients and we have not had one case of AIDS. For this we have to thank our Immunotransfusion Institute and its capillary organization of donor and biological product control (Visentini and Losasso, 1983; F. Biffoni, personal communication).

It is our firm belief that the success of our results is in a large measure due to the fact that we have behind us an organization that enables us to perform with a high degree of safety the resuscitation of severely burned patients with the plasma, derivatives and blood that this organization provides in the abundant quantities that we require.

In the course of time we have developed the clinical concept that early therapy to replace initial plasma losses effectively prevents a whole series of early and late general and local problems and complications such as those that have to be faced when resuscitation is essentially based on the massive administration of electrolytic solutions (G. Crua and A. Bonzanino, personal communication). It also ensures stability of the basic biological parameters and enables the patient to maintain a good level of coenaesthesia (Visentini *et al.*, 1980).

Our experience is that there are serious drawbacks to the clinical procedure of administering a massive quantity of electrolytic solutions in the initial phase and of reintegrating the lost plasma fraction when capillary transudation tends to cease. This rigidly stoichiometric concept in our opinion takes little account of the reality of the situation, as it proposes the re-equilibrium of the 'plasma balance' when organic damage is already established. With adequate introduction of plasma in the first 24–48 h, even extensively burned patients remain lucid and compliant and the base parameters are stable, so that biological tests can be limited to those that are absolutely essential. Nutrition problems can also be overcome immediately and easily, and to the patient's satisfaction. Even when the final outcome is negative, the initial period is often overcome with a certain ease, and the mean survival period approaches 2 weeks (Table 3).

As a result of the rapid restoration of clinical stability surgical treat-

Table 3. Mean survival time of patients dying with 51–100% burns (from 1986 to 1991)

Patient	*Age*	*% burn*	*Days of survival*
R.M.	63	62	1
B.G.	75	80	7
P.D.	16	92	58
R.I.	83	95	1
B.G.	70	95	2
M.C.	87	60	30
L.G.	68	51	24
V.E.	70	88	1
C.G.	73	93	1

Mean survival time: 14 days

Table 4. Mean hospital stay of surviving patients with 51–100% burns (from 1986 to 1981)

Patient	*Age*	*% burn*	*Hospital stay (days)*
Z.R.	41	62	64
B.R.	32	81	18
S.A.	51	63	80
P.S.	41	84	78
V.S.	26	52	81
V.E.	27	60	39

Mean hospital stay: 60 days

ment can be initiated early. This reduces the risk of complications and reduces the length of hospital stay (Paladini and Galla, 1986; Table 4). In our most extensively burned patients the mean period between the accident and initiation of surgical therapy is about 12 days.

The problem of bacterial colonization still exists, as everywhere else, but we very rarely have serious septic problems. With limited and careful use of antibiotics we have observed more and more frequently the presence of a very varied polymicrobial flora which is not difficult to attack. The increased number of *Staphylococcus aureus* and *Pseudomonas* strains that we have observed as a result of this therapeutic policy is amply compensated for by the greater sensitivity of these bacteria even to antibiotics not of recent introduction (Tables 5 and 6).

The fact that non-burned and burned patients live together in the same wards has not yet created any evident clinical problems. One im-

Table 5. Colonization rate of *S. aureus* and *Pseudomonas* in burn patients as measured by antibiogram (from 1989 to 1991)

	1989	*1990*	*1991*
Total number antibiograms	154	163	252
Positive for *S. aureus*	70 (45%)	55 (34%)	133 (52%)
Positive for *Pseudomonas*	22 (14%)	32 (20%)	36 (14%)

Table 6. Sensitivity *in vitro* to antibiotic agents (from 1989 to 1991)

	1989	*1990*	*1991*
S. aureus	50% antibiotics tested	44% antibiotics tested	65% antibiotics tested
Pseudomonas	17% antibiotics tested	25% antibiotics tested	67% antibiotics tested

The number and type of antibiotics tested have been practically the same in the last three years portant point must however be considered: the problem of the risks due to transfusions. We are firm believers in the resuscitation of burn patients using plasma but we are fully aware of the dangers that this may involve. A seriously burned patient runs two risks: one immediate, related to the trauma and its evolution, which we must endeavour to control, and the other hypothetical and long-term, related to the possible transmission of diseases.

The immediate danger is direct, and no one would consider countering it without the use of plasma, blood and derivatives. Limited use of these therapeutic means in the initial phase of the burn disease may complicate the solution of the patient's physical problems, and even if the patient survives this early experience he is not covered from risk of infection.

It is our opinion that the crucial and hard to identify point of discrimination is the definition of the conditions that indicate the necessity of the use of plasma. Until a few years ago, as the burn surface increased, therapy based solely on electrolytic solutions gradually gave way to a broad band of cases in which blood and its derivatives were used in increasingly greater quantities. This band is now reduced to a narrow margin above which the use of blood and its derivatives is absolutely out of the question and below which they can be used with complete freedom. The important point now is to define the exact position of this margin.

We have briefly described our structural organization and our operative principles, together with our results, because we considered these elements important with regard to the point of view that we are about to present.

For the care of burn patients the law in Italy provides for a number of organizational modules with large bodies of medical and paramedical personnel, plus – in the case of severely burned patients – special intensive therapy facilities (*Gazzetta Ufficiale*, 1988). In numbers and structures we are far from the prescribed parameters, and yet we achieve in the entire Friuli Venezia Giulia Region results that are not dissimilar to those obtained in specifically equipped centres.

Obviously this has not been a deliberate choice on our part, but it has in fact become an opportunity for us to compare our own experience with other quite different experiences. This comparison between what we might define as 'experimental data' and 'controls' may provide useful elements for value judgements and precise suggestions for future planning.

Although our personnel is limited in number (six physicians for a total of 30 beds) and engaged in providing medical and surgical care for both non-burned and burned patients, the time and energy commitment of each single member of the staff is quite within reason, since the evolution of the burns disease, in our patients, is very straightforward and requires therapeutic and control procedures that are simple and spread out over a period of time.

The State Health Service is currently going through a somewhat delicate phase because of general economic problems and internal conflicts. This is a moment of social, economic and technical transformation. In this context we may question whether a 'closed' burns centre with its overabundance of personnel and facilities – with all the costs involved – in fact represents a valid operative solution.

When we consider a facility planned for burns therapy, regardless of the clinical policy that each one may intend to pursue, we cannot ignore the necessity for large quantities of blood and derivatives. This means that every Immunotransfusion Centre related to these facilities becomes an irreplaceable 'functional appendix' of the facilities.

That being the case – and also in the light of some recent behavioural guidelines suggested by the Italian Health Ministry (Ministero della Sanità, 1992) regarding the use of blood and derivatives – one may wonder whether during the planning phase of a burns centre it is not advisable to envisage an increase in the activity of the immunotransfusion centre, in its supply and control procedures and in any other activity capable of assuring a wider and safer use of the biological product that it provides.

The more technologically advanced countries are generally the first to create new instruments and social structures, in response to the demand for better qualified services and greater availability of financial resources.

These new developments, in turn, are taken as examples to be imitated or to be proposed to developing countries or to areas – in some cases national areas – that are not provided with these structures. As every technological product has a natural tendency to become obsolete, it is both a necessity and a duty to review it critically after a period of time. This should enable us to plan operative units that are technically adequate and at the same time easily realized in the different social and economic contexts that we see about us.

In Italy we have a long experience in the field of burns centres, which have been progressively equipped with ever more sophisticated technical means without, in our opinion, evolving on the structural level.

In the 'Mediterranean' context of this Conference we have a number of participants with a wide background of different realities and experiences, and I would suggest that it might be advisable and profitable to carry out a critical analysis of this theme in order to provide a newly conceived operative model that is more open to current developments, more flexible, less expensive and more effective.

BIBLIOGRAPHY

Gazzetta Ufficiale della Repubblica Italiana (1988). Decree of 13 September 1988. Serie Generale n. 225, 24.09.88

Ministero della Sanità, Commissione Nazionale per il Servizio Trasfusionale (1992). *Il buon uso del sangue*, Rome, July 1992

Paladini, E. and Galla, A. (1986). L'uso della colla di fibrina nel trattamento chirurgico degli ustionati. *Riv. Ital. Chir. Plast.*, **18**, 305

Visentini, P. A., Gozzi, C., Linda, G., Longato, F. and Paladini, E. (1980). La monitorizzazione della proteinemia nell'ustionato. *Riv. Ital. Chir. Plast.*, **12**, 221

Visentini, P. A. and Losasso, G. (1983). Ustione ed epatite virale. *Min. Chir.*, **38**, 417

85

A proposed computer file for use in burns centres

M. COPPOLA, A. APOLITO and G. DE NICOLA
Ospedale A. Cardarelli, USL 50, Regione Campania, Italy

It is scarcely necessary to stress the importance of computers in medicine or to produce new arguments to demonstrate that health management and medical research have benefited enormously from their use.

In a burns centre the handling and analysis of data from the patients are of paramount importance. The first problem is the collection of data in the most accurate and straightforward manner possible, with the aid of clinical computer files. Such files simplify data collection, standardize the required information, and allow its organization into homogeneous groups in order to reduce subjective interpretation to an absolute minimum. The filing and management of clinical data are as important as the analysis and processing of the data collected. The clinical file must have no limitations with respect to either the type or the quantity of data to be memorized; it must also be modifiable in the course of time on the basis of experience acquired or new needs that may develop.

These considerations have prompted us to prepare a file that we define as 'basic', in the sense that it can subsequently be integrated with other data and information. The file has been compiled for use in a uniform manner in different burns centres, taking into consideration different parameters and different realities. The basic file is divided into a number of sections:

- patient's personal details and specific data;
- assessment of the main and secondary causes of the burn accident;
- description of the patient's clothing at the time of the accident;
- extent and nature of the patient's burns.

The main problem in the preparation of a clinical computer file is how to combine the operative procedures that have traditionally developed in medical practice with the logical organization of the data processing procedures required by a computer.

Appendix 1. Basic file

Surname .... First name (s) .... Sex: M ☐ F ☐ Born at .... on .... Home address .... Town .... Phone number .... Age .... Weight in kg .... Height in cm .... Date of accident .... Hospital of origin .... Date of admittance .... Progressive number .... Date of discharge .... Duration of hospitalization .... days

ACCIDENT: time ... day ... month ....exitus ☐ on ... due to ....

PLACE: town ☐ country ☐ public place ☐ private place ☐ house ☐ building ☐ public premises ☐ office ☐

NATURE OF ACCIDENT: *Domestic*: ☐ kitchen cooker ☐ barbecue ☐ brazier ☐ cooking oil ☐ boiling water or liquid ☐ TV, electronic apparatus ☐ electric wiring ☐ heating ☐ household appliance ☐ other: specify ....

SECONDARY CAUSES: epilepsy ☐ cerebral ictus ☐ drug addiction ☐ alcoholism ☐ loss of consciousness ☐ flammable substances ☐

specify .... self-inflicted: first attempt ☐ repeat attempt ☐
Circumstances of accident ....
Number of victims .... number of persons burned .... only person burned ☐
others burned: family ☐ neighbours ☐ strangers ☐

CLOTHING: cotton ☐ wool ☐ synthetic ☐ other ☐ **UNDERWEAR:** cotton ☐ wool ☐ synthetic ☐ other ☐

OCCUPATION: unemployed ☐ housewife ☐ worker: public company ☐ private company ☐ office employee ☐ farmer ☐ shopkeeper ☐ factory worker ☐ liberal professions ☐ other: specify ....

•••

CONTACT BURN: hot gas ☐ steam ☐ liquid ☐ solid ☐ other ☐ specify ....

FLAME BURN ☐ **EXPLOSION BURN** ☐ *liquid agent*: petrol ☐ diesel oil ☐ surgical spirit ☐ cooking oil ☐ cleaning products ☐ other: specify .... *gas agent*: mains gas ☐ bottled gas ☐ other: specify .... *solid agent*: wood ☐ coal ☐ synthetic material ☐ other ☐ specify ....

CHEMICAL BURN ☐ agent .... FROSTBITE ☐

ELECTRIC BURN ☐ from direct contact ☐ electric arc ☐ flash ☐

SMOKE PRODUCTION: wood ☐ petroleum products ☐ plastic, synthetic material, nylon, etc. ☐ other ☐ specify ....

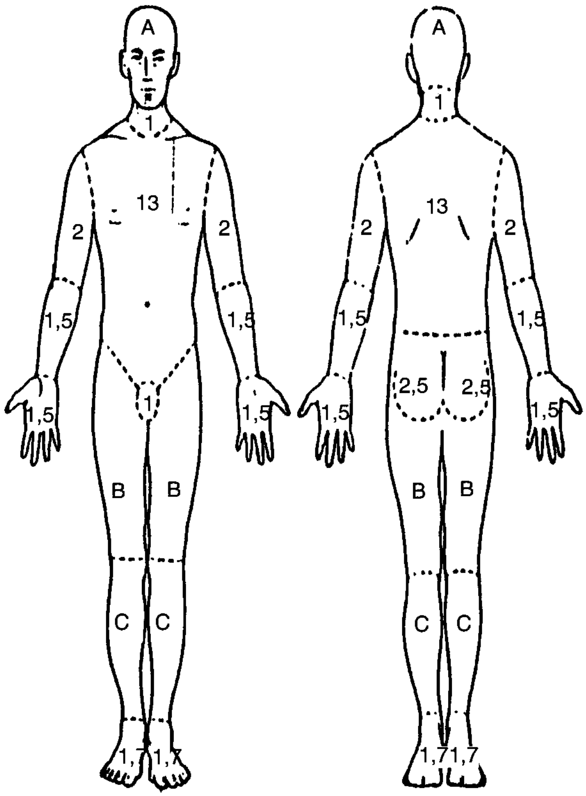
ASSOCIATED TRAUMA: before burn ☐ during ☐ after burn ☐
cranial ☐ fracture ☐ specify ....
dislocation ☐ specify ....
abdominal syndrome ☐ specify ....

PREVIOUS PATHOLOGIES

ENDOCRINE: diabetes ☐ other ☐ specify ....
RENAL: failure ☐ other ☐ specify ....
CARDIAC: right failure ☐ left failure ☐ infarct ☐ angina ☐ other ☐ specify ....
VASCULAR: hypertension ☐ failure ☐ other ☐ specify ....
RESPIRATORY: failure ☐ other ☐ specify ....
DIGESTIVE: gastric ulcer ☐ duodenal ☐ other ☐ specify ....

DIAGRAM OF BURNED SURFACES

Superficial burns: RED
Deep burns: BLUE



Burned surfaces
Head ....
Neck ....
Trunk ....
Arm ....
Forearm ....
Hand ....
Genitals ....
Buttocks ....
Thigh ....
Leg ....
Foot ....
Superficial burns % ....
Deep burns % ....
Total % ....

PROPORTION OF BURNED SURFACES IN RELATION TO AGE

Years	*0*	*1*	*5*	*10*	*15*	*Adult*
A	9.5	8.5	6.5	5.5	4.5	3.5
B	2.8	3.3	4.0	4.3	4.5	4.7
C	2.5	2.5	2.7	3.0	3.2	3.7

The different types of information make it possible for the file to be used not only for statistical surveys of a vast amount of data but also for collaboration in the management of burns departments. The total data collected will therefore constitute not just a rigid archive related to a specific application but a data base whose flexibility increases proportionally as the purposes of the units having access to the data base are more numerous.

For these reasons we think it may be useful to compare this basic file with those used in other Centres in order to collaborate on the production of a single computer file, which would be of undeniable importance in the field of the statistics, research and prevention of burns.

Section XVI

Forest fires

86
Forest fire behaviour and fireline safety

D. X. VIEGAS
Department of Mechanical Engineering, University of Coimbra, Portugal

INTRODUCTION

Forest fires are among the most dangerous natural accidents that occur in practically all Mediterranean countries. These fires cause great damage to the environment, including wildlife, but also socially and economically. One cause of major concern is the threat that these incidents pose to human life. Many accidents in the past have proved that forest fires constitute a hazardous environment and the effort to extinguish them is a dangerous activity. One of the main causes of this is certainly the great variability of fire propagation properties, owing to a vast and complex set of influencing factors. Although in principle the behaviour of a flame front can be predicted, sufficient information may not be available to make a very accurate prediction. Scientific research is working on the development of models that are both robust and simple to provide support in the management of this type of accident. The problem of fireline safety has been addressed by many authors, including Chandler *et al.* (1983) and Palmer (1988). It is an issue that is present in all fire-fighter training programmes and in basic texts that support these courses, of which those published by NWCG (1986) and by NARTC (1983) are good examples.

The analysis of past accidents is helpful as it provides information about capabilities and decisions that did not work for one reason or another, which may be helpful to prevent future disasters. Descriptions and reports on accidents can be found in the literature, namely in Chandler *et al.* (1983), Pyne (1984), Simard *et al.* (1983) and Washburn *et al.* (1986). With this purpose four case studies are presented that show how a misjudgement of fire behaviour led to disaster, with loss of human life.

FOREST FIRE BEHAVIOUR

Fire propagation regimes

A forest fire is generally a dynamic phenomenon that changes its properties and behaviour from one place to another and with the passage of time. Owing to the fact that the forest fuel available in a given location is limited, for a fire to continue it must spread to neighbouring fuel. This is possible through the complex heat-transfer and thermochemical processes that determine fire behaviour.

Without going into the process in detail, it is important to recognize that there are various stages of fire growth and decay, and some typical fire propagation regimes. In order to understand the safety problems created by forest fires to human life it is necessary to be familiar with the above-mentioned concepts.

Fire growth and decay

A forest fire starts when a heat source – usually a small flame – ignites available fuels. If conditions are favourable the fire will propagate and grow both in size and intensity.

Combustion may be either non-flaming or with a flame. In the first case ground fuels usually burn very slowly, and this type of fire does not create a great threat to human activity, unless it changes to flaming combustion which grows and propagates much faster. If there is sufficient fuel on the ground and near the surface the fire will attain a steady state of propagation called a surface fire (Figure 1).

In forested areas a surface fire may grow vertically and reach the tree crowns, with the support of an ascending slope or strong wind. The fire will then propagate as a crown fire, which is extremely dangerous and difficult to extinguish. This is the so-called large fire regime. Large fires may be propagated either by wind and slope or by their own convection. In the first case we have a conflagration fire and in the second a mass fire. In large fires we have not only crown fire propagation but also spot fire propagation. These spots consist of burning embers that are projected great distances, creating secondary fires that may cause great danger to people near the fireline.

When there is no fuel available for combustion, or when topographical or meteorological conditions change, the fire decays and we have a similar phenomenon occurring in reverse. A large fire may decay and become a surface fire, which may degenerate into a ground fire until it is extinct and ceases.

Fire spread regimes

There are three main regimes of fire propagation: (i) ground fire; (ii) surface fire; and (iii) crown fire. The rate of spread and in particular the

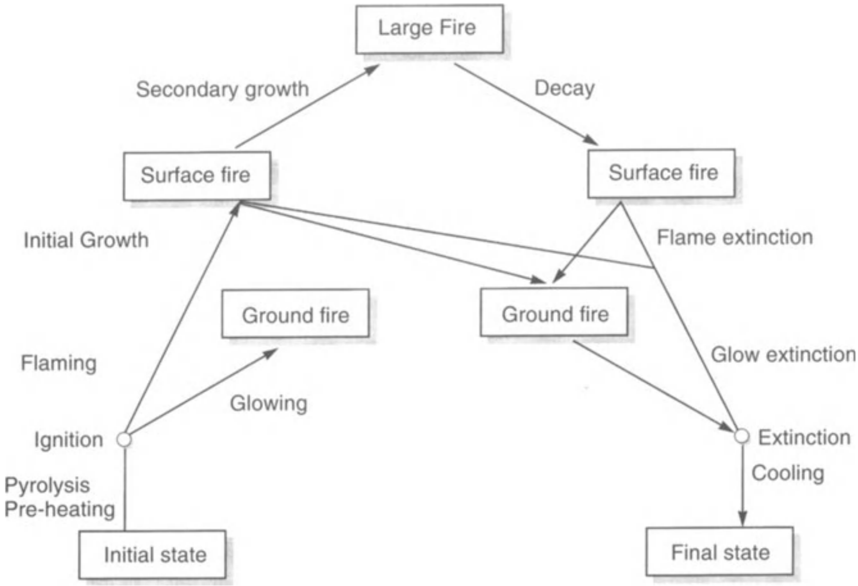


Figure 1. Phases of development and propagation regimes of a forest fire

heat released by the fire varies by several orders of magnitude between these regimes and we must therefore analyse each one separately to show its respective threat to human life. Ground fire is not important in this context and we shall thus concentrate our attention on surface and crown fire.

Surface fire is by far the most common type of forest fire in the Mediterranean environment. Given the large variability of fuel and meteorological and topographical conditions, a surface fire may propagate in a wide range of values of rate of spread and of fireline intensity (defined as the heat released per unit length of fire front per unit of time). A very important and visible effect of fire propagation is the flame front. Flames are the loci of very intense exothermic reactions and constitute the main heat source in a forest fire. Flames consist of gases at temperatures varying between 1000 and 2000°C and are characterized by a certain length or height, inclination and depth. All these properties are relevant to personal safety in a fire front. Surface fires may have flames ranging from 0.1 to 5 m and a rate of spread ranging from a few metres per hour to 10 km per hour.

Crown fires are characterized by much larger flames, of the order of 20 to 50 m and consequently higher rates of spread.

Although large fires and crown fires are potentially the most dangerous, NWCG (1986) found that most fatal accidents in past occurred in relatively small fires or quiet sectors of large fires. This is understandable as normally no one would risk his life or that of others in clearly dangerous situations, as is obviously the case in large fire propagation.

There are of course also exceptions, due to an erroneous perception of the situation or to changes in the conditions affecting fire spread that were not noticed by the victims.

Factors affecting fire propagation

We have already mentioned the three groups of factors that affect fire behaviour: (i) forest fuels; (ii) topography; and (iii) meteorological conditions.

Forest fuels have different properties depending on the plant species present in the area, on whether they are alive or dead, on the size of their particles, on the amount of fuel per unit area and on its spatial distribution. The moisture content of fuel particles is of great importance for fire propagation, as high values of moisture content damp or even prevent fire spread. As a rule fine dry particles propagate fire faster and more easily, as we see in grass or light brush fields.

Topography is of utmost importance in fire behaviour. A fire spreads much faster uphill than on a horizontal surface or downhill. Even in the absence of wind this fact may be overwhelming and a fire front may run uphill, catching people in its path, as too many past accidents have unfortunately demonstrated.

Meteorology affects fire propagation with both long-term and short-term action. Long-term action is determinant for the moisture content of forest fuels, including that of fire fuels. Short-term action concerns air temperature, relative humidity and the wind conditions that directly affect fire behaviour. Of these by far the most importance is wind, defined by its velocity and direction.

Wind blowing in the same direction as that of flame propagation will increase the rate of spread from five to 100 times that in windless conditions. This action is stronger with light fuels, such as grass or light brush. These are usually considered not very dangerous fuels, although they may become so owing to the potentially high rates of spread that make entrapment relatively easy.

Wind may vary because of general changes in the atmosphere (large scale or weather changes) that usually occur slowly. The interaction of wind with topography creates a very complex flow pattern near the ground, with large variations of wind velocity and direction, sometimes with reversed flow, i.e. with a direction contrary to the main wind, in certain zones. As the flame front moves from one zone to another, even under constant wind conditions, it may experience considerable changes in its behaviour. It has been reported in the past (NWCG, 1986) that some fatal accidents occurred following unexpected wind shifts or increases in wind speed.

This brief description of the various regimes of fire spread and of the factors that affect them shows that accidents during forest fires can happen very easily. A person near a forest fire, even one with experience in the field, does not normally have all the information and knowledge necessary to evaluate how the fire will develop in the near future. There are so many factors and, especially for a person on the ground, it is not easy to form an overall view of the scene and predict if the fire will maintain its properties or accelerate, change direction, decay or do something else. With the exception of persons caught quite inadvertently inside a forest fire, the main cause of fatal or near fatal accidents, in the author's opinion, is misjudgement of fire behaviour.

Heat and smoke

Heat transfer mechanisms

In a forest fire the main heat transfer mechanisms are radiation and convection. Given the low thermal conductivity of the materials in a forest, thermal conduction is a relatively minor heat transfer mechanism.

Working in the proximity of a flame front exposes persons to important heat fluxes. If these are greater than the body cooling capacity a heat stress situation may arise, with all its medical consequences.

Chance contact with flames, very hot particles or gases may cause burns, the severity of which depends on the temperature of the heat source and on the exposure time. In a military context it has been established (Chandler *et al.*, 1983) that a person exposed to a radiation source of about 1000°C cannot survive exposure for 18 s. At 15 s about 50% incapacity is attained and practically no incapacity occurs at times of less than about 9 s. If we apply these considerations to the case of a person crossing a flame front we have the following situation. Given a flame front 3 m in height and an average temperature of 1000°C, and a person running through the flame at a velocity of 5 m/s, we may calculate that in the approach phase the person is exposed to that temperature for about 2 s. This leaves some 7 s to cross the flame front. Supposing that the person is able to maintain the same velocity, we may conclude that the person could cross a flame front 35 m deep. Although some of these considerations may be unrealistic, they give some encouragement to the decision to cross a flame front in the event of entrapment. It also shows that if a person tries to run in front of the flame front he is more likely to be exposed to severe burns and heat stress.

The convection of hot gases is another factor in heat stress in individuals. The inhalation of hot gases in particular may cause severe damage to the respiratory system which can be fatal, even if no major burns occur. This must also be kept in mind when considering the question of crossing a flame front. In the previous example it was assumed that there was no inhalation of hot gases from the flames, which is not easy to achieve.

Smoke

The combustion reaction in a forest fire is far from being complete and efficient, and large amounts of smoke composed of gaseous, condensed and solid products, with important effects on people working near the flame front, are released. Given the diffusion of smoke near the ground a situation of long exposure to smoke particles and to toxic gases can arise, with all its consequences.

In terms of fireline safety the loss of visibility created by smoke particles is very dangerous because it creates a sense of disorientation and aggravates the difficulty for a person to judge and evaluate the situation correctly. This particularly applies to drivers caught in roads full of smoke even if only for a short time-span. Even more dangerous is the case of pilots of low-flying planes or helicopters who may lose sight completely of the ground, with easily imaginable consequences.

In the composition of smoke we find carbon monoxide and occasionally some other toxic gases. The concentration of CO varies from around 10 to 20 ppm away from the fire to around 100–200 ppm at the edge of the fire. Protracted exposure to CO, even at low concentrations, can affect the nervous and cardiac systems and in extreme cases even cause death.

Fire behaviour prediction

The foregoing considerations clearly show that it is very important to be able to predict the behaviour of a fire front, in order to prevent situations dangerous to human life.

Past accidents have shown that even experienced fire-fighters are sometimes caught by surprise by unexpected danger, either because they did not correctly evaluate the situation, or because they did not have complete information, as for example the perception of some overall change.

In order to assist the persons in change of fire-fighting operations, especially in the event of a large fire, it is important to have a team working on fire behaviour prediction. With the support of mathematical models of fire behaviour and modern techniques of data collection and processing the process of decision making can be facilitated. Fire suppression can thus be carried out more efficiently and more safely. Decisions to evacuate fire crews from a flame front or to evacuate the population of a house or a village can be supported objectively and taken well in advance.

Fireline safety

Actions to promote the safety of personnel dealing with forest fires must be directed first above all at those involved in fire suppression. We cannot however forget the general public, because in many instances persons who have nothing to do with fire-fighting activities are caught inadvertently, by curiosity or by the desire to protect nature.

It is beyond the scope of this work to give a detailed treatment of the problem of fireline safety. We shall mention only briefly some aspects of two basic conditions for safety: training and equipment.

Personnel training is very important in order to teach crews to work as a team, to improve their technical skills and to provide the essential concepts of fire behaviour and the necessity of putting safety first.

Besides the essential tools and equipment, it is necessary to provide each fire-fighter with personal gear that affords him comfort and protection in the hard conditions of their mission. Jukkala and Putnam (1986) present a short description of the properties of each item of protective personal equipment, and similar descriptions can be found in NWCG and Chandler *et al.* The equipment should include flame-resistant overall clothing, leather boots and woollen socks, gloves, a hard hat and goggles. There have been interesting developments in Europe in the quality of the various pieces of equipment, especially in overall clothing. The work by Rouget and Drouet (1987), for example, describes tests with protective equipment for fire-fighters and contains some suggestions for protective equipment to be adopted in the forest fire environment. It is very important to ensure good protection while working near the flame front, without loss of comfort while travelling or walking. Adequate clothing in this environment can prevent the risk of burns, especially in delicate parts of the body.

One very important piece of safety equipment is the so-called fire shelter, which is a sort of aluminium-coated tent that can be carried in a small bag and put up rapidly in case of danger. Each fire shelter can provide excellent protection for one person, even in the event of entrapment by a large fire. In the writer's opinion this item should be mandatory for all those involved in fire-fighting. Its effectiveness has been well proved in many past cases and some fatal accidents could probably have been avoided if such shelters had been available. The report by Mutch and Rothermel (1986) is quite impressive in this respect.

A final remark to conclude this comment on safety: it is sometimes argued that protective equipment may induce overconfidence and thus provide ground for accidents. This will happen only if adequate training is not given in order to emphasize the capacities and the limitations of the equipment and of the human body.

CASE STUDIES

To illustrate some of the ideas developed in this chapter we shall now briefly present four case studies of fatal accidents caused by forest fires. Unfortunately there are many examples that could have been quoted here in order to give some insight into the problem and to learn how to avoid danger.

In Portugal 55 persons were killed by fire in three major accidents: in 1966, 25 soldiers were trapped in Sintra; in 1985, 14 fire-fighters were killed in Armamar; and in 1986, 16 fire-fighters were caught in Agueda. In 1992 seven persons were killed in five different accidents, including two pilots of fire-fighting aircraft.

From these and other accidents we choose four cases that will be briefly described below.

Armamar

This accident occurred on 8 September 1985 near Armamar, in the north of Portugal. Figure 2 gives a schematic view of the area. On the third day of a large fire, a crew of 15 men, most of them well-experienced fire-fighters, had just extinguished a fire in a pine-stand (point A in Figure 2) and was moving across a valley to help a small village that was experiencing some fire starts around it during a thunderstorm.

They were descending down a slope covered by heavy bush in a sort of small valley (B). In the meantime, under a heavy wind, the main fire made a long run along both sides of the valley. This was not noticed by the men until it was too late. They tried to run to their right, cross the small valley and climb to the other side, because they could see only the flames on their left.

In spite of the problems of progressing in such a terrain and in difficult psychological conditions five men reached the top of the valley (C), but there they were caught by the flame front approaching along the right side of the valley. In the meantime the others were caught in the middle of the two flame fronts. Only one man escaped: he was the last in the line and decided to run down the valley along the water line and survived (D). Everything was over in less than 20 min after the team first saw the danger.

Nagoselo do Douro

This accident occurred near the village of Nagoselo do Douro, also in the north of Portugal, not far from the site of the previous accident, on 31 July 1992.

A small fire was caused by a thunderstorm on the top of a hill, near a small chapel (see location A in Figure 3). The owner of the land, which

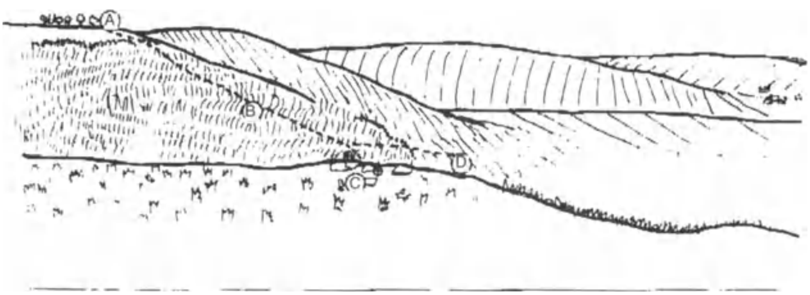


Figure 2. Schematic view of the accident area at Armamar

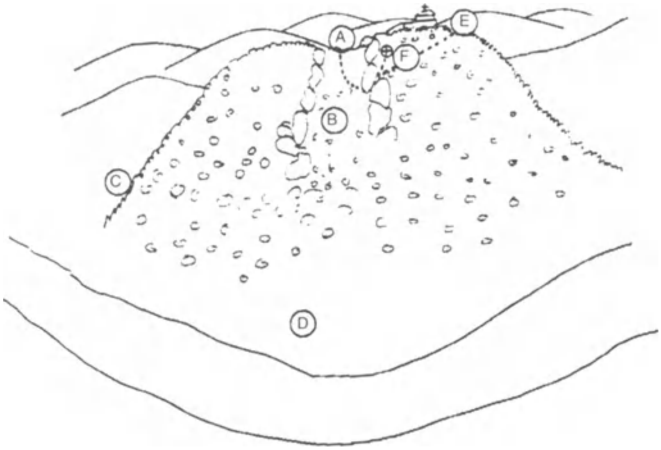


Figure 3. Perpective of the accident site at Nagoselo do Douro

was covered in fine oak trees, tried to extinguish the fire in its initial stages. A soldier who had just arrived home on leave went immediately to the area, taking with him four boys he met on the way.

The six people were at the bottom of a canyon approximately two-thirds up the side of the hill (B), with very poor visibility to their back and sides and with very bad escape routes. Unbeknown to them the fire spread down the opposite slope, around the hill (C) and appeared at their back at the base of the hill on the bank of the River Douro (D). With the help of wind the flames roared uphill giving very little chance of escape. The four boys were more fortunate and reached a safe point (E), but the soldier and the land-owner, who was a 56-year-old man, perished in the fire (F).

Fronhas

This accident occurred near the Fronhas dam on the River Alva, 40 km from Coimbra, in central Portugal, on 6 August 1992.

At about 2 p.m. a fire started about 5 km away from the Fronhas dam, where a crew of workers were installing a steel structure in the exterior of the central building of the dam (location A in Figure 4). Although they saw the fire they went on working until at about 4 p.m. they noticed that the flame front was coming in their direction and was very close to them. Although the span of the top of the dam is about 100 m and there is a road along it they decided to run to the bottom of the dam and wait for the fire there (B). There was a jet of water that sprinkled them and kept them cool and comfortable.

For some reason two of the men – one of them was actually an off-duty fire-fighter – decided to walk along the river (C) and cross to the other side. When they were climbing the steep slope on the other side,

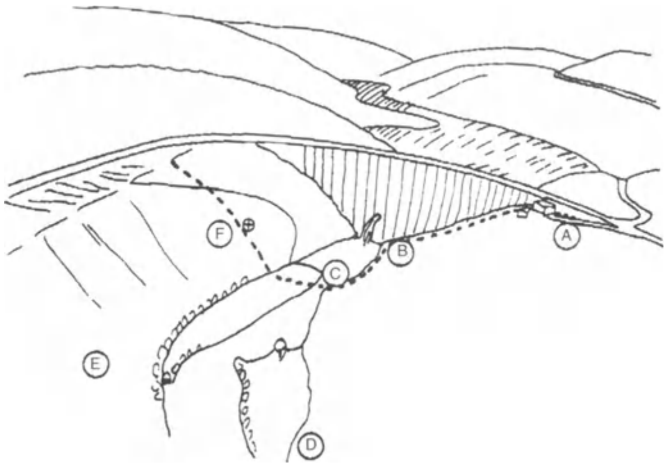


Figure 4. Perspective view of the site of the accident at the Fronhas dam

the flames appeared on the other bank (D) and propagated to the slope where they were (E). The first man managed to reach the top of the slope but the fire-fighter did not and was caught by the flames rapidly ascending through grass and light bush (F).

Celavisa

This accident occurred on 7 August 1992, near the village of Celavisa, about 20 km from the place of the previous accident and actually in the same large forest fire.

A young man who had just arrived to spend his holidays in his native village accepted the suggestion of his 12-year-old daughter to go and get a closer view of the fire. They went by motorcycle along the road and

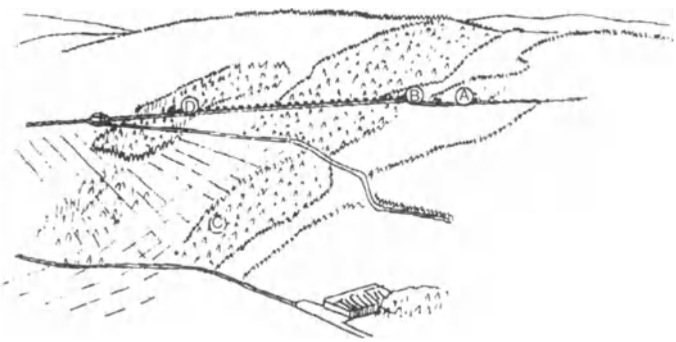


Figure 5. Perspective view of the Celavisa accident

suddenly were surprised by a column of smoke from a fire downhill (location A in Figure 5). Instead of turning back, perhaps because the fire had cut their escape, they left the motorcycle at the side of the road (B) and walked on down the road, probably looking for shelter in a house some 300 m from the place where they left their motorcycle. Unfortunately they did not reach the house and were both caught by the ascending flames (C), ironically in the middle of the only stretch (about 400 m long) where the fire crossed the road (D).

CONCLUSION

This chapter attempts to give a general idea of the complex phenomenology of forest fire propagation, in order to emphasize the danger that this type of natural accident represents for human life.

As general rule one can say that the basic cause of every forest fire accident is some misjudgement of the behaviour of the propagating fire front. Given the vast amount of variables that govern this behaviour, it is not difficult to appreciate this difficulty. Scientific research on fire behaviour and the development of fire prediction systems and protective equipment are valuable tools to improve fireline safety and can be very helpful in the prevention of such accidents.

The case studies presented support the idea that even experienced and well-trained fire-fighters can sometimes be trapped in apparently non-dangerous situations. As untrained persons can also be caught in a fire, the problem of public awareness is very important.

Joint research between medical doctors, scientists and operational institutions is needed in order to provide better ways of preventing injuries and fatalities due to forest fires. The author hopes that this work may be of help in this direction.

ACKNOWLEDGEMENTS

The author wishes to thank the institutions that support the research programme on the physical aspects of forest fires, in the framework of which this chapter was written, namely the Junta Nacional de Investigação Científica e Tecnológica, the Comissão Nacional Especializada de Fogos Florestais, and the EEC. A particular acknowledgement is made to the Serviço Nacional de Bombeiros for the information provided regarding the accidents described.

BIBLIOGRAPHY

Chandler, C. P., Cheney, P., Thomas, L., Trabaud, Williams D. (1983). *Fire in forestry*, vol. 2. New York: Wiley, 231–248.

Gaylor, H. P. (1974). *Wildfires*, R. J. Broady Co., 67–87.

Jukkala, A. H., Putnam, S. E. (1986). Protective equipment for the wildland. Seminar on Firefighters, Methods and Equipment for the Prevention on Forest fires, Valencia, 30 Sep.–4 Oct.

Mutch, R. W., Rothermel, R. C. (1986). 73 Fire-fighters survive in shelters. *Fire Command,* **30–2**.

National Advanced Resource Technology Center (1983). *El combate de incendios forestales.* Curso Internacional Avançado, Arizona, vol. 2

National Wildfire Coordinating Group (1981). *Fire Behavior S-390 (Student Guide and Text),* Boise Interagency Fire Center

National Wildfire Coordinating Group (1986). *Fire-fighters Guide,* USDA, NFES 1571, Boise Interagency Fire Center

Palmer, S. L. (1988). Emerging issues and concerns about wildland fire-fighter safety. In: Alexander M. E., Bisgrave G. F. (eds), *Proceedings of the Art and Science of Fire Management*

Pyne S. (1984). *Introduction to wildland fire – fire management in the United States.* New York: Wiley, 390–400

Rouget, Y., Drouet, J. C. (1987). Essais de vêtements et dispositifs de protection individuelle des personnels luttant contre les feux de forêts. *RGS,* **62**, 50–7.

Simard, A., Haines, D. A., Blank, R. W., Frost, J. S. (1983). *The Mack Lake Fire.* USDA, Forest Service, North Central Forest Experiment Station, Gen. Techn. Rep. NC-83

Washburn, A. E., Harlow, D. W., Fahy, R. F. (1985). U.S. fire-fighter deaths in 1985. *Fire Command,* **21–38**

87
Current trends in forest firefighting techniques

GIOVANNI BOVIO
Dipartimento di Agronomia, Selvicoltura e Gestione del Territorio, Università di Torino, Italy

The protection of our forests from the hazards of fire is a complex activity. Successful results require planning of the appropriate responses, which must be correctly divided between the prevention and the extinction of fire, without unduly privileging one or the other. This concept must be borne in mind in all measures taken in the planning of forest firefighting, even if different territorial conditions require substantially different approaches when operating in small or extensive areas. In all cases, however, it is essential to ensure a link-up with response facilities on a larger scale. For this reason, in order to be functional a local town plan, or one for a small natural park, must be linked up with regional and national planning.

Another, possibly even more important, consideration in forest firefighting planning is the influence of activities related to afforestation, land improvement and agriculture, which have a direct effect on the evolution of fires.

The way in which firefighting planning is conceived, i.e. the purposes it is intended to achieve, inevitably becomes a characterizing element of the plan, which may aim either at intervening in all cases of fire of whatever nature or at distinguishing between fires on the basis of their gravity and thus realizing a priority of intervention. The objective of eliminating all fires occurring in the territory may be theoretically valid, but in practice it is advisable to have a more realistic aim, i.e. by defining first of all the forest area that can acceptably be destroyed by fire.

The second stage in a modern forest firefighting plan is the definition of the pyrological characteristics of fire-fronts that can be allowed to pass over predetermined zones. The plan is based on the predictable behaviour of the fire-front in the various zones of the territory. In particular, the linear power, i.e. the quantity of heat generated by the fire-front per unit of space per unit of time, the height and length of the flame, and the time the fire has been burning are key points of information on the basis of which decisions regarding overall responses can be taken.

The mean values per hectare considered acceptable for a given plan, in relation to the various parameters of fire behaviour, are calculated considering first of all the capacity of the forest vegetation to survive fire damage. Secondly, a calculation will be made of the real possibilities of fighting the fire on the basis of the various potential responses provided for in the plan. It is very important to decide the relative weight of preventive measures, infrastructures and fire extinguishing.

The concept of integrated planning suggests that these three sectors should be appropriately distributed. It is true in theory that any one of the three sectors, if extensively developed, could keep fires under control without assistance from the other two, but in practice this solution is unacceptable because of its great expense and uncertainty.

This is proved by the poor results that have been achieved wherever an attempt has been made to solve the problems by concentrating on one sector alone. The error has sometimes been committed of making extensive use of aircraft without at the same time providing for other elements essential for fire prevention and extinction. Correct planning must provide for direct prevention measures in order to contain the flammable biomass within values that do not permit the development of the fire fronts of greater intensity than that planned for.

It is therefore necessary to have an 'integrated system' relating the various constituent parts (prevention, fire extinction, reafforestation) to forest territory management measures that may affect fires. Afforestation and land improvement operations principally affect the available flammable biomass. Certain operations in the field of wildlife management may also affect the biomass and have some influence on fires breaking out and spreading.

Forest fire prevention plans must therefore take into account all the environmental elements concerned, with particular regard to forestry conditions in the zone. The plan must have a specified period of validity, during which time specific activities have to be performed, and at the end of which a revision can be made, rectifying any errors that may have become manifest.

The continuity in time of plans that are gradually being improved is the correct procedure for achieving effective protection from fire. This can never be obtained by a single isolated plan. It is therefore necessary to assess the success of the various measures that have been proposed. This must begin during the period of the plan's validity and will be completed on its termination. The hypothetical objective, expressed in terms of maximum surface affected annually by fire, can be achieved through the combination of various possible measures, with their relative costs.

These choices can now be made using simulation models which process algorithms and provide indications, on the basis of varying components, regarding the extent of forest surface affected by fire and the number of fires in a given territory. By considering the variables expressing the forest and territorial characteristics that are liable to change, with the measures proposed by the plan it is possible to determine the optimal value to impose on them in order to achieve the desired effect.

The models can be used in the planning phase to determine the size of the various sectors of the firefighting complex. They can also be used to check the efficiency of planning measures that have already been adopted and to test the flexibility of the plan. A level of autonomous functionality then has to be established for single operations, independent of any other response, that is to be considered the minimum level necessary for their realization. The functionality of these operations will however be estimated, in the framework of the plan, on the basis of the effect deriving from their synergy, as indicated in the concept of integrated programming that has already been mentioned. Particularly as regards fire extinction, there will be an efficient and autonomous organization, but which at the same time will benefit from all the various prevention operations. In order to obtain maximum efficiency of the plan it is therefore necessary to pay special attention to certain organizational aspects and in particular to the firefighting operations of teams of volunteers that are central to the containment of the fire.

It has been observed with growing frequency that the inefficiency of ground forces limits the success of firefighting operations even when there is the cooperation of aircraft.

The firefighting teams on the ground must attack the fire front directly for as long as possible, using indirect methods only when absolutely necessary. In direct attacks the fires are faced immediately without waiting to operate in more favourable circumstances, as is the case in the indirect attack when more extensive forest areas are necessarily sacrificed to the fire. The direct attack is more difficult on sloping terrain because of the firefighters' difficulty of movement and the increased length of the fire front and its faster spread.

In many forest areas this technique of fire extinguishing is impracticable and it is preferable to operate in areas where the fire front can be made to have more limited pyrological characteristics. The firefighting teams can increase their activity in the presence of firebreaks, which are an important element in fire protection. Firebreaks can be either 'passive' i.e. intended to interrupt spreading of the fire because of their great width, or 'active', i.e. intended to reduce the power of the fire front without actually stopping it, which can be achieved by firefighters. Firebreaks are structures that highlight the necessity of close relationships in the planning phase between prevention and firefighting. Firebreaks have to be able to contain the power of the fire front below a given value in order to enable the firefighters to attack the flames directly yet safely.

The capacity of reducing the power of the fire depends on the characteristics of firebreak construction. These vary in relation to the nature of the forest vegetation. Also, the value of power of the predicted fire front cannot be constant because it expresses the maximum limit (multiplied by a safety coefficient) of the power that can be attacked directly. This depends on the nature of the forest in the zone and on the composition of the firefighting teams. Firebreaks should contain the power below 120 kcal/ms, especially in places where firefighters have to use mainly manual equipment to extinguish the flames, as for example in remote areas without roads where the teams have to move on foot.

The planning phase must therefore take into account the relationship between the relative positioning of the firebreaks, the characteristics of their construction, and the nature of the firefighting teams. Clearly, for a given slowing-down effect by a firebreak on a fire front, the chances of stopping the fire entirely depend on the possibility of the firefighters' response, on the equipment and on their training. Bearing in mind the characteristics of the forest vegetation, firebreaks must be constructed with the intention of transforming treetop fires into ground fires. The width of the firebreak is determined in relation to the height, depth and length of the fire and the angle it makes with the terrain. The last figure is important because it expresses the configuration coefficient, which measures the proportion of radiation directed towards flammable matter, and therefore causing preheating.

The same radiation transfers heat towards firefighters directly engaged with flames. In the planning phase, indications come from numerous empirical and analytical expressions which can be used to calculate maximum width measurements, allowing a wide degree of tolerance because of the large number of variables involved, including the fundamental factor of the power of the fire front.

The plan thus has to be based also on factors affecting this power. These are in part predictable and not modifiable, such as wind and the dryness of the vegetation, and in part predictable but modifiable, such as the flammable biomass. This can be reduced by preventive forest clearing activities, in inverse proportion to the firefighting team's response potential. Evidently, the greater the team's capacity to combat high-power fires the less is the need to reduce the extent of the flammable biomass, with consequent saving of cost.

This description of the firebreaks is intended to stress the importance of the close relationship necessary between the planning phase of prevention measures and the organization of the firefighting teams. The teams must also be taken into account in the general project, which will define the nature of their firefighting activity.

If the ground forces are conceived and organized in this manner, they will be in a position to make the correct response priority choices. This aspect is extremely important in firefighting, and any uncertainties will seriously reduce the efficiency of firefighting operations. These operations must always be conducted in conditions most favourable to the safety of the firefighters and to the safeguarding of the forest. The kind of action taken by the teams, even if this may appear to be an initiative depending on spontaneous decisions of the moment, must be prescribed in detail in the general plan. The plan indicates what technique to adopt and what apparatus to use in order to operate safely in the face of any kind of fire behaviour. The situations described and provided for in the firefighting plan must be known to the firefighters, who will thus be able to make their priority choices also on the basis of their detailed knowledge of the forest.

The damage caused by fire affects not only the forest vegetation but also the general environment. The damage to the forest is known to all, while damage to the wider environment is often completely ignored, such as atmospheric pollution. The gas masses and solid particles can give rise to convection columns thousands of metres high which tend to form thick horizontal banks of cloud.

We will consider for a moment atmospheric pollution due to forest fires because, although these consequences are possibly slight compared with other more immediate effects, this will provide the opportunity to stress that the technical training of firefighting teams is of extreme importance and can be achieved only as part of a general plan. Pollution from forest fires – once never considered – has now become a much discussed matter in large Italian cities such as Turin and Milan since the problems caused by the accumulation of atmospheric polution in the winters of 1988–89 and 1989–90. One of the objectives of forest firefighting must be to reduce the sources of pollution due to fires, which may even be favoured by the same atmospheric conditions that aggravate the difficulty of the elimination of polluting material in the atmosphere.

During a forest fire the cellulose, hemicellulose and lignin in the vegetal biomass is only partially burned. Many compounds, including resins, oils, terpenes, etc., are also involved, though present in lesser quantities. The combustion of vegetable matter releases hundreds of different compounds into the atmosphere. Carbon monoxide and dioxide are formed, together with a very large number of molecules containing only carbon and hydrogen. There is a considerable quantity of unburned hydrocarbons. Nitrogen oxide and sulphur dioxide are formed in only very small quantities, if at all, because wood burns at a temperature lower than that necessary for their formation. Phenomena of nucleation, condensation and coagulation then give rise to liquids and solids. Liquids make up 60–70% of the mass produced, and when released into the atmosphere their dimensions vary between 0.1 and 10 μm.

Particles measuring from 5–10 μm remain suspended in the air for long periods until they are brought down by rain or captured by surfaces able to absorb them, such as leaves on trees. Particles 2–3 μm in diameter, if inhaled, remain in the lungs.

These products of incomplete combustion are associated with particles of ash of all dimensions. These are transported by the convection column which is much hotter than the surrounding air and therefore rises rapidly. The quantity of polluting matter varies according to the characteristics of the forest fire. When the fire advances rapidly it releases into the atmosphere more polluting matter than when it advances slowly, even if the quantity of material burned is the same.

For firefighting to be efficient, in these cases, it is advisable to give priority to the extinguishing of fire fronts that produce higher quantities of polluting matter. If a fire consumes 5 tons of biomass per hectare the quantity of pollutants released into the atmosphere will be 10 kg/ton burned. As the amount of burned biomass increases in rapidly advancing fires, the quantity of pollutants also increases, exceeding 30 kg/ton burned when the fire consumes 30 tons/ha, as in the case of violent forest fires that have not been kept under control.

The most obvious remedy for pollution derived from forest fires would be the immediate extinction of the flames. However, in conditions of extreme dryness, when many fires are concentrated in short periods, this is practically impossible. Although many serious fires occur in conditions of strong wind which blows the smoke away, fires also break out after long periods of drought when there is a drop in temperature and no wind at all. In these conditions fires may easily occur that are of low power but very numerous and extensive, and also simultaneous. Enormous amounts of smoke are released into the atmosphere, tending to remain stationary at a certain height. These conditions hamper air-borne operations so that firefighting is mainly or entirely the responsibility of ground forces deprived of the assistance of air support.

The problem of atmospheric pollution poses once again the need for technically qualified teams and the presence of experts who are capable of taking spot decisions and have a theoretical and practical knowledge of fire behaviour. The emission of pollutants can be limited by fighting first of all the parts of the fire front that are advancing most rapidly. This may seem obvious but is not always easy to realize, as many problems have to be considered together – including pollution, which as has been said is not generally considered a priority.

The team coordinators have to know what priorities to assign to the various operations in order to extinguish some parts of a fire before others or one complete fire before another fire. These priorities are based on an evaluation of all the effects of a fire on the environment, including that of atmospheric pollution, which despite its topicality is one of only relative importance. The problem has been considered in order to underline the fact that a problem of this nature can be faced only through a process of planning which takes into account the entity of the biomass, its evolution and the possible behaviour of the fire front. The success of firefighting operations requires not only an efficient operating centre and correct prevention but also the maximum possible technical competence of the firefighting teams on the ground.

BIBLIOGRAPHY

Andrews, P. L. (1986). Behave: fire behavior prediction and fuel modeling system–Burn Subsystem, Part 1. *Intermountain Research Station Ogden: General Technical Report INT-194*

Bovio, G. and Saitta, L. (1979). Modello di propagazione di un incendio boschivo. *Regione Piemonte: esperienze ed indagini per una selvicoltura moderna*, Vol. 2

Bovio, G. (1992). La protezione dagli incendi boschivi nella pianificazione forestale. *Il bosco e i suoi valori: esperienze e prospettive per una pianificazione forestale* (Unif.: Brasimone)

Bovio, G. (1992). Forest fires and the danger to fire-fighters. In: *The Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Kluwer Academic Publishers, Dordrecht, Boston, London

Kilgore, B. M. (1984). Fire management. *Western Wildlands*, **10**, 2–29

Liacos, L. (1985). Pascolo e fuoco controllato, strumenti di gestione della foresta mediterranea. *Ann. Acc. It. Scienze Forest.*, **34**, 15–21

Mobley, H. E. *et al.* (1976). Southern forestry smoke management guidebook. *USDA Forest Service: General Technical Report SE-10*

Mutch, R. W. (1976). Fire management and land use planning: tradition and change in the forest service. *Western Wildlands*, **Winter**, 13–19.

Rothermel, R. (1980). Measuring and interpreting fire behavior for correlation with fire effects. *DA Forest Service: General Technical Report INT-93*

88
The protection of forests in Sicily from fire risk

ERNESTO MESSINEO
Direzione Aziende Forestali, Regione Siciliana, Sicily, Italy

INTRODUCTION

In Mediterranean countries, forest fires represent a serious risk to the natural environment and in particular to forest areas. Annually some 50 000 fires affect an area of 1 000 000 ha, causing considerable economic and environmental damage and the loss of many human lives.

Throughout the Mediterranean basin, the outbreak of forest fires is favoured by climatic conditions and particularly flammable vegetation, and the situation has been aggravated by the abandonment of many forest areas where there is no longer any economic interest in their exploitation. In Sicily, however, the phenomenon does not appear to be related to this contributory cause nor indeed to strictly climatic considerations. More than 50% of forest land in Sicily, i.e. ~150 000 hectares out of a total of 260 000 ha, is managed by the Regional Administration. In these forest areas, a series of technically and socially oriented decisions has led to an annual work-force of about 30 000 labourers being employed in rotation for a total of some 2 500 000 working days. This makes it possible to carry out all afforestation and maintenance operations necessary for the prevention of forest fires (creation of a network of firebreaks; clearing of broad strips of woodland adjacent to firebreaks and forest pathways; elimination of fallen deadwood and other easily flammable material).

If we compare data regarding forest fires over a sufficiently long period with the climatic conditions when they occurred, we find that there is not always a correlation between the two, except that in the presence of adverse weather (e.g. sirocco wind) firefighting operations are extremely difficult, and the damage therefore much greater.

What then are the causes of forest fires in the Sicilian Region? If we calculate that fires due to natural phenomena or accidental causes represent 1–2% of the total and that 5–6% are of uncertain origin, the remainder, i.e. some 92%, are due to human action, of which by far the majority, some 80%, are malicious in origin rather than unintentional.

The causes of maliciously caused fires can be summarized as:

- revenge, rivalry, spite
- fires started to drive out game
- feuds between shepherds
- speculation
- pyromania
- desire to create opportunities for employment

In the face of intentions to set fire to forest areas it is extremely difficult to organize a model of defence, especially because of the lack of objective elements of preventive analysis.

THE ORGANIZATION OF FOREST FIRE PREVENTION IN THE SICILIAN REGION

The organization of forest fire prevention in the Sicilian Region is mainly directed at all elements that contribute in some way to rapid intervention with the appropriate means, in an attempt to counteract the unpredictability of criminal action with a series of early responses.

Sighting is assured by 215 look-out towers, plus a number of mobile units, strategically distributed in order to keep all the main forest areas under visual control; between June and October these are continuously manned by a contingent of 1000 men (Figure 1).

Emergency service is provided by 70 motorized teams consisting of 7–8 men, plus driver, distributed around the local operation headquarters. These emergency teams are assisted in fire-extinguishing operations by all-terrain vehicles equipped with 450-litre 'Blitz' modules and by tank-lorries (1000, 3000, 5000 and 8000 litres). The all-terrain vehicles and the 1000-litre tank-lorries are used for patrol activity in some provinces and therefore have a protective function.

A great number of water tanks of various types have been set up in forest areas. Funds allocated by regional laws (most recently Law 11/89) have made it possible to construct a total of 292 tanks, 162 of which have a capacity of 500 m^3, 34 of 1000 m^3, and 96 of > 1000 m^3. Some mobile tanks of variable capacity between 2500 and 25 000 m^3 are deployed seasonally in certain areas for the local refilling of tank-lorries and helicopters.

An experiment has recently been carried out in land belonging to the Sicilian Region in the Province of Trapani, consisting of a fire-extinguishing system comprising a series of underground polyethylene pipes filled with water from tanks and provided with hydrants capable of supplying water at a working pressure of 5–9 atmospheres.

All of the look-out towers, emergency services and vehicles used by the 63 forest units in Sicily (a number that will soon be increased)

Figure 1. Fire-watching tower

possess radio equipment. A network of link-ups makes it possible to provide rapid information about outbreaks of fire so that appropriate action can be taken. The look-out towers report fires to the provincial operating stations, where the Forestry Technical Managers order the intervention of local teams, which are responsible for the actual firefighting operations, and arrange if necessary for the assistance of more men and vehicles. The Sicilian Region was the first to set up such a radio network, of which it is justly proud. The entire network is now being restructured and updated.

The forest path network is well developed and has the dual purpose of facilitating the access of firefighting teams and their vehicles and of assisting sylvicultural operations. The paths also space out the undergrowth and thus act as firebreaks slowing down the spread of flames (Figure 2).

As a further preventive measure, daily labourers engaged in routine agriculture work are employed in shifts in order to provide a more complete human presence throughout the whole day.

This system of organization means that the time of first intervention in the event of a forest fire is just 20–30 min, thanks to which the damage caused by the numerous forest fires has been relatively limited. This success is also due to the large number of Forest Officers and Forest Guards (1100 in all), who are assisted in firefighting operations by 600 Technical Agents.

Legislation

Article 7 of Law 47/75 establishes that responsibility for the sighting, extinguishing and limitation of forest fires lies in the first instance with the Forestry Stations, the Carabinieri and the local Communes, in accordance with the plans prepared by the Forestry Body together with the Fire Brigade, as provided in Articles 1 and 2 of the aforesaid Law.

In 1974, Law 36 of the Sicilian Regional legislation attributed the task of preventing, sighting and extinguishing forest fires to the Regional Forestry Body and in 1975 Regional Law 88 took cognizance of State legislation. The Regional forest fire plan was promptly set up and is now in the process of revision.

A better defence of forest areas might be proposed through new legislation based on State Law 47, by extending to territories subject to hydrogeological, landscape and environmental restraints all the prohibitions prescribed for forest areas liable to be affected by fire, with particular regard to animal farming activity which is often conducted with little respect for environmental considerations.

The phenomenon of forest fires, especially in the south of Italy and on the islands, is related to lack of proper information in the family and social context. It has therefore been decided to devote more attention to the aspect of propaganda and mass information, with particular reference to schoolchildren, who are in the process of learning the basic principles of public awareness. We have therefore printed a number of pamphlets, leaflets, posters and books, prepared audiovisual material and given talks as part of a capillary programme of promoting awareness of the problem, with the collaboration of teachers and school organizations. Much still remains to be done, however, with a greater level of professionalism and with perseverance, so that these informative

Figure 2. Forest path cum firebreak

activities become an integral part of basic prevention activity, also in association with professional figures.

One of the fundamental deficiencies in the present organization of forest firefighting is the specific level of training possessed by all those involved (qualified firefighters, specialized firefighters, long-term personnel, forestry technical agents and forestry officers) (Figures 3, 4 and 5).

These deficiencies have often caused dangerous situations for firefighters, with heavy responsibilities for all those involved in decision-taking. The deficiencies are often aggravated by a lack of proper personal equipment, which is partly due to the fluctuating nature of the work-force and the consequent difficulty of keeping it adequately supplied.

The annual number of forest fires in Sicily is about 300 (1991 figures) with an average duration of 3 h of firefighting operations. The risk of burns is therefore extremely high, considering also the high number of firefighters involved in each fire.

These problems are of great relevance and require immediate solutions, including a higher level of professionalism, which methodical training can provide, improved personal equipment, and the elimination of the shift system of employing casual local labour for firefighting operations. The latter could be achieved by regular seasonal contracts. It will also be necessary to provide for a greater number of mobile units in the various provinces of Sicily, in order to integrate the helicopter emergency rescue service (freephone number 116), which itself should be put

Figure 3.

Figure 4.

Figure 5.

on a regular radio link-up with the frequencies allocated to the Regional Forestry Body.

Finally, it is hoped that there will be a general improvement in preventive and response services. This can be achieved by increasing the availability of helicopter operations, which are essential for a complete strategy of forest fire prevention.

89
New technologies for predicting, preventing and extinguishing forest fires

RICARDO VÉLEZ
ICONA, Ministry of Agriculture, Fishing and Food, Madrid, Spain

INTRODUCTION

Forest fires in mountain areas constitute one of the main causes of deforestation, both in developed countries and in the Third World. In the less populated regions of the world, fires are usually caused by lightning, while in the Mediterranean area, including Spain, the majority of fires are caused by human activities. The chronic character of the phenomenon shows that there must be permanent structural conditions at the root of the problem. The classic simile of the triangle that is used to explain how fires begin also serves to underline the structural causes of fires. The fire triangle is composed of climate, vegetation and population with particular characteristics.

The vegetation, which in general has adapted to fire, produces enormous accumulations of dead combustible material where fires can start. The Mediterranean climate has a hot dry season, sometimes with strong winds, during which the humidity of dead combustible material is considerably reduced. It is therefore easily ignited by the heat of even small fires and propagation is more rapid.

The population in Mediterranean areas increases considerably during the dry season, and people invade the forest areas for recreational purposes, sometimes using fire in the process. Rural populations, although decreasing in number, have conserved the ancient practice of using fire as a means of preparing the land for agriculture and animal farming. It is possible to educate people (as an immediate cause of fires) through the social sciences, by performing analyses of its behaviour, and through legislation, directing it towards a more conservationist spirit.

The role of the new technologies is to modify the vegetation in such a way that outbreak and propagation of fire become more difficult. In this respect, we can consider two groups of new technologies, those related to data processing and those related to new materials.

Data processing technology will make it possible to computerize a great variety of parameters, to handle and process a large quantity of data and to transmit information rapidly over great distances. The technology of new materials will make it possible to obtain results that from the point of view of duration and performance are far superior to traditional materials.

In this chapter we will make an inventory of current possibilities and paths that can be explored in order to reduce the problem of forest fires, analysing the possibility of applying the technologies both for prevention and extinction of fire.

PREVENTION: PREDICTION OF THE DANGER

Knowledge of the conditions in which a fire can break out is essential for the preparation of methods of fire fighting and for planning campaigns of persuasion and dissuasion directed at the public. Acquisition of this knowledge requires research, filing of results and data processing. The research phase may include meteorological observations made by automatic stations provided with adjustable sensors for data recording and transmission in real time by radio, telephone or satellite, and also on screen or in printed form. ICONA has set up stations of this type in high-risk forest zones in order to complete the network of the Instituto Nacional de Meteorología (INM) (National Meteorology Institute). A detector station for electrical discharges with a range of 400 km has also been established to identify places at risk from lightning. The main area covered is that of the mountains of the Iberian System (Central-East Spain), which have the highest frequency of lightning-induced fires. The INM radar network provides national cover for this risk; satellite pictures follow the situation over large areas. Weather forecasting makes continuous use of this method (METEOSAT). The INIA is studying the application of NOAA-AVHRR images in order to determine differences in vegetation humidity levels that show increased or reduced danger levels. The application in real time and the cost question are perhaps the main problems that have to be resolved before this can be operative. Another use of satellite detection is the evaluation of burned areas and monitoring of developments after fires, a subject on which there is already a series of positive experiences and which requires the development of methodologies suitable for the necessities of forest fire statistics. ICONA has developed a project in this field with the University of Alcalá de Henares.

Data filing requires systems of geographic information for the creation of data banks which use digitalized cartography to hold information regarding mountain forestry conditions, species, combustion models, etc. The ARC/INFO data base and the new Forest Inventory are the instruments which ICONA is setting into operation with this purpose.

Information processing to predict danger depends on the development of models of fire behaviour derived on the basis of data regarding combustible material, meteorology and land relief. In Spain a Canadian model had long been used which gave appropriate information, but in a very limited manner. Subsequently, following FAO recommendations, we tried an Australian model, which provided very interesting predictions. At present we are using the system developed for the US Forest Fire Laboratory, with very positive results. This system requires the identification of models of combustible materials, according to a standard classification, a process that is being carried out for ICONA with the collaboration of the INIA. Codes corresponding to the mountains throughout the Peninsula are already available, and the year 1992 saw its completion in the Balearic Islands and the Canary Islands.

It also requires the development of computer programs that make it possible to use the models rapidly and simply. A CROM is available to calculate HP 71B and a diskette with the BEHAVE program for IBM-compatible computers, which facilitates its use in the field and in operation centres. These programs give predictions regarding the speed with which a fire advances, its calorific intensity, the height and shape of the flames, and they also assist in decision-making, such as the use of aircraft as a support for ground forces. In recent years ICONA, together with the Universidad Politécnica of Madrid, has developed a simulation program, known as CARDIN, which makes it possible to predict the most probable evolution of a fire. This program runs on 386 computers with VGA card. For its application we are preparing and digitalizing maps on combustible material in various risk zones. CARDIN is completed with DIGICAR, a program for the creation of the geographic data base, and with GFUEGO, a program for the management of extinguishing materials, thus jointly creating an expert system.

As part of this system a risk index calculation module is calculated starting from the probability of the ignition of fire, dead combustible material and taking into account wind direction and strength. This permits the definition of three stages of danger: pre-alert, alert and alarm. We are studying the possibility of applying the METAFIRE system to predict the probability of extensive fires. This system starts from data calculated using meteorological numerical models and determines this probability for climatic zones, according to combustible model groups, with 2 days' forewarning.

INFRASTRUCTURE: DETECTION AND COMMUNICATIONS

Preventive measures can reduce the number of fires, but it would be unrealistic to expect none to occur. It is therefore necessary to have adequate firefighting means and a system of mobilization. In this last field modern technology offers numerous possibilities, such as:

1. The installation of operation centres, where it is possible to concentrate complete systems of general communications, telephone, telex

and fax and to coordinate independent FM radio networks for local use and HF networks for regional use. These centres play the important role of coordinating the communication media, with the assistance of personal computers which make it possible to use the above-mentioned fire behaviour prediction programs, fire data banks and media inventories in order to manage them with maximum productivity.

2. Ground vigilance structures, consisting of the classic lookout towers from which personnel acquainted with the local territory detect fires. The use of structures made of laminated wood or other wood derivatives improves living conditions in these towers and helps them to harmonize with the environment. The lack of personnel for detection work has led to the use of infrared (IR) sensors combined with video cameras (CCD for day vision and TUBO for night vision). On an experimental basis ICONA has set up two stations with this equipment for the development of easily managed programs of alarm identification and long-distance transmission (radio and videotelephone). The range covered goes up to 15 km. A mobile unit (IR/CCD) has also been constructed for transfer to the fires and observation of hot areas in the perimeter.
3. Mobile ground vigilance, which is essential in order to complete the information given to fixed stations. The current trend is to combine this with the first attack. For this purpose ICONA is developing all-terrain vehicles, fitted with detachable tanks (capacity 300–400 litres), and motor-pumps to be used as patrol vehicles in high-risk areas, with the additional function of playing a preventive role by being visible to the public.
4. Air vigilance, which makes it possible to achieve complete vigilance in very mountainous regions where there are numerous 'blind' areas not visible to any fixed station. For this kind of vigilance the use of GPS equipment may be very useful for the exact localization of the fire by means of coordinates. This apparatus also has a role in media management and in the rapid measurement of burned surfaces. Simple air detection has been improved by the possibility of using television and IR rays. Aircraft equipped with IR cameras can map out fires in progress, 'seeing' through dense smoke and providing valuable information to the firefighters on the ground. Air teams can also transmit maps to operation centres via telecopier. TV cameras on helicopters can likewise transmit pictures of the development of fires so that they can be more easily extinguished. ICONA has for some time been analysing the operativity of these systems in order to complete experimentally the coverage that is already provided by light aircraft and visual detection. We have also considered unmanned aircraft, although at the moment their development is too costly to be considered.
5. Mobile meteorology and transmission units. These are all-terrain vehicles fitted with communication centres and a relay station for FM, AM and HF networks in order to facilitate link-ups in the

field, especially in the case of extensive fires. The units developed for ICONA are also equipped with an automatic weather station and a 386 computer to predict the evolution of the fire.

INFRASTRUCTURE: FIREFIGHTING TEAMS ON THE GROUND

The best ground firefighting team is a group of trained men in good physical condition and with experience in firefighting operations. However, their work can be facilitated and their efficiency can be improved by the application of modern technology.

Personal protective equipment

New non-flammable fibres make it possible to have working clothing that provides sufficient protection when passing through bushy areas, without interfering with movement and at the same time preventing burns when cinders fall on the material. Helmets, goggles, gloves and boots provide, together with this material, adequate equipment for firefighting activities. In dense smoke firefighters have to be provided with masks. ICONA is also beginning to consider the possibility of introducing forest fire shelters, a kind of aluminium tent which is carried folded in the belt and which has saved lives in the USA and Australia as a form of personal refuge against fire.

All-terrain firefighting vehicles

In Spain various factories produce excellent all-terrain motor chassis on which bodywork can be built suitable for forest fires, with 3000–3500-litre tanks, plus pumps, hoses and auxiliary material. The most recent designs allow a high power of penetration in very irregular territory and water can therefore be transported wherever it is needed to fight or extinguish the fire, as the network of forest paths – for economic or ecologic reasons – can never be as close as firefighting operations might require. These vehicles are also currently being equipped for use with foam and long-range retardants in order to obtain maximum performance from the water transported.

Retardants

A new method for the application of retardants, consisting of 'explosion extinguishers', has been developed by a Spanish firm. These are water-filled plastic spheres containing retardants that are placed near the fireline. They are provided with a heat detonator which makes the sphere explode when the fire approaches so that its contents are dispersed and extinguish the fire over a wide area.

90
Forest fires in Ticino Canton, Switzerland

G. ORTELLI
Military Department, Bellinzona, Ticino, Switzerland

GENERAL POINTS

The Ticino is the canton most affected by forest fires in all Switzerland. Its geographical position at the southern foot of the Alps determines a climate that is extremely favourable to the development and spread of forest fires. The most favourable factors are the long droughts in both winter and summer, and the mild winters, without snow but with strong, warm, dry, north winds (föhn). The climate also favours the growth of lush vegetation, with abundant foliage, bushes and long grass which in the dry state (dead season or summer drought) provide flammable material and fuel for the combustion and spread of forest fires. The Ticino has always been affected by forest fires: early chronicles report fires lasting weeks in the 17th century. Statistics have been kept by the Forestry Service for at least a century (Figure 1).

There has been an increase in the number of fires in the period following the Second World War until the mid-1970s, followed by a slight reduction until the present day. The increase can be attributed to the effect of the great social and economic transformations in the post-war period, which completely destroyed the traditional relationship between man and nature. As a consequence we have witnessed the almost total abandonment of agriculture and the loss of importance of the forest for the life of the population, in the very zones most menaced by the risk of fire (south central Ticino). After the mid-1970s a new awareness of environmental problems developed in the population, and the vital importance of nature in general, and the forests in particular, was recognized. This without any doubt contributed to the reduction in the number of forest fires. The importance of forest fires in the Ticino can be deduced from statistics recorded since 1953 (Figure 2) and from the damage caused to the forests. Fire obviously destroys only the vegetation but it is the environment that suffers in its entirety.

FOREST FIRES IN TICINO CANTON, SWITZERLAND

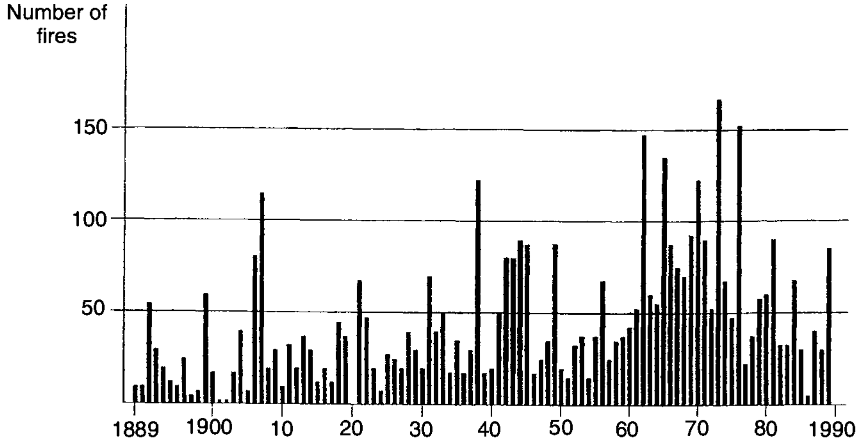


Figure 1.

We need only to consider the destruction of the microfauna, modifications of the herbaceous vegetation and the desolate aspect of the burned areas. No effort can be spared in the fight against this phe-

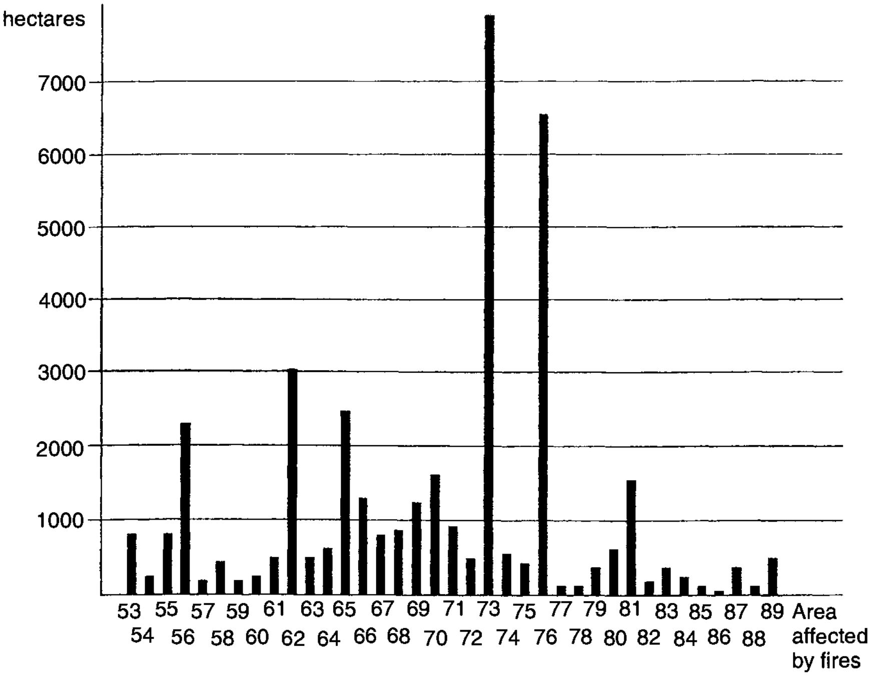


Figure 2.

nomenon, on the one hand by prevention and the organization of fire-fighting procedures and on the other by creating in the general population a greater awareness of the importance of the forest and the environment in general.

PREVENTION

Prevention has been discussed since the beginning of this century when the Forest Service invited local schoolteachers and clergy to carry out propaganda work. In 1927 the first fire danger notices were set up, and this became systematic throughout the canton at the beginning of the 1960s. From the legislative point of view, the fundamental law for prevention is Art. 4 of the Regulation (04.07.78) on police fire control, which states: 'It is forbidden to light fires in the open in periods of drought or on dry windy days. The reports of the Locarno-Monti Meteorological Station, as broadcast by radio and television on the basis of reports from the Forestry Service, are binding in this respect'.

At times when the risk of forest fire is greatest, radio, television and the national press are used to arouse public awareness of the potential danger.

ORGANIZATION OF THE FIGHT AGAINST FOREST FIRES

General organization

A number of regular organizations collaborate in the fight against forest fires: city fire brigades, mountain fire brigades, military and civilian helicopter services and the Forestry Service, aided by military and Civil Defence forces. The structure is pyramidal, with the city fire brigades first group (rescue centres) at the top, and the city fire brigades second group, third group and mountain fire brigades at progressively lower levels.

Depending on the importance of the fire and its zone of development, the organization can be mobilized either entirely or partially, in any possible combination. The first response to the fire alarm (telephone number 118) is generally by the first and second groups of the city fire brigades which can intervene immediately with the necessary means of transport, followed by the mountain fire brigade. Helicopters are used only on specific request and under the direct control of the Rescue Centres. The Forestry Service acts as adviser to the fire brigades. The military and Civil Defence forces are alerted only in situations of particular gravity or in fires that are protracted in time.

Mountain fire brigades

The creation of the mountain fire brigades dates from the 1970s. In the 1980s they were specifically organized for the control of forest fires.

Their purpose is to reinforce the personnel of the city fire brigades in the fight against forest fires. The mountain fire brigades are organized in a dense network in high-risk areas throughout the canton, constituting a body of motivated fire-fighters with experience in mountain operations and thorough knowledge of the local terrain, qualities which are so important in fighting forest fires and which the city fire brigades clearly lack.

The mountain fire-fighters receive equipment and training specifically aimed at forest fire-fighting. At present in Ticino there are 57 mountain fire brigades with 1090 fire-fighters. A certain number of fire-fighters (480 in all) belonging to the city fire brigades (2nd and 3rd group) have been equipped and trained for forest fire-fighting.

EXAMPLES OF FOREST FIRE-FIGHTING OPERATIONS

To give an idea of how forest fires in the Ticino are dealt with, we will describe three representative cases. The first is a night-time fire of limited dimensions and short duration. We will then illustrate the use of large-scale counterfire employed in the extinguishing of a massive fire.

Case 1

Fire on 6–7 January 1990 at Cima Pianca-Pian Pulpito in the commune of Novaggio. CN (Swiss National Map) 1:25 000, 1352 Luino, 1333 Tesserete, 1353 Lugano. Coord. 707500/98500.

General situation

The fire area was at an altitude of 1300 m above sea level on the ridge running from Mount Forcora towards Mount Lema. The fire immediately threatened the 100 ha of plantations of the Federal Polytechnical School Forestry Project (Zurich) as well as the Mount Lema hotel and chairlift station. The fire broke out at night (10 p.m.) in fine, cold weather (–5°C). There was no wind and the moon was full. The fire was probably of criminal origin. Access to the fire zone was by a motor-vehicle forest track as far as an altitude of 1100 m, after which it was necessary to proceed on foot along a path.

The fire-fighting operations

22.00 – Alarm given by private citizen to Novaggio fire brigade: forest fire in Pian Pulpito area. Mobilization by siren of all Novaggio fire-fighters. Forestry service alerted.

22.05 – Departure of first group for Cima Pianca, arrival at Cima Pianca, despatch of fire-fighting squad on foot to Pian Pulpito.

22.30 – First fire-fighters at fire site, initiation of extinguishing operations, base established on forest track at Pian Pulpito, formation of two squads, one on each side of the fire. Request made to Lugano Fire Chief for helicopter assistance, telephone contact by fire brigade on the spot to pilot and illustration of situation.
22.45 – Danger of fire spreading towards Forcora plantations, request made to Caslano for tank truck.
22.55 – Request to Lugano for pioneer vehicle to illuminate small lake at Astano (helicopter water-loading base).
22.35 – Tank truck ready to operate at Cima Pianca along forest track.
22.45 – Illumination of lake at Astano operative. Arrival of helicopter and coordination of water-drops by Forestry Service.
22.50 – First water-drop.
00.12 – Arrival of ambulance at Cima Pianca as precautionary measure.
00.50 – End of helicopter operations and return to base.
02.00 – Fire extinguished. Cleaning-up operations.
02.30 – Withdrawal of Lugano pioneer vehicle from Astano Lake. Withdrawal first group of fire-fighters and organization of cleaning-up and control operations.
03.30 – Return of tank truck to Caslano.
04.00 – Return of last fire-fighters.
06.00 – End of operations.

Personnel and vehicles used

Novaggio Fire Brigade: 24 fire-fighters; Aranno Fire Brigade: 8 fire-fighters; Malcantone Mountain Fire Brigade: 5 fire-fighters; Caslano Fire Brigade: 2 fire-fighters; Lugano Fire Brigade: 2 fire-fighters; Total: 41 fire-fighters.

Novaggio Fire Brigade: 1 jeep, 1 Landrover; 1 Volkswagen bus; Caslano Fire Bridgade: 1 tank truck; Lugano Fire Brigade; 1 heavy pioneer vehicle; 1 Lama Eliticino helicopter with Chadwick 650-litre bucket, pilot and mechanic.

Forestry personnel of 6th Sector (Forestry engineers and local forestry guards).

Operation tactics and technique

To direct the helicopter operations, the pilot was given the following information on take-off: good visibility due to full moon, water-drop area with low vegetation and no power-lines, no wind, landing ground at Novaggio sportsfield for contact purposes illuminated with car headlights, water loading point at small lake at Astano (length 100 m, width 50 m, illuminated by 1000 W headlights). On the basis of this information the pilot decided that the operation was feasible. After a reconnaissance flight the pilot started the water-drops directed from land by his mechanic.

It was decided to extinguish the flames directly by helicopter water-drop, followed by immediate operations by the fire-fighters to complete extinction of the flames and prevent recombustion. The fire-fighters mainly used personal equipment (shovels, beaters, rakes), plus two blowers. The 1.5 km of firefront were completely extinguished in 2 h. The helicopter made 35 drops in 150 min.

Case 2

Fire on 25–28 March 1990 on Mount Ferraro, commune of Arosio and Mugena. CN 1:25 000, 1333 Tesserete. Coord. 712500/102000.

General situation

We describe only the counterfire operation, performed on 26 March 1990 to block the fire on the left bank of the River Magliasina below Mount Ferraro.

Situation of fire at 12 a.m. on 26 March 1990 (see 1:25 000 national map): fire descending from Mount Ferraro towards Mugena plantations, difficult, steep terrain, strong north wind; serious danger for Mugena plantations and possibility of fire spreading slowly but dangerously to the Alpe di Monte woods.

The Fire Chief and the Forestry Service decided to use a counterfire operation with the aims of saving the Mugena plantations, preventing any spread of the fire northwards and extinguishing the fire before nightfall.

Development of counterfire operations

12.00 – Meeting of fire-fighters, forestry guards, helicopter pilots to coordinate operations.

12.30 – Transfer of command post to counterfire zone.

13.00 – Initiation of counterfire operations: a group leaves from right flank (path Piano della Rave–Pol Alps, top left corner Mugena plantations), with counterfire operations along the west edge of the plantation as far as the aqueduct. Here a change of direction was made, and the Varera road was followed. The helicopter backed up the counterfire operations, taking great care not to drop water on the fire zone, but wetting a safety strip between the screen and the edge of the plantation, behind the men. Coordination between the helicopter and the counterfire group was supervised by the Commandant. A second group began counterfire operations in the Monte zone, coming down towards the Varera road, at point 1045. From this point the counterfire continued in the direction of Mugena until it encountered group

1. The helicopter backed up the operations, creating the safety strip.

Features of forest fires

The decisive element in forest fires is the type of plant involved in the combustion, i.e. trees, shrubs, grasses, plant terrain. The different types of vegetation burn whether alive (i.e. during their life cycle) or dead (i.e. dry leaves, dry grass, fallen branches). The various types of vegetation in our territory and the consequently varying degrees of combustibility correspond to notable differences in flammability, speed of combustion, and caloric power. These features are considerably affected by climatic factors (wind, humidity, temperature).

The types of fire depend on the combustion of plant combustible material and climatic conditions. Underground fires affect plant terrain (moss, peat, humus, pine needles, etc.). Combustion is slow but long-lasting. In surface fires, herbaceous vegetation and all plant combustible material (grass, leaves, branches) burn if lying dry on the ground. The fire is usually fast-spreading but not very intense. Treetop fires occur when the tops of shrubs and trees catch fire. These are very fast-spreading fires, with production of intense heat. This subdivision is not absolute. The same fire can have different features in time and in space. In the most serious cases, the three types of fire occur together.

In particular atmospheric conditions and with large amounts of dry vegetation, the hot air produced by the fire rises and causes violent air currents (firestorms) which carry burning embers and ashes great distances.

OPERATIONAL TECHNIQUES

General remarks

In forest fires, as in any kind of fire, the response depends on the principle of breaking one side of the fire triangle: heat/oxygen/combustible material. There are two systems of response.

Direct attack

The direct attack strikes directly at the flames, using a variety of methods and equipment. The direct attack is possible when the violence of the flames and the intensity of the heat do not make it impossible to approach the flames and the vegetation, which can therefore be attacked directly (shovels, earth, water, etc.).

Indirect attack

The indirect attack is carried out some distance from the flames. Various methods are used to create a strip of land which the fire cannot cross. The indirect approach is adopted when the violence of the flames and the heat prevent a direct attack. As a general rule, underground fires require direct attack, surface fires direct and indirect attack, and treetop fires indirect attack.

Particular techniques

Use of water

Water is ideal for both direct and indirect attacks. It is used with the standard equipment of all fire-fighting teams (tank trucks, type 1 motor-pumps, etc.).

Defence lines

These are strips of land from which combustible vegetation is removed in order to prevent the flames from advancing. Their width depends on a variety of factors, including type of fire, morphology of the terrain, characteristics of the vegetation and wind intensity. As a general rule, the strips should have the following dimensions: underground fire: width, 30–50 cm; depth, down to hard rock; surface fire: width 1–4 m; crown fire: width 10 m.

The defence lines are made using shovels, rakes, blowers, etc. They can be made more effective with water, e.g. by wetting the area nearest the flames to slow down the fire front and to permit a direct attack. It is possible to make defence lines by wetting the vegetation, without eliminating it, i.e. by use of a helicopter. The position of the defence lines is decided by fire-fighters with good local knowledge. Natural lines of defence such as roads, paths and streams, where the fire slows down naturally, should be exploited. The defence lines have to be kept under constant watch by the fire-fighters. If necessary a fire that has slowed down can be attacked directly. Defence lines are an essential element in counterfire action.

Counterfire

Counterfire means the deliberate burning of vegetation in front of the fire-front in order to destroy combustible material and prevent the fire from spreading further. Counterfire operations must in all cases start from a safe line of defence (anchor-point) (Figure 3).

The defence lines must surround the fire. The counterfire must be ignited before the fire-front reaches the defence line. It is important to

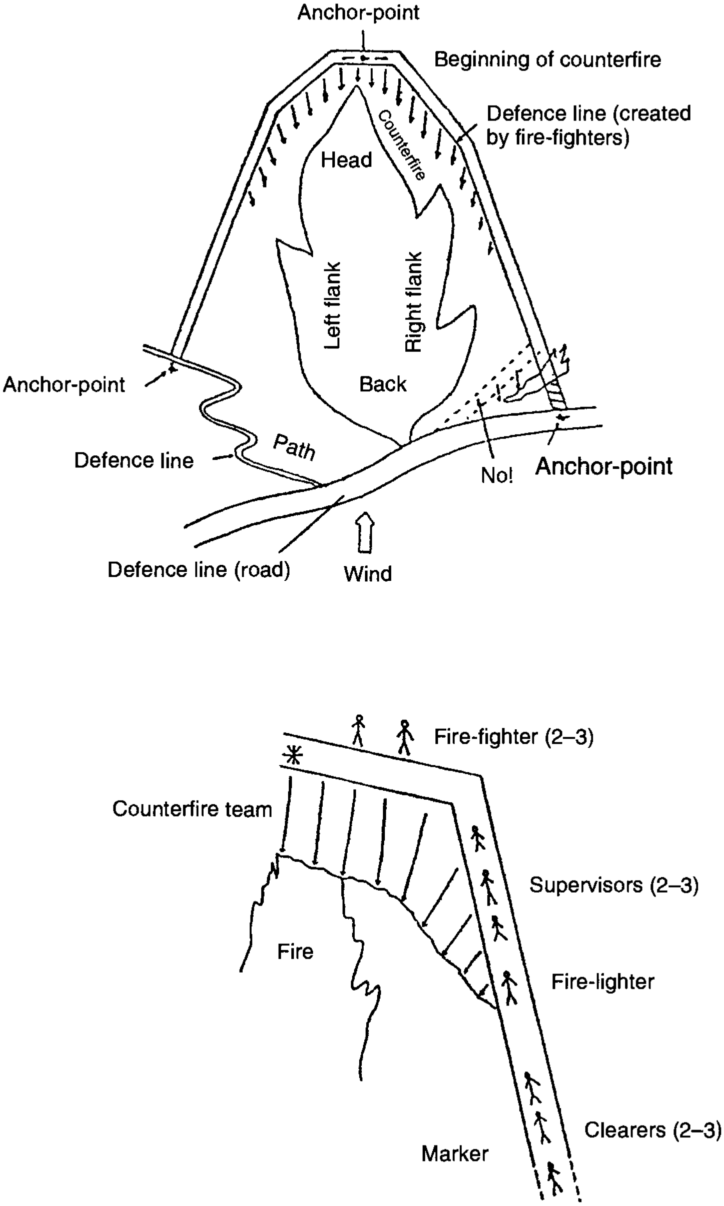


Figure 3. Counterfire operation

assess the speed of the fire in order to make sure there is sufficient distance between the defence line and the fire-front. It may be necessary to sacrifice some woodland to increase the efficiency of the counterfire and for greater safety. In sloping terrain the defence line must be created taking care that burning embers etc. do not fall back on the unburned zone.

Marker

The marker decides on the direction of the defence line, marking it out with simple means (shovel, sickle, by radio communication). The marker has to know the terrain well. He leads the team and is in radio contact with operational headquarters.

Clearers

The clearers clear the defence line, using shovels, rakes and blowers (2 or 3 fire-fighters, proceeding together in a team).

Fire-lighter

The fire-lighter lights the counterfire, following behind the clearers. He is in radio contact with the marker in order to maintain the right speed. Equipment: a shovel.

Supervisors

The supervisors check that the counterfire does not cross the defence line (2 or 3 fire-fighters spread out but within shouting distance). Equipment: shovels.

Fire inspectors

The fire guards make sure that the fire is extinguished along the defence line (at least 2 fire-fighters). Equipment: shovels, radio.

Counterfire team

At least 8–10 fire-fighters. Never begin counterfire operations with an insufficient number of fire-fighters. Counterfire is an extremely effective fire-fighting technique. It must however be used only by well-trained and competent personnel who have thorough knowledge of the terrain and of the dynamics of the fire, and who are therefore able to make an accurate estimate of the outcome of the counterfire operation. Never underestimate the risk of losing control of the counterfire.

Helicopter operations

Helicopters can be used in the fight against forest fires for reconnaissance flights, transport of fire-fighters and equipment and water-drops for fire extinguishing purposes. Helicopters in the Ticino area are provided by the Italian Air Force and two private companies which in periods of high risk guarantee a response within 20 min in any part of the Canton. Between November and May there is a stand-by skeleton staff on public holidays. In the event of an extensive fire, or several simultaneous fires, more than ten helicopters can be mobilized. The helicopters are mobilized and coordinated by the Rescue Centres (First Brigade Firemen). The need for helicopter operations has to be assessed carefully but rapidly. The following aspects have to be considered:

- weather conditions (especially wind)
- time of request for aid (day/night)
- possibility of loading water (time of return flights to and from water supply points)
- probable evolution of the fire
- population, property, etc. to be protected.

When it has been decided to use helicopters, local operations must be organized to make the most rational use of them. It is essential to have direct contact with the helicopter pilot, by discussion on the ground and if necessary by performing a reconnaissance flight. It is therefore important to give the pilot a rendezvous point where he can land. Football grounds are often the ideal solution, and they can nearly always be reached by tank trucks for refuelling of the helicopter. In the 1990s every commune in the Canton will be provided with a helicopter landing point. These landing points will be created by the Military Department for use in disasters and forest fires.

The use of helicopters in fire-fighting operations follows the same principles as land operations. Water-drops (300–3500 l) can be used for direct attack (water-drop on the flames) or indirect attack (creation of defence lines). The choice between these two approaches depends on the type of fire, morphology of the terrain, intensity of smoke, wind direction and strength, type of vegetation (combustion potential), duration of helicopter return flights, availability of fire-fighters, number and type of helicopters used and population, property, etc. to be protected. The technique of attack may have to be modified in the course of operations. It is therefore essential to maintain radio contact (fire-fighters operational command helicopter). The direct attack is most effective when the water-drop is immediately followed up by clearance operations by fire-fighters to prevent spontaneous recombustion. Water supplies come from natural water sources (lakes, ponds, rivers). These points are known to the fire-fighters and pilots and have been tested over the years and from man-made water sources. These are mobile tanks (2500 l), easy and quick to mount, filled by motor-pumps. The helicopter picks up the water directly from the tank in its bucket. In some parts of the Canton there are fixed water-tanks for helicopter loading operations (Brissago, Val Colla).

MATERIAL AND EQUIPMENT IN THE FIGHT AGAINST FOREST FIRES

Individual equipment

This consists of red overall (for visibility), lemon-yellow helmet (for visibility), gloves, torch with spare batteries, belt and mountain boots.

The boots (specifications laid down by the Canton authority) are purchased by the individual fire-fighter, who receives a special allowance on the basis of the hours of use.

Extinguishing equipment

Individual

This is the standard equipment that has been used for years: shovels, rakes, sickles, hoes.

Fire-fighting unit

The large and small tank-trucks, motor-pumps and fire-hoses used in city fires are also used in forest fires. Also useful are type 1 pumps, small diameter 25 pipes with small Storz attachments, and blowers (see Swiss Firemen's Journal N° 12, 1987).

Radio equipment

Great progress has been made in the quality of fire-fighting operations in the last few years with the more powerful radio equipment now used by all First and Second Group Units and which when necessary is also issued to Third Group and Mountain Brigades. Many Third Group and Mountain Brigades have recently been equipped with radio transmitter-receivers.

Aircraft

Aircraft, and in particular helicopters, have revolutionized the technique and tactics of fire-fighting. In the 1960s the legendary pilot Geiger, following the example of other countries, began to experiment with water-drops from his Pilatus Porter plane. The first drops (56 in all) with the

Pilatus Porter were made at Quinto. A demonstration with the Pilatus Porter piloted by Geiger was made at Locarno in 1963.

In 1968 the Air Military Department made available a number of Pilatus Porter aircraft which by 1987 had performed over 2800 drops. In 1974 military and then civil helicopters began to operate, initially for the transport of fire-fighters and material. After 1975 they were equipped with buckets for water-drops (300–800 l), completely replacing fixed-wing aircraft. Since 1987 the Super Puma (both civil and military) has been used. With its great capacity (3000–3500 l) this helicopter opens new prospects for the future.

Thousands of hectares of woodland are destroyed every year by fires that are mostly caused by carelessness and negligence. Fire inflicts untold damage on the ecosystems of the Ticino Canton, as well as severe economic losses due to the expense of fire-fighting operations and reforestation.

Section XVII

Industrial fire disasters

91
Triage in major technological health disasters: chemical poisoning, radiation injury, fire injury

E. MELORIO
President, National Commission on Major Hazards, Italy

GENERAL CRITERIA FOR TRIAGE

During major emergencies difficulties concerning health problems arise from:

1. The extreme urgency for intervention: any waste of time limits the possibility of an efficacious intervention with geometrical progression.
2. The number of victims needing treatment who in most instances arrive as a massive and sudden influx.
3. The seriousness and often the coexistence of more than one lesion, in the presence of jeopardized general conditions (shock).
4. Exceptional environmental conditions.
5. The hostile and vulnerable land conditions often presenting a risk to both the wounded and the rescuers.
6. Difficulties in health transportation and supply delivery.
7. Damage or destruction of local health facilities in a wide area.
8. The extreme psychological malaise of wounded individuals and the survivors, with possible individual and mass abnormal psychogenic reactions.
9. The destruction of local social structure.

These factors produce a marked disproportion between available resources and needs, in an overall atypical situation.

Since it is fundamental that the result of an intervention is strictly proportional to its timeliness, the rescue chain must be mobilized as soon as possible. This may be described in its essential aspects as the flow of health transportation to and from the hospitals of the area where the wounded will be brought for definite treatment as the upstream pole, and the advanced medical unit (mobile medical and surgical unit) as the downstream pole; the latter, together with the first intervention rescue teams, works directly at the disaster site performing rescue, first lifesaving measures, stabilizations and sorting of the wounded so as to enable their adequate and prompt evacuation. These operations are a fundamental element of the rescue chain.

Since the event is both unexpected and unforeseen, influx of victims is massive and disorderly and consequently both supplies and specialized personnel will soon be inadequate. It is therefore necessary to classify and select victims in order to save the greatest possible number of wounded: that is to say, apply 'triage'. Triage has the aim of concentrating efforts on those who have more chances of benefiting, once at the other end of the rescue chain, from appropriate definite treatment. When the number of wounded is such that the equipment is not enough for all, the choice must fall on those among the wounded who have more chances of surviving if treated.

Triage must be based not only on the most correct and quickest diagnosis, but also on stabilizing local and general conditions of the wounded to prepare them for transportation to hospital. The overall diagnosis must also be as complete as possible (anatomical, aetiological and functional) as multiple lesions of different nature are possible, involving different parts of the body (fractures, wounds, poisoning, burns, radiation injury, hypovolaemic or normovolaemic shock etc.). Stabilization of the lesions and preparation for transportation must be as accurate as possible to prolong the time available for ultimate treatment and to reduce deaths during transportation. Stabilization must mainly aim at recovery and/or maintenance of cardiac and respiratory functions, haemostatis of accessible vessels, temporary immobilization of fractures, sterile protection of wounds, analgesia, sedation, and shock prevention.

A fundamental characteristic of triage is that it must be flexible along the different stages of the rescue chain: it must be started by the physician in charge of the health team which rescues the victim from the disaster site (during this stage the very first treatment for survival must be administered); it must then be completed at the advanced medical unit (at this stage treatment for stabilization of both general conditions and lesions is necessary); and it must be finally completed at the hospital where the patient is delivered to receive ultimate treatment in a specialized ward according to his needs. The flexibility of triage also involves its general organization on the field: this must be adapted to the events which influence the overall policy for evacuation, i.e.

1. the general aetiology and the gravity of the pathology;
2. the number of wounded and the rate of their arrival at the advanced medical unit;
3. weather and environmental conditions and their evolution;
4. the availability of supplies, men, and health transportation means;
5. road conditions;
6. the condition of equipment for communication;

7. the efficacy of the logistic organization and the co-ordination of operations.

TRIAGE IN MAJOR TOXICOLOGICAL EMERGENCIES

Since chemical industries have massively entered all aspects of man's life, and their products have become indispensable, plants for the manufacturing of the most varied compounds (for agricultural use, building, domestic use, pharmaceutical use, etc.) have spread throughout all advanced nations. This has brought problems concerning chronic chemical agent environmental contamination, together with a growing imminent risk of massive and acute contamination of wide areas surrounding the plants. This serious problem has spurred lawmakers in all industrialized countries towards the acquisition of new scientific knowledge in order to be able to issue precise laws aimed at preventing immediate consequences and potential accidents.

The topic we will deal with concerns the health operations needed to save as many lives as possible operating on the site of a toxicological disaster. As already mentioned while describing the most important general criteria which health personnel must follow while administering first aid and during evacuation of victims, the fundamental element on the site of a chemical accident is good triage organization.

Besides the general criteria described above, triage must follow certain criteria:

1. Identification of the toxic compound and its concentration in the environment;
2. Present injury to the victims and evolving injury;
3. Protection of operators and of victims;
4. Immediate treatment;
5. Possibilities of confinement and/or evacuation of the victims according to the gravity of their lesions.

Prompt analytical information about the accident, its causes and the producing plant will provide data about the dispersed compounds and their immediate toxic effects. In the event of unknown substances (in such cases it is advisable that first intervention health teams be flanked by an expert, with adequate portable equipment for physical and chemical qualitative and quantitative data collection), a preliminary investigation should be undertaken. It is indispensable to evaluate the evolution of the compound diffusion in terms of space and time which, besides its concentration and its physical and chemical properties, will also be related to the possibility of neutralizing it in time and to weather and land conditions.

With respect to triage, it is indispensable to evaluate the clinical toxic effects on the victims, even before the results of toxicological analysis: this will allow general orientation of first aid operations.

Symptomatology related to chemical poisoning may be divided into three groups, according to symptoms:

1. Regional: irritation and burns of the skin, ocular annexes and upper airways;
2. General: respiratory distress, cardiovascular disorders;
3. Neurological and psychic: paresis, plegias, convulsions, psychic depression or excitation.

Triage is inseparable from medical first aid operations also because of the quick evolution of toxic syndromes. These operations consist of:

1. Protection of the rescuers by means of isolating suits covering the entire skin surface, universal filter masks or closed circuit respirators.
2. Symptomatic therapy of respiratory distress, according to seriousness, by oxygen supply by mask at variable flow rate or by automatic mechanical ventilators preceded by intubation, parenteral steroid administration, sedation and skin decontamination by means of washing under running water. Irritation of eye annexes requires abundant washing with sterile water.
3. Prompt and medically assisted evacuation of the most serious patients to hospital wards where they will undergo final external and internal decontamination, specific disintoxication, normo- and/or hyperbaric oxygen therapy in closed circuit, monitoring of vital functions and if necessary haemodialysis and exchange transfusion.

We must stress that intoxicated patients transported on stretchers must be placed in the safety position, i.e. in lateral decubitus, in order to prevent abnormal mucous secretions and vomit from obstructed airways. Evacuation of victims without serious injuries may be performed on an out-patient basis and need not be strictly medically supervised: it must be prompt and may make use of confinement, in rooms (homes, offices) where toxic substances have not entered and cannot enter because of technical interventions (padding of cracks in windows and doors) or in open-air areas far away from the site and which toxic compounds are unlikely to reach.

If the planned evacuation routes of lightly intoxicated people and of survivors who have not been injured cross even briefly a gas-contaminated area, hoods may be used, if the rescue teams have been previously sufficiently supplied with them.

TRIAGE IN MAJOR HEALTH EMERGENCIES DUE TO NUCLEAR ACCIDENTS

Making a schematic classification of injuries to people after a nuclear accident, we may distinguish:

1. Immediate direct irradiation: This affects people working in the plant and people who happen to be near it. It is due to ionizing radiation which is released within the plant itself. Direct irradi-

ation in such cases is always particularly serious, as in most cases it is above the threshold of 25 rad. Acute effects, also known as early effects, are directly related to the dose: nausea, vomiting, gastro-intestinal disorders, blood disorders, bullous erythema and even necrotic dermatitis, neurological and psychic disorders.

2. Deferred direct irradiation: This concerns the population within a few km of the plant and is due to radiation from the radioactive cloud released from the plant. In this case the early irradiation syndrome is directly related to the amount of radiation and to the distance of the subject from the source. Symptoms are similar, in different grades, to those already described.
3. Direct radioactive contamination: This concerns people within a few km and is due to inhalation of radioactive substances transported by the cloud and suspended in the air and/or to absorption of material deposited on the skin and on uncovered mucosae, as well as on garments.
4. Indirect radioactive contamination: This concerns populations, vegetables and animals even quite distant from the disaster site and is related to intake of particles resuspended from the ground and of contaminated water and food.

We will deal with irradiation and direct radioactive contamination in the acute phase concerning a considerable number of individuals, as may happen in a major accident in a nuclear plant (we will exclude nuclear disasters due to war.

One cannot consider efficacious a massive health intervention on the accident site if there have been no previous dispositions for a general organizing plan concerning the technical preparation of personnel, no previous preparation of means and equipment and no proper information of the population. Besides the detection of radioactivity, to establish the degree of contamination with the elaboration and monitoring of all parameters, (close co-operation between the chief physician and the sanitary physician in charge is required), there will be need of mobile telecommunication equipment; sufficient and suitable transportation means; ample field hospitals, easy to transport and to set up immediately near the disaster site for temporary confinement and decontamination of survivors; ready-to-use health facilities; drugs to prevent and/or limit the effect of metabolized radionuclides; specialized technical staff; police forces or similar bodies, sufficient in number and equipped with means of protection, to set up defence blocks and compulsory road routes, and to regulate the influx of transportation means, personnel, moving population, the evacuation of the victims, etc.

Criteria for triage will fundamentally be as those described in the general introduction but they must be suitably aimed at the particular pathogenesis of the syndromes. These are very often accompanied by toxic phenomena, skin and respiratory lesions due to burns, wounds, fractures, etc., so that the overall judgement to sort the victims will also have to consider as a priority conventional traumas and surgical pathologies (due to shock-wave, fire, wounds from blunt or penetrating objects, gas or toxic liquids).

Evacuation must always be preceded by prompt lifesaving interventions and by stabilization of the lesions. Decontamination of wounds (which are one of the most likely points of access for blood and lymph contamination) and of skin must be considered priority measures as also the administration of stable iodine (capsules containing 50 mg of potassium iodide) at an adequate dose: children under 3 years of age half a cap., 3–14 years of age one cap.; 15–40 years of age 2 caps. The prophylactic effect of stable iodine (which limits radioactive substance deposition in the target organ, the thyroid gland, as it is a metabolic competitor) is strictly proportional to the timeliness of administration. It has been estimated that if administration takes place within 10–15 min it prevents absorption of the radionuclide by nearly 100%; if within 6 h it reduces it by 50%; after 12 h, reduction is only 5%. If this time period has already elapsed and radioactive iodine has already been fixed, administration of metimazole, 30 mg daily (in wounded patients the drug must only be administered in hospital settings and under careful monitoring), may be useful.

Protection of health personnel, technicians and auxiliary staff is basic throughout all rescue operations and triage: skin and mucosae must be protected with waterproof suits, and the airways with filter masks. As a rule operators should also undergo pharmacological prophylaxis with potassium iodide.

As for the rooms to be set up for triage (shelter tents should be quickly mounted and with a double opening) it must be kept in mind that those which are designed for reception should be wide and divided into:

- general reception room where the victims will be sorted into a) irradiated and / or contaminated subjects with no injury, b) irradiated and / or contaminated subjects with specific injuries or disorders, c) irradiated and / or contaminated subjects with ordinary injuries;
- decontamination room where, in addition, compounds which are metabolic competitors for radionuclides are administered;
- a room subdivided into three sectors: one for irradiated and / or contaminated subjects with specific and / or ordinary injuries, who are to undergo decontamination, one for re-evaluation of triage, one for lifesaving measures and stabilization of local and general lesions.

Injured patients who have also been irradiated and / or contaminated will be evacuated to hospitals equipped for definitive treatment (the field co-ordinator in charge will take care of maintaining continuous radio and / or telephone link-ups with the operational headquarters of hospital emergency departments).

We stress that the external decontamination of wounded patients is extremely important and must be part of basic triage operations because it greatly reduces (if early) both direct skin injury and internal absorption and the passage of radioactive compounds to blood and lymph and to the critical organ. It also prevents spreading of radioactivity to transport vehicles and to intermediate and final medical facilities.

The quickest means of decontamination is, for intact skin, abundant washing with lukewarm water and neutral soap, and for mucosae (eyes, nose, ears, mouth) with water first and then with a hypertonic solution (1.4% NaCl). In the event of wounds, the patient must be washed with an weak alkali solution or Prussian-blue solution and then abundant physiologic solution (when the patient has reached hospital, it will be possible, in relation to the radioactive substances absorbed, to proceed to treatment of residual contamination of the wounds, by means of chelating compounds and, if necessary, surgical excision, if insoluble radioactive elements persist at significant levels).

Internal decontamination of the wounded (gastrointestinal and respiratory apparatus) must also be performed in hospitals designed for final treatment.

For patients who are contaminated but present no injury it could be useful, in order to avoid or limit transportation of contaminating elements in rooms and places which have not been reached by radioactive substances, to effect internal decontamination directly in those rooms which have been reserved for confinement: this reduces absorption and facilitates radionuclide elimination.

Emergency plans must include field teams composed of two trained physicians and one nuclear physicist who should be able to intervene promptly in these questions. The necessary means and equipment are: well protected drinking water containers, large ampoules of physiologic solution and neutralizing hypertonic 1.4% NaCl solutions; bottles of 3% ammonia solution, DTPA solution and powder and Prussian blue for their chelating action; containers of $MgSO_4$ for its precipitating action, ion exchange resins, etc. Aerosol devices and irrigators are also indispensable.

If the number of wounded is very great it will be necessary to provide tankers of uncontaminated water for all washing operations and sufficient supplies of clothing.

We will not consider the medical check-ups for all those who may have been exposed to radiation because this goes beyond our topic; but for this to happen systematically, health personnel in charge of first intervention must present to the responsible health authorities lists with the names of all those who have come to the reception and sorting ward of the mobile health units active on the site of the accident.

TRIAGE IN MAJOR HEALTH EMERGENCIES DUE TO FIRE

A fire disaster may cause specific injuries of the skin and upper airways, intoxication due to smoke and/or toxic gases produced by combustion, concurrent superficial bruises, deep lacerated wounds and bone fractures due to many mechanisms: explosion, falls during escape, crushing, etc.

During triage it thus becomes indispensable to make a careful and global evaluation of the victim in order to establish priorities for intervention and evacuation.

In fire disasters burns are the lesions requiring most immediate attention. In order to concentrate efforts on patients who have the greatest chances of survival if treated it is indispensable to follow pre-established diagnostic and prognostic procedures.

The first triage will subdivide burned patients into three categories:

1. Burned surface over 20% and U.B.S. under 100 (the product of the coefficient for the burned surface multiplied by the coefficient for the approximate depth of the burn), **first priority** for evacuation;
2. Burned surface less than 20%; **second or third priority** according to the seriousness of the lesions and to the part affected;
3. Burned surface over 20% and U.B.S. coefficient over 100.

WAITING PRIORITY

These criteria for a subdivision into categories are only to be used for general orientation because when there is the concurrent presence of burns in the upper airways and/or intoxication by combustion products, or very serious burns in highly vulnerable body areas (such as the face, hands, perineum, or genitalia, joint surface, etc.), or of other serious conventional lesions, overall evaluation must be perfected and thus a first judgement of second or third priority, due to skin burns on less than 20% of the body surface, may be changed into a first priority.

An essential aspect of triage operations, also in the case of burns, is first aid which, besides being lifesaving and important to limit further injury, also facilitates a more accurate and aimed choice concerning the hospital for final treatment.

The most urgent essential interventions are:

1. **Oxygen therapy** with a face mask, and orotracheal intubation and mechanical automatic ventilation if there is serious injury due to burns in respiratory mucosae and/or serious intoxication due to inhaled compounds.
2. **Cooling** of the burned skin surface with cold water and wound covering with sterile pads soaked in physiologic solution and antiseptic solution of quaternary ammonium (or polyvinylpyrrolidine iodide or chlorhexidine) to prevent soiling or bacterial colonization. It is important that pieces of clothes sticking to burn areas should not be removed so as to avoid further trauma to tissues which are already injured. It is also important not to remove phlyctenae: these may be emptied with an incision in a small part of the dome because they are themselves a protection against bacterial contamination and they also facilitate spontaneous repair of the epithelium.
3. **Fluid therapy** by continuous infusion with isotonic solutions such as Ringer's lactate to restore fluid losses which may reach 5% of

body weight in the first days (or even more according to the extent and gravity of the wounds; 50% of fluid loss must be restored in the first hours). At the hospital, fluid requirements will be accurately estimated, as also sodium concentration by means of Parkland's equation. Plasma and albumin solutions are not to be administered during first aid but as a rule only 24 hours after the accident and in hospital. Corticosteroids and other drugs are also to be administered only after the patient is in hospital. Burned patients should not receive blood transfusions. In the event of extensive blood losses due to concurrent lesions, transfusions must be evaluated after careful examination of biological parameters.

4. **Analgesia**: important also because it reduces pain-induced excessive catecholamine release: if pain is severe diazepines may be associated to the analgesics (mepheridine, morphine) so as to reduce concurrent psychic stress. If there is only slight pain paracetamol or similar compounds are sufficient.

First aid interventions must make use of physiological solution and diluted antiseptic solutions, and avoid the use of topical medications (pomades, powders, etc) on burned areas.

Burn patients are one of the great issues of emergency medicine because their prognosis *quoad vitam* and *quoad valetudinem* (the latter considered as quality of life after final outcome of scars), is closely linked to the first measures on the accident site: 1) prompt and complete diagnosis, 2) first undelayable measures (cooling of the burned areas, protection against contamination, fluid therapy, analgesia), 3) medically assisted transportation in optimal conditions, 4) carefully evaluated and coordinated choice of hospital for final treatment.

It must be stressed that 20% of body surface is the threshold over which burns induce general symptoms in the adult patient, i.e. pathology is not confined to local symptoms but affects all organs and functions (especially the kidneys) and the patient may be affected by toxic shock; in children the threshold of burned body surface is 12%.

92 The problem of fire disasters in Russia, including fires at Chernobyl-type nuclear plants

S. SHOIGU
Minister for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters, Russian Federation, Moscow

---

Fire disasters are among the most important factors that destabilize economic and social development. During the last 5 years nearly 200 000 buildings in Russia have been destroyed by fire. Their total area exceeds 13 000 000 m^2, including nearly 10 000 000 m^2 of dwellings. Millions of hectares of forest are also destroyed by fire. For instance, in 10 days of August 1992 up to 300 forest fires occurred every day, some of them covering 3000 hectares. In the central part of Russia alone, 9000 people equipped with 1300 units of fire-extinguishing material were engaged in forest fire-fighting.

The number of industrial fires is also increasing, with more and more serious consequences. In the first quarter of 1992, there were 67 643 registered fires, causing damage amounting to 200 million roubles and 2738 deaths. Compared with the same period of 1991, the number of fires increased by 3.4%, material losses 2.4 times, and fatalities by 8.4%. During the above-mentioned period there were six fire disasters killing more than five persons at once (compared with five in 1991).

The causes of fires are various. More than 75% of forest fires are due to human fault (careless handling of fire). Fires in dwellings and other non-industrial buildings are mainly caused by careless handling of fire, misuse of heating devices, defects in the electricity supply network, children's pranks and sometimes arson.

The explanation for the increased number of industrial fires is the use of flammable materials in construction, the wide application of new fire-dangerous technologies, and the shortage of automatic fire-fighting devices, fire-extinguishing means and warning systems.

There is also a lack of legislation on industrial safety in Russia. A genuine system of laws determining economic sanctions for damage inflicted is still to be developed. In order to prevent and combat fire disasters the relevant organizational, technical and medical measures are being elaborated and implemented in Russia, on the basis of the formation of socio-economic and judicial mechanisms for ensuring security for the population and the environment in emergency situations.

One of the most significant developments is our latest example of fire-extinguishing machinery. A new fire-fighting IL-76 TP aircraft has recently been constructed in Russia. It is designed to extinguish forest fires, to restrict them by setting up barrier bands, and to deliver and parachute down teams of firemen with their equipment. The aircraft is capable of pouring down 44 tons of fire-extinguishing substance in 6 s, covering an area 500 m long and 100 m wide. It is irreplaceable in combating complicated fires such as those in military ammunition depots. Unfortunately, disasters of this kind also happen in the former USSR. The explosion of shells makes the use of surface fire-fighting means impossible. Our fire-fighting aircraft was recently tested in action in a fire disaster at ammunition depots in Armenia in April 1992. We are ready for international cooperation in the use of our fire-fighting IL-76 TP aircraft.

The experience of other countries in fighting fire disasters, and the approaches to the matter from the point of view of international and national law are vitally important.

A major outstanding problem in Russia continues to be the organization of first aid and urgent medical aid, especially when the number of injured is considerable. An example of this, which has already become an academic model, is the disaster caused by the explosion of a pipeline in the Ufa area on 4 June 1989. The explosion struck two trains passing near the pipeline. Of the 1500 passengers in the trains 1220 were affected, 806 requiring admission to hospital. More than 97% of the patients suffered burns affecting the airways, the upper and lower limbs, and the faces and hands.

In this disaster the arrival of medical help was not sufficiently prompt. Anti-shock therapy started only 6 h after the event. This reduced the effectiveness of treatment and aggravated the consequences of the disaster. If specialized health teams had reached the disaster area earlier and the injured had been hospitalized more promptly, more patients would have survived. The contributions of foreign specialists were welcome.

Taking into consideration that specialized health teams based in big cities cannot generally reach the place of a disaster in less than 4 h, the main role in immediate medical aid is the responsibility of the local health authority including ambulance services, urgent medical aid and general purpose hospitals. On this level it is necessary to set up mobile and fully equipped medical teams. The most rapid and mobile medical service is that provided by ambulances. This can become the base for the setting up of disaster health teams.

Fire disasters have shown that preparedness of the general population is very important. We are currently involved in development of the Russian System of Disaster Management (RSDM), which would set up a mechanism of governmental coordination of all rescue teams and services engaged in disaster relief operations. We are sure that the most important principle of disaster management is the priority of medical aid.

The theory and practical experience of disaster management shows that the most acute problems are caused by fires followed by nuclear catastrophes. Experience of the operation of nuclear plants shows that fires there usually do not result in breakdown of the reactor. But fires at Chernobyl-type (RBMK) nuclear plants are a major danger: the Chernobyl catastrophe was a special case which resulted in numerous fires all over the plant and the firemen had to act under the influence of radiation. It is clear that such fires aggravated the conditions of the response operations and caused losses among the firemen.

The most common violations of anti-fire security system for nuclear plants are bad maintenance of buildings (26.3%) and breakdowns in the electric supply system (24.7%). A comparison of the projected level of fire security in nuclear plants with that in the RBMK reactor shows that only the latest designs meet the necessary requirements. There are still, however, certain elements of vulnerability, such as roofing, cable insulation, etc. After the Chernobyl accident additional steps were undertaken to improve fire security.

The problem of graphite flammability (as in the Chernobyl reactor) is being solved within the framework of the enhancement of general security in nuclear plants. This includes reinforcement of security control systems in order to prevent all possibility of a nuclear reaction in the initial phase of automatic protection, which will be improved in view of the possibility of graphite fire at a temperature of 800°C. It is important to increase the fire resistance of the steel framework of the building and that of reactor cooling pipelines. The experience of nuclear plant operation shows that fires do not normally result in the breakdown of the reactor. They are normally extinguished in time. The Chernobyl catastrophe is a lamentable exception, with international repercussions.

The problem of the prevention of fire disasters and of the necessary response is therefore an acute issue in Russia. It demands a comprehensive solution based on worldwide experience.

93
Evolution of burn accidents in a hydrocarbons complex: Sonatrach 1985–1990

R. SIDANI
Human Resources, Sonatrach, Algeria

DESCRIPTION OF SONATRACH

Sonatrach is a national company for the exploitation, production, transport, liquefaction and marketing of hydrocarbons, with a work force of 32 628, > 100 work sites. Work groups contain 6 people while > 3600 people are located at industrial sites. The company is geographically distributed in 48 *wilayate* (departments) covering 2 380 000 km^2, of which about three-quarters are desert.

OBJECT

The object of this brief description is to illustrate the difficulty of taking workers into health care. We have endeavoured to limit the population exposed to accidental burns, to compare work activities specific to the petroleum industry and support industries, to examine causes and origins, to assess the overall impact and above all to identify shortcomings in the care of victims and to take the necessary corrective measures.

In the 6-year period 1985–1991 we have collated 305 industrial burn accident files (Figure 1). There was no significant difference between the professions as regards burn risk (Figure 2): while 42% of burns affected oil industry personnel, 49% affected mechanics and electricians in the construction industry. A total of 81.5% of our patients were between 20 and 40 years of age, while 18.5% were between 41 and 60 years of age; 85% were workmen and 13% management personnel.

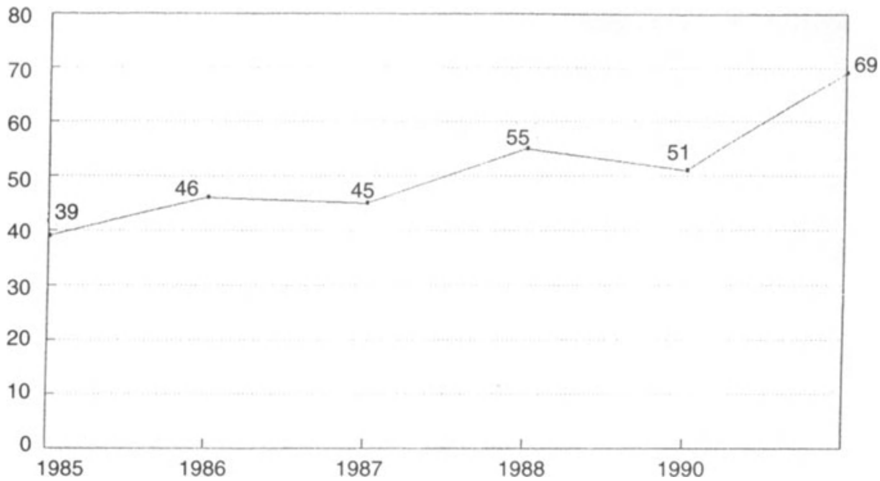


Figure 1. Accident evolution curve. The mean number of accidents is 51 per year.

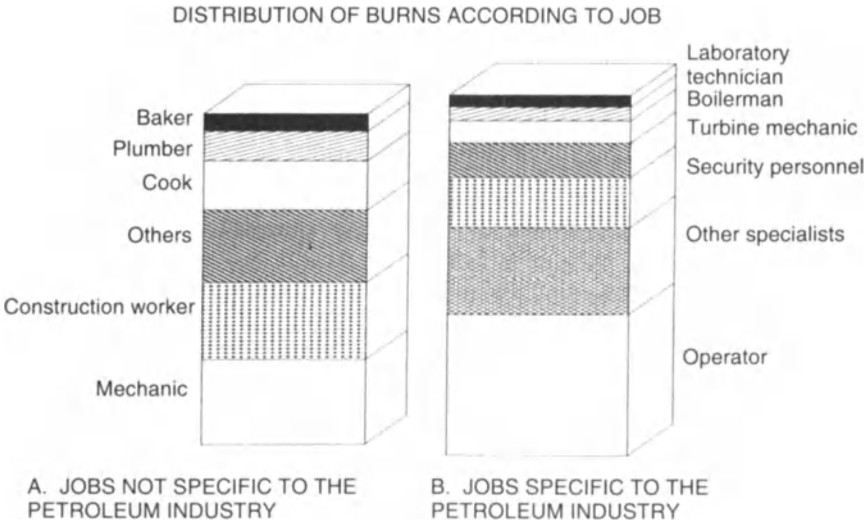


Figure 2. Distribution of burn victims according to job. (**a**) Functions not specific to the oil industry: 133 cases; (**b**) Functions specific to the oil industry: 148 cases.

DEGREE OF LESIONS

First-degree burns accounted for 75.4% of the cases. The remainder were second- and third-degree; in most cases, there was a mosaic of burns (first, second and third degree).

Figure 3 shows the parts of the body burned. These involve predominantly the upper limbs (52%), the face (26%), the lower limbs (12%).

Figure 4 gives the origin of burns: flames (30%), chemicals (28%) and hot liquids (13%) constitute the main origins. Figure 5 shows the causes of burns, which are overwhelmingly due to human error (76%).

EVACUATION ABROAD OF SERIOUS CASES

We have reported elsewhere on the cases of burn victims requiring evacuation by air ambulance to specialized centres in Europe. This was undertaken for five patients in 1986, one patient in 1987, two patients in 1988 (third-degree burns), nine patients in 1989 and for none in 1990.

The duration of hospital stay varied between 1 and 425 days (two cases). There were five deaths, four in the first 48 h and one on the ninth day. In the remaining 12 cases the average stay in hospital was 4 months.

Nearly one-third of the patients who were evacuated (and died) were sent abroad because of psychological or sentimental considerations for their families or work colleagues rather than for improved survival prospects ('administrative evacuation'). Appropriate first aid and care

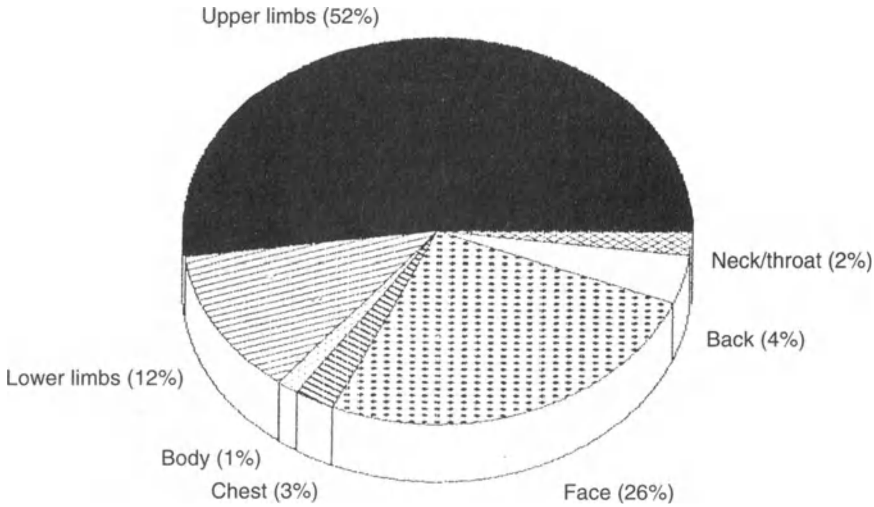


Figure 3. Parts of body affected.

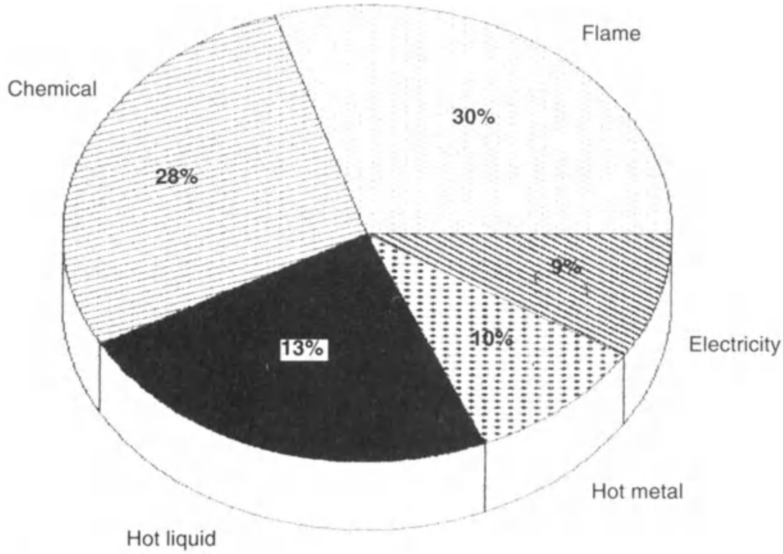


Figure 4. Origin of burn.

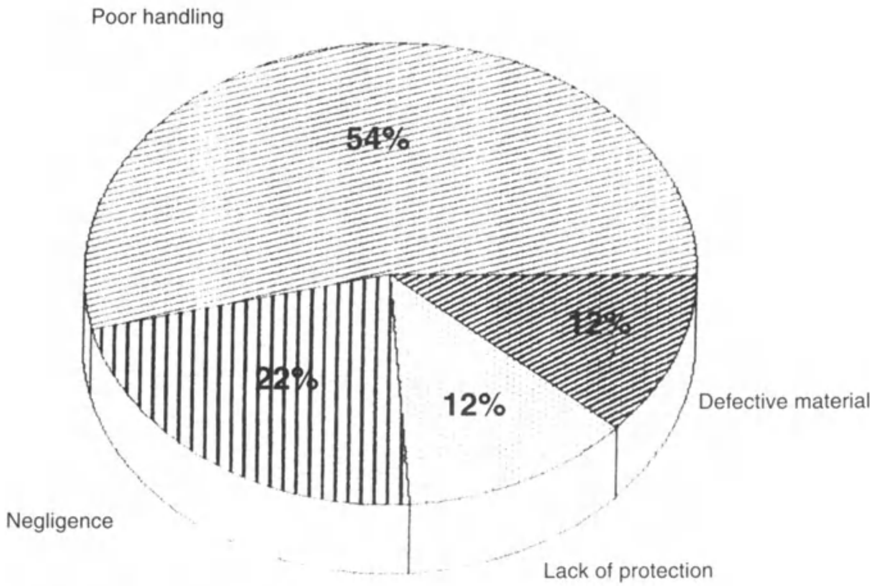


Figure 5. Cause of burn (human error).

was not given on work sites. There were long delays between the time of the accident and the taking in charge of the patient by a medical team due to long distances, bad weather conditions, lack of runways.

CONCLUSIONS

The above statistics show that the number of burn victims at Sonatrach is relatively low, considering the high risks that are present at all times (flammability, explosion). This is due to the vigilance of the medical and security teams.

Sonatrach bases its efforts to reduce to a minimum the effects of accidents / incidents on the following guidelines:

1. Training of professional first-aid workers.
2. Promotion of the practice of cooling, i.e. using water to cool all burns for a least 15–20 min, and to cover burn victims with a clean blanket until they are taken in charge by a medical team.
3. Avoidance of evacuation of burn victims at all costs without due medical opinion; the most important priority is to guarantee the patient's vital functions.
4. Correct compilation of accident dossiers.

The management of Sonatrach intends to set up small intensive care units in every industrial area, as well as a traumatology and burns hospital.

REFERENCES

La sécurité et l'hygiène du travail dans l'industrie pétrolière à la lumière de l'évolution des techniques (1973). *Organisation internationale du travail, Commission du pétrôle, 8ème session, Genève,* 35–46

Rapport II (1978). *Organisation internationale du travail, Commission des industries chimiques, Genève,* 43–53

Les conditions et le milieu du travail dans l'industrie pétroliòre y compris l'industrie en mer (1980). *Organisation internationale du travail, Commission du pétrôle, 9ème session, Genève,* 33–55

Statistiques accidents de travail 1985 à 1990 (no date given). *Direction des Oeuvres Sociales, Départment Santé, SONATRACH*

Burkhard, H. (1990). Worker production and accident statistics in 1988 (1990). *VIII Welt Kongress für Arbeitsschutz, Hamburg*

Desoillé, H., Scherrer, J., Truhaut, R. *Précis Méd. Travail Brûlures,* 3rd ed., Paris: Masson

Firki, O. K., Kanjia N., Benamor, J., Khourassani M. *et al.* (1991). Le poumon du brûlé. *Rev.AMELISAP,* 7, 18–19

Masellis, M., Gunn, S. W. A., Eds. (1990, 1991, 1992). *Ann. Medit. Burns Club.* Various issues.

Ménage, P., Lenz, T., Ritcher, F., Julien, H. (1990). Cooling. *Rev. AMELISAP,* **6**, 3

See also *in this book*: Wasserman, D., Lebreton, F., Schlotterer, M. and Chaouch, A., Comparison of epidemiological data and life prognosis in patients transferred from the Maghreb and in all patients admitted to a hospital in France, pp. 169–173.

94

Industrial burns prevention and fire disaster management: the ENI experience

M. MONTI
Security Office, ENI, Rome, Italy

The purpose of this chapter is to illustrate the point of view and the policies of a large industrial group, ENI, as regards the protection of industry from fire risk.

The ENI (Ente Nazionale Idrocarburi – National Hydrocarbon Agency) Group is an important industrial organization in Italy in which numerous companies operate in a wide variety of sectors, including:

- exploitation of oil fields
- transfer / transport of hydrocarbons, crude oil and refined products
- hydrocarbon refining
- petrochemicals
- chemicals
- mechanical engineering
- mining
- non-ferrous metallurgy
- tourism, hotels

Many of these sectors carry a high risk of explosion and fire and therefore of severe burns.

The rapid developments in the field of technology and managerial and organizational expertise have induced the ENI Group to carry out a continuous process of study, research, experimentation and definition of technical standards, together with the updating and training of operators at all levels and the technical and organizational upgrading of plant and operative structures, not excluding the field of the prevention of fire and/or burns risk.

The Companies belonging to the Group are well aware that the unification of Europe will bring with it further commitments for the introduction of new and more incisive technical and preventive standards, the realization of which will require expertise and skills involving a wide variety of specific sectors.

ENI has long placed at the centre of its strategies and included among its operative programmes all actions and activities aimed at guaranteeing the physical safety of its workers and the protection of its property (plant, structures, etc.) from fires, explosions or damage of whatever origin. Proof of this is the drop in the number of accidents from 66 in 1980 to 34 in 1990, with a trend towards further reduction.

In this context, ENI has collaborated with the National Brigade of Firemen, with satisfying results. Common activities have been developed in the field of the training and professional updating of the personnel of its two relative administrations, together with advantageous collaboration in the field of technical standards. We are convinced that specific training and preparation in the field of fire prevention have contributed significantly to reducing the extent of accidents, their consequences and the possibility of their occurrence.

The ENI Group has paid particular attention to the consequences of accidents involving personnel – and here of course we are referring to burns victims. In this view, the policy of the Group has been to highlight the need to provide Companies with specialized structures which in many cases have multidisciplinary characteristics and complexities that go well beyond the standards prescribed by present legislation. Every decentralized structure is provided with medical facilities for first aid and specialized medical check-ups (the main specialization is Industrial Medicine); every leading Company in its respective field disposes of a Medical Service that coordinates peripheral medical facilities, just as at ENI central level there is a medical service operating in the field of coordination, general activity and support, if necessary.

The factory physicians and health coordination personnel are periodically invited to attend refresher courses and training courses, in which paramedical personnel may also participate.

In view of the social and economic effects of burns and the concept that burn victims constitute a problem regarding company experience and culture, ENI has supported a programme of scientific collaboration with the *Fondazione piemontese studi e ricerche sulle ustioni* (Piedmont Foundation of Burns Study and Research). This has led to the agreement of a protocol which, taking into consideration on the one hand ENI's interest in research directed at improving therapy and reducing the consequences of burns and on the other the Piedmont Foundation's competence in the field of burns treatment, intends to promote experimentation and studies in this field, to provide scientific documentation to update information on the subject, to perform specific training activities, to identify new materials and/or means of protective clothing and to set up a highly specialized structure capable of providing burn victims from ENI Group companies with the best possible care and assistance.

The concept of burns, in the policy of the ENI Group, comprises in equal manner the consequences of fires (thermal burns) and the consequences of contact with acids/bases (chemical burns). The field of attention is thus very wide and concerns plants in the majority of the companies operating in the Group.

The Group has always devoted great energy to the search for the best ways of reducing to an absolute minimum the specific risks of the various production processes and the risks of thermal and chemical burns by following two basic guidelines:

- adoption of active safety measures; plans for plant checks and maintenance; and use of best available technology, a concept that has recently been recognized by Italian law;
- adoption of passive safety measures by the use of personal clothing and equipment offering workers the greatest possible protection.

Factory plants are characterized by the presence of high risk, such as fire, explosion and the escape of dangerous substances, and they are the object of growing attention from the outside world, which has become extremely sensitive to all the events, of greater or lesser importance, occurring inside them. As a result, and also to protect the high-level image that the ENI Group has succeeded in projecting to the public, the business world and abroad, the companies belonging to the Group have been invited to carry out research for solutions that can best contribute to the real improvement of personnel security.

A typical case is that of the experience of the NUOVA SAMIM company, the Chief-of-Sector Company for non-ferrous metallurgy (Pb, Zn, Cu, etc.). This company has branches in many regions of Italy. The risk of burns due to splashing with molten metal or waste matter or from contact with high-temperature surfaces is present in many of its factories.

It has become a firm commitment of this Company to provide its workers with protective clothing which has a high level of resistance to elevated temperatures and to splashing with incandescent material and which can therefore offer the most effective protection possible.

In collaboration with ENI, NUOVA SAMIM has also set up a system of specialized care for burn victims that acts both on the training level for personnel giving first aid (the first care, of fundamental importance, that burn victims receive) and on the organization level, providing the most rapid transport possible, which in some cases has enabled casualties to receive the highly qualified care offered by the Piedmont Centre.

With the support of the ENI Safety, Quality and Environment Service, research was also initiated outside the range of products that were commercially available, none of which provided adequate protection from the type of risks involved.

The research on protective clothing was carried out by Professor G. Magliacani, of the Turin Traumatological Centre. This has led to the production of special textiles that have made it possible to design working clothing that is particularly suitable for protection from the risk of burns (these items of clothing are manufactured and marketed by the Prometeo company). Some factories have begun to use this type of clothing to protect their personnel, with extremely positive results, as shown by the fact that from 1991 until the time of writing there has been not one noteworthy case of thermal burns; a few workers have received simple medication for small burns caused by incorrect use of other protective means such as face-masks and goggles.

The ENI Safety, Quality and Environment Service continues to organize and support the presentation of NUOVA SAMIM's results in this field to other companies interested in the problem of protection from burns.

In addition to this project, ENI has renewed its plan of collaboration with the Piedmont Foundation for Burns Study and Research and issued a series of general guidelines aimed at providing further support for the commitment to improve protection standards as regards both property and human life in the factories that it possesses.

REFERENCE

Magliacani, G., Romano, C. (1992). Personal protective equipment in operations involving burns risks: theory and practice. In *The Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, Eds. Dordrecht, Boston, London: Kluwer Academic Publishers.

95

Safety features of protective equipment for work in the presence of high temperatures and methods for testing their efficiency

G. MAGLIACANI* and R. PACIUCCI**

**Centro Grandi Ustionati, CTO, Turin, Italy; **Ufficio Sicurezza e Prevenzione, Italian National Research Council*

Risk is implicit in every kind of human activity and the probability of its occurrence and the gravity of the consequences depend on the type of activity involved.

The damage caused by a traumatic event occurring during work may differ in type in relation to traumatic agent that is the cause and the manner and intensity of its action. For this reason protection is offered to workers, the purpose of which is to eliminate – or at least to reduce to what may be considered acceptable levels – the probability of accidents occurring and their consequences.

The protection of the individual is a problem that can be satisfactorily solved only if it is approached globally, since most accidents are caused by the simultaneous effect of a number of undesirable factors. That being so, the kind of work performed and the environmental conditions both play a decisive role: for example, people who are tired because the work is exhausting or because the work environment is difficult are less aware of the development of abnormal situations and as a consequence react more slowly. Accident prevention therefore has to take into account all the single elements which together can lead to an accident.

As a general principle, the necessary steps for accident prevention are:

- accurate assessment of the activity in relation to the type of organization and the work cycle, in order to minimize risks;
- correct choice of machinery and equipment;
- use of technical safety systems;

- creation of work environments capable of reducing worker fatigue so that levels of attention remain high and reaction times are sufficiently rapid;
- personal protection.

In many cases, individual protection has a marginal role that is merely complementary to other safety systems. However, it often happens that the use of appropriate personal protection (i.e. special clothing) is the only guarantee that a certain activity can be performed in acceptable conditions of safety.

There are in fact a number of dangerous activities, e.g. in the industrial, military and sporting world, in which it is not possible to eliminate all danger at source by means of technical protective systems and which therefore involve a varying degree of personal risk. The same applies to activities performed in conditions of high temperature. The temperature conditions may be an inevitable feature of the production cycle (blast furnace, glassworks, etc.), may arise in situations caused by accidents (involving racing car drivers, military vehicle crew, air pilots, etc.), or may be present when it is necessary to intervene in emergency situations (e.g. when extinguishing fires of all types).

In these cases appropriate individual protection that guarantees personal safety – or limits damage – in the event of an accident must be available.

In the ordinary work environment the problem might appear the easiest to solve, as the function of personal protection would respond to a single objective, that of enabling people to work in tolerable fashion in given environmental conditions, without suffering burns. In reality, however, in many of these activities the risk of burns cannot be ruled out *a priori*.

In the other cases mentioned, the situation is clearer. Protective clothing or, to use the correct term, 'protective equipment', has to provide the necessary degree of safety in moments of need, while at the same time being comfortable in normal working conditions – otherwise it could not be used at all. The two needs of protection and comfort cannot be easily reconciled, even with modern technology.

In order to be considered protective, equipment has first of all to be made in such a way that it can resist specific external agents for a determined period of time, with no physical damage to the person wearing it; in other words it must have thermoinsulating characteristics. It must eliminate the heat produced by the wearer, allow ease of movement for performance of the specific tasks involved and not be excessively heavy. For a more complete treatment of the theoretical prerequisites and the specifications for personal protective equipment in operations involving the risk of burns, we refer to our publication of 1992.

One feature that is much discussed but not yet clarified is the methods by which specifications of personal protective equipment are assessed. The mobility allowed and weight are easy enough to ascertain, but other features that are also important for self-protection are more difficult to evaluate. On the assumption that fire resistance, thermal non-conduction and permeability to airborne substances are characterizing features, a study was performed of the tests that are most frequently performed to rate the reliability of protective equipment and its real protective capacity.

THE ASSESSMENT OF PROTECTIVE EQUIPMENT

If testing methods of protective equipment and its components are to be considered reliable, they must be strictly scientific and be directly relevant to the features they are intended to identify, so that the results can be related to real cases. The tests must also be repeatable.

Our study therefore excluded tests on features that were not relevant to protection from burns or to personal comfort or were intended to demonstrate purely commercial aspects, as this did not fall within the province of our research. Further tests may be carried out on other subsidiary items of clothing which have to be compatible with fire and heat protective clothing.

For this reason not all the international standard methods were taken into consideration. We only assessed tests designed to evaluate the capacity of protective equipment to protect from heat and fire; and comfort (the presence of which is an essential factor for efficient protection).

PROTECTION

Our research has found that the following tests have to be performed in order to ascertain the protective capacity of clothing.

Test C8E RF 1/75 (UNI 8121) – Determination of the reaction of materials when exposed to fire

In this test a gas jet flame is applied to a sample of the protective clothing consisting of a 'sandwich' of the material of which the clothing is made stretched over a special vertical-standing frame. The flame is applied for a determined length of time to the lower part of the sample so that both sides (i.e. the outer and the inner surface of the clothing) are exposed. The time of post-combustion and of post-incandescence, the presence of liquid due to fusion of the material and the extent of the damaged zone are then evaluated. This experiment has shown that it is essential to test together all the protective clothing between the external surface and the person's skin: the test is often passed by individual components of protective clothing which itself does not pass the test.

Only protective clothing that passes this test can be used in tests to measure heat transmission when exposed to flames.

CEN prEN 367 (ISO CD 9151) – Clothing for protection from heat and flames

This test uses a special apparatus fitted with a heat source consisting of the flame from a meker lamp burning propane gas (80 kW/m^2). Samples of protective clothing (140 × 140 mm) are passed horizontally over the meker lamp on a special trolley. A count starts which stops when determined heat levels are reached in the inner surface of the sample (i.e. in contact with the wearer's skin). Heat transfer is determined by means of a special calorimeter. The time necessary to reach the established heat transfer index (HTI) is measured, corresponding to a 24°C increase on the calorimeter. The times necessary to reach the pain threshold and the irreversible burn threshold (Stoll and Chianta, 1969) are also measured, in accordance with standard *CEN prEN 368*. The replacement of the meker lamp by electric panels, as established by standard *CEN prEN 366*, has given analogous and also comparatively inferior results, probably because the greater dimensions of the panels compared with the flame, that are necessary to obtain the same heat flow values, cause heating of the entire surface of the support carrying the samples and thus accelerate the time needed to reach the thresholds in question. The temporary impossibility of having a sufficiently fine means of regulating heat flow so that this is regulated identically for the two heat sources may also have a certain influence.

Another set of apparatus has been devised to simulate in laboratory conditions the behaviour of protective clothing worn by a firefighter exposed to the action of a radiant heat source that reaches the pain threshold and to evaluate if the internal temperature of the clothing continues to increase and causes irreversible burns, even after the radiant heat source has been eliminated. This test apparatus consists of:

- a 120 × 60 mm radiant electric panel, with automatic temperature control (accuracy ± 1°C), capable of reaching a maximum temperature of 600°C and with a running temperature of 400°C;
- an optical pyrometer, with spot reading every 0.2 s of the temperature on the inner surface of the exposed sample, at a distance from it of 600 mm, connected to a computer providing a reading response for every second of the trial;
- a metallic sample support, the same size as the radiant panel, on which the samples are placed;
- a device for moving the sample support that positions the sample 10 mm from the radiant panel and automatically determines the start of the trial.

As the air contained in the component 'sandwich' might be measured in the resistance power of the equipment, another trial has to be performed in which the sample is crushed between the heating surface and the calorimeter, at a predetermined pressure. This is possible using standard *CEN prEN 702*, which establishes that the sample has to be crushed between two circular surfaces of diameter 25 ± 0.05 mm at a force of 49 ± 0.5 N.

In this way it is possible to predict the behaviour of protective clothing in particular conditions, as for example when firefighters fall on hot surfaces.

Tests on the protective capacity of clothing must also take into account the effect of humidity on heat protection. The evaporation of sweat in fact plays an important role in terms of comfort and heat isolation.

When a sample is exposed to a temperature of 200°C, the isolation values recorded are 50% lower when the sample contains an amount of water corresponding to the quantity of sweat produced in conditions of heavy work. An increase in the humidity level also considerably lowers the pain threshold.

Taking as a point of reference a man 170 cm tall weighing 70 kg engaged in work activity requiring an energy expenditure of 400 kcal for 50 min, the production of sweat will be 259 g for the trunk (6896 cm^2), equal to 0.04 g/cm^2. On a circular sample of 10 cm radius there should therefore be 12.56 g of solution with chemical characteristics similar to those of sweat.

Correct assessment of the isolating power of protective clothing must therefore take into account the quantity of sweat remaining within the clothing.

COMFORT

In protective clothing, comfort plays a fundamental role and is in fact an essential quality, for if clothing is not comfortable it will not be possible for firefighters to use it.

Comfort is the result of a combination of characteristics which have to be present together in the protective clothing, consisting essentially in the clothing's capacity to allow freedom of movement in relation to the activity performed and to permit personal heat regulation by the evaporation of sweat.

Clothing should be lightweight, easy to wear and adherent to the body, qualities that can be rated only in practical trials.

Permeability is very difficult to achieve in protective clothing intended for activities involving exposure to high temperatures, fatigue and states of anxiety and/or mental effort. The evaporation of sweat, in the form of drops of liquid, is in fact only possible if the space between skin and clothing presents favourable levels of temperature, relative humidity and air speed.

If these conditions are unfavourable evaporation will not take place, causing hyperthermia with all its negative consequences. To prevent hyperthermia, protective clothing must therefore permit the evaporation of sweat. We should consider, for example, that an accumulation of 77 $kcal/m^2$ of body surface increases body temperature by 1.8–1.9°C.

If we define the minimum required perspiration (MRP) index of protective clothing as its capacity to allow the evaporation of sweat produced in certain climatic and energy expenditure conditions, it is possible to evaluate the value of MRP necessary for each activity examined.

On the basis of these considerations, we assessed the testing methods normally used to determine protective clothing comfort levels. Sometimes the methods used are not in line with the prerequisites outlined above, and they therefore produce results that are without any value in real operating conditions. This is the case of tests *DIN 53 122 (parts 1 and 2)* and *UNI 4816*, which do not take into due account basic aspects of human physiology:

- a sweating person emits drops of sweat with a temperature of 36.5–37°C and not vapour at a temperature of 80–90°C;
- the environment in which evaporation takes place, i.e. the air space between the protective clothing and the skin, is not devoid of humidity, as the tests presuppose; in this space there is no ventilation, the air is soon saturated with humidity, the temperature gradient is extremely reduced and therefore, if there is no communication with the external environment, it is extremely difficult for evaporation to occur.

For these reasons, we examined the air permeability test established by standard *UNI 8727*. This method makes it possible, by means of a special apparatus, to measure the quantity of air passing through a protective clothing sample of known surface area under the action of a known pressure increase. For reliable results, this test should be performed after washing of the protective clothing because there could be considerable differences between the new material (i.e. all the material used in the various components of the clothing) and the material after laundry operations which may considerably modify the nature of the fibres.

The results then have to be compared with results from tests performed in a climate chamber in order to identify any possible references and existing ties. The climate chamber is only used to test complete sets of protective clothing that have passed all the other tests in order to establish how use of the clothing affects fatigue in a sample number of firefighters of similar condition (i.e. as regards physical characteristics and training levels) performing a physical activity involving predetermined energy requirements and characterized by a series of typical working movements for which the clothing is intended.

By following these procedures it will be possible to design protective clothing that can be used in complete safety and reduce burn risks without increasing the risks of accidents due to overfatigue of the wearer.

CONCLUSIONS

An analysis of the tests performed and of those proposed by internationally important standards organizations and industries producing burn protection clothing shows that the use of testing systems not fully consistent with the purposes of the tests may lead to results that are not only unreliable but also totally misleading. This is, for example, the case in tests performed on equipment worn by dummy figures equipped with sensors. In such conditions, the test provides the heat resistance value provided by the equipment plus the air space between the equipment and the sensors. The consequence of this method is that the heat isolation provided is a function not only of the thickness of the air space but also of the quantity of air contained in all the protective clothing, which determines the extent of possible convective movements.

In order to evaluate this parameter, we should bear in mind that an individual 170 cm tall weighing 70 kg has a total body surface (calculated by the Dubois method) of 18 097 cm^2, which reduces to 14 628 cm^2 if we exclude body areas not involved in the test (head, hands and feet).

The quantity of air present in the space between body and protective clothing increases by 14 628 cm^2 simply by raising the clothing 1 cm above the body surface.

Leaving aside theoretical considerations, according to which it is not the clothing but the air space that is to be defined as protection, this type of method prevents any comparison between different kinds of protective clothing because the tests are not repeatable, as they can in no way guarantee a consistent distance of the clothing from the sensors. The results will depend essentially on the size of the protective clothing and its position on the dummies, which will produce a greater or lesser distance of the clothing from the sensors.

The difficulty of regulating the gas flow and the resulting incident energy represents a further obstacle to repeatability of the test.

It has to be added in conclusion that the above tests attribute excessive protective value to clothing with poor heat retractility. In real-life situations persons invested by flames that are carbonizing their clothing do not remain motionless like the dummy figure, and the stresses on the clothing are certainly sufficient to lacerate carbonized material, which cannot therefore offer protection of any kind.

It also has to be mentioned that these tests seem to have little relation with safety from the medical point of view.

The tests are performed by exposing a sample to thermal energy for a predetermined time and then observing the damage present. This however ignores the fact that the purpose of tests on protection should be to establish the time period in which lesions do not in fact occur. Such tests could establish the real safety limits that must not be exceeded in order to prevent the occurrence of lesions.

BIBLIOGRAPHY

Magliacani, G. and Romano, C. (1992). Personal protective equipment in operations involving burns risks: theory and practice. *The Management of Mass Burn Casualties and Fire Disasters*. Dordrecht/Boston/London: Kluwer Academic Publishers

Stoll, A. M. and Chianta, A. M. (1969). Method and rating system for evaluation of thermal protection. *Aerospace Med.*, 1231

96
Chemical spillage – a preventable disaster?

L. ROSENBERG and U. SHABSHIN
Department of Plastic and Reconstructive Surgery, Soroka Medical Center and the Center for Research and Development in Plastic Surgery, Ben Gurion University of the Negev, Beer Sheva, Israel

---

INTRODUCTION

The need for chemicals in our daily lives and the rapid expansion of the human population mean that chemical plants are often situated near heavily populated areas. The use, transportation and storage of these chemicals pose the constant threat of a spillage disaster. Each chemical substance has its own environment contamination potentials, which are defined by a number of criteria:

1. Mass (m)
2. Toxicity. This is defined by the National Institute for Occupational Safety and Health (NIOSH) as immediate danger to life and health (ILDH)[1]. This value relates to the maximum concentration of the chemical substance in the air to which a healthy employee could be exposed for at least 30 min with no irreversible adverse effects.
3. Volatility, defined by the vapour pressure (VP) of the substance (in mm Hg) at room temperature.

The potential environment contamination (PEC) $= m \times VP \times 1/ILDH$.

Some chemical plants stockpile compounds with a high poisoning capacity and high PEC, which means that evacuation has to be completed within 30 min of a spillage occurring (Toxicology and Clinical Pharmacology Department, Cheim Sheba Medical Centre; personal communication).

Israel, a small country with a population of 5 000 000, has had several cases of chemical spillage accidents. To mention the last two: in 1992 a loaded truck full of bromide skidded on an open road, far from any urban area. The tank was crushed and the highly volatile liquid spilled out, creating a gas cloud that spread all over the area. Before dying, the driver radioed the security service at his chemical company and the police quickly blocked the road. The cloud of suffocating and corrosive gases dispersed, and the driver was the only casualty. The second incident occurred in a chemical factory situated in a huge industrial zone near a heavily urbanized area where a chemical spillage was caused by the accidental bursting of a tank. As it was Friday evening the factory and the whole industrial zone were practically deserted. There was no wind and the only victim was a guard who suffered moderate injuries and was evacuated to the nearest hospital and treated successfully. These accidents fortunately caused only a limited number of casualties, but the outcome would have been different if the truck had crashed in a heavily populated urban area or if the industrial zone and the factory had been full of employees during regular daily working hours. Such accidents can happen any time, anywhere.

There have been chemical disasters in all parts of the world, including Bhopal, India, in 1984[2–5]; the Hinton train disaster in Canada in 1986[6] and the Bashkirian train disaster in the USSR in 1989[7]. Thousands of people were killed or injured in these accidents. The problems do not end after acute exposure to the chemical cloud: every year after the Bhopal disaster at least 15 people exposed to the cloud died every month[2].

A number of national and international control organizations have been established for these toxicological disasters, including CIMAH (Control of Major Accident Hazards, UK), PEC (Pittsburgh Emergency Poison Center, Pittsburgh, USA) and UNEP (United Nations Environment Program, UN)[8,9]. However, even with these organizations, is our society ready to deal with such disasters? Is the medical establishment prepared?

In this chapter we will consider the position of the medical establishment and its role in preparedness for chemical disasters. Our aim is to establish a comprehensive protocol to guide the various authorities during a chemical disaster.

MATERIALS AND METHODS

In Israel the management of chemical spillage basically follows the management of chemical warfare activities (i.e. with mustard gas, sarin, etc. as the contaminants)[1]. On detection of a chemical spillage, the police, security forces and the army take control of the situation. A control group is established to coordinate all the teams and forces that may be involved, including communication and the media (Figure 1). The police are responsible for sealing off the contaminated area and organizing evacuation, if necessary. Medical and paramedical troops such as MDA (Red Magen David), reinforced by well-protected trained rescue teams capable of functioning in contaminated areas, providing first aid and evacuating casualties, are sent to the scene.

When a spillage accident has been announced, a mobile unit of the Ministry of the Environment arrives on the site to test and diagnose the

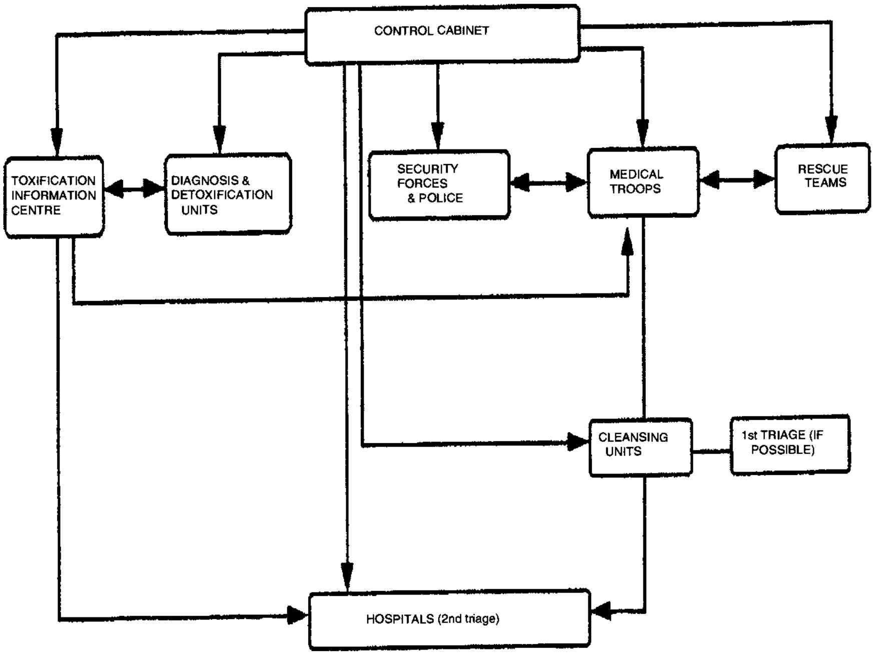


Figure 1. Algorithm representing management of a chemical disaster

nature of the contaminant and to inform the control group. Information about the contaminant is also provided by one or more security mobile units of the company involved in the spillage. The country should be divided into areas, each with its own mobile spillage control unit. The control group distributes the information to the rest of the forces, including medical staff (field level and hospitals). Evacuation should be performed by trained and specially protected teams in order to prevent spreading of the contaminant.

In the hospitals evacuated patients are treated according to a specific chemical poisoning protocol which is in two main phases: cleansing and detoxification and medical treatment. Cleansing and triage posts in the hospital should be located in an open place (e.g. a parking area) if possible. The posts should have cleansing facilities (showers, shower stretches, cleansing agents, etc.) and protected, well-trained personnel. Triage should be performed according to a casualty scale by well-trained and experienced physicians, protected if necessary. Treatment posts should be set up in the entrance of the hospital beyond the cleansing posts and should be divided for different levels of casualty severity. Treatment must start as soon as possible.

In the immediate area of contamination, besides cleansing and diagnosis of the toxic agent, treatment should be only supportive, particular attention being paid to respiratory tract symptoms (Figure 2).

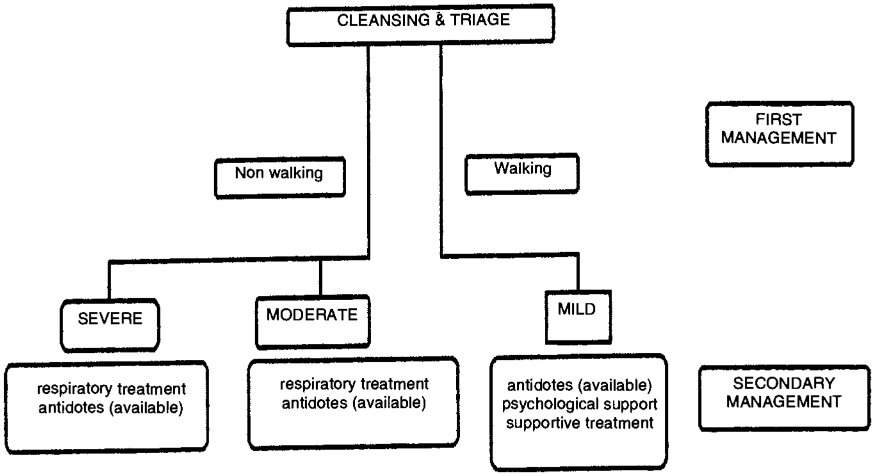


Figure 2. Management of casualties arriving at the hospital

Antidotes for some well-defined toxic agents (such as 4-DAMP, amyl nitrite and sodium thiosulphate for cyanide, BAL or other chelators for arsine, and calcium gluconate for fluorides) should be kept in a regularly replenished store. Local hospitals, with their normal facilities, are the natural and logical centre for the medical care of the victims.

Chemical spillage accidents, unlike wartime incidents, occur without warning. The number of casualties is often higher than predicted and is determined by the toxic properties of the chemical substance and the circumstances of the accident. Following individual or badly organized evacuation patients may reach the hospital before the medical staff have been informed and specific facilities prepared. In such cases, the cause of the accident and the number and severity of injuries are unknown.

For each potential chemical poisoning a specific protocol including toxicology (early and late) and treatment should be prepared and sets compiled for disaster management. These sets of protocols should be supplied to every hospital that may be involved in chemical disasters (e.g. because of its vicinity to a chemical factory, chemical depot or transport routes). All hospitals should obtain a list of chemical substances in general use in their area. The protocols should be available at all times.

Each hospital should prepare its own trained medical and paramedical staff, with representatives of all disciplines (i.e. intensive care, plastic surgery, toxicology, internal and paediatric physicians, etc.). The training of these teams should include refresher courses and the checking of techniques and equipment, including antidotes[1]. An emergency communications network system to contact teams in the event of an emergency should be prepared and practised. There should be reserve

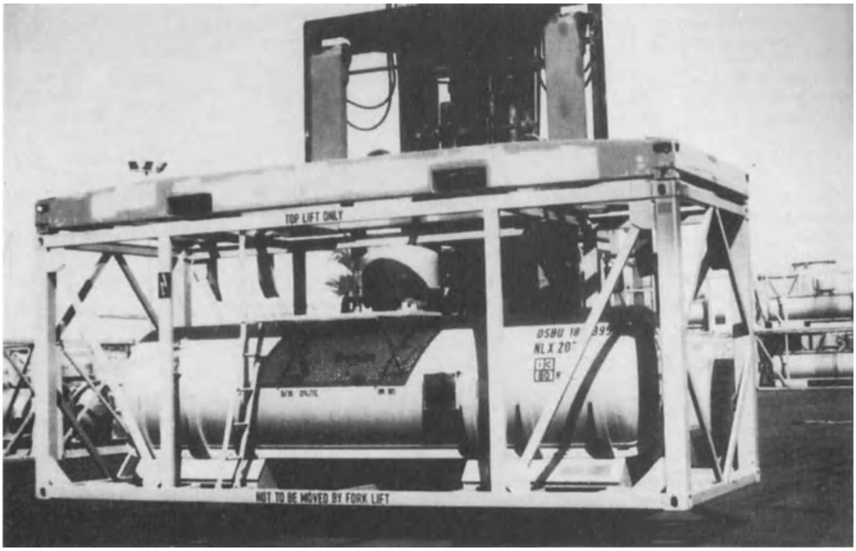


Figure 3. Careful handling of chemical tank

personnel for each discipline. National and international toxicology staff should also be included in this network.

DISCUSSION

Chemical spillage can happen at any moment. Dangerous chemicals are often stored in populated areas and when transported they pass along heavily congested routes, exposing thousands of people to deadly hazards (Figure 4).

In Israel, owing to the threat of chemical warfare such as in the recent 'Desert Storm' war, a system for treating civilian chemical victims at field level and in hospital had to be organized and implemented. The same system could be used for chemical spillage accidents (Figure 3).

The success of handling accidents and victims depends basically on:

- decisions taken by the control group,
- early detection of the chemical substance,
- distribution of clear and effective information and orders,
- the ability to detoxify the substance,
- the handling of the evacuation of casualties,
- the functioning of the medical team at field level and in hospital,
- correct use of media and communication systems.

The arrival of patients at the hospitals should be coordinated and the cause of the accident and the number of patients and their severity determined.

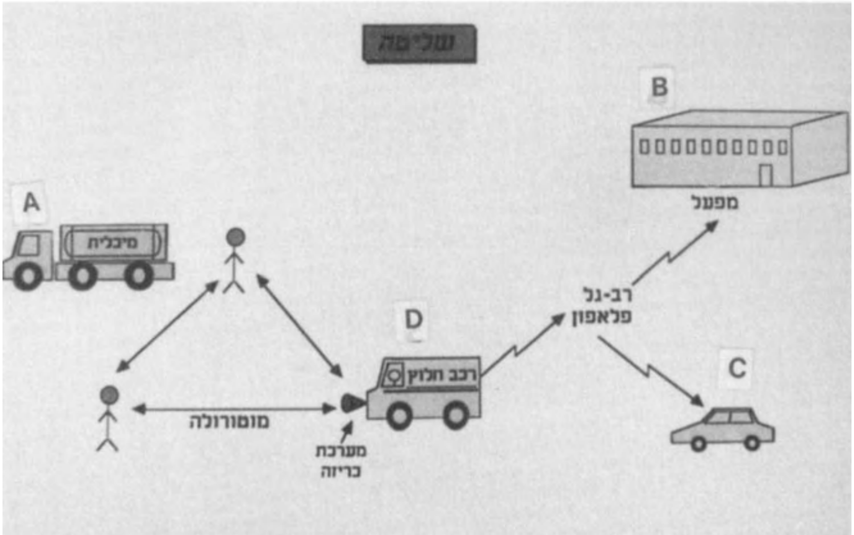


Figure 4. Monitored transportation of chemicals (from chemical factory manuals): (**A**) chemical tanker and driver, (**B**) chemical factory or enterprise, (**C**) motorized chief supervisor, (**D**) rescue and intervention vehicle. All these bodies are connected with at least two different and independent communication networks, with a third, short-range communication network used between the chief supervisor, the tanker and the rescue and intervention vehicle. The manuals and the spillage management set-up design were supplied by Bromine Compounds Ltd., a subsidiary company of ICL (Israel Chemicals Ltd.)

Experience from past incidents (such as Bhopal) shows that the number of casualties in the population at risk will be 25% in the contaminated area, 5% of whom will be dead or badly injured, while 15% will have intermediate injuries and 80% mild injuries[1,10,11]. The most frequent injuries will be in the respiratory tract, mucous membranes and skin[12,13]. Respiratory tract symptomatology ranges from mucous membrane irritation to severe chemical pneumonitis[14,15]. Eye symptomatology ranges from conjunctival irritation to orbital oedema, infections and even blindness[17]. Skin symptomatology ranges from mild irritation to severe chemical burns. The diagnosis of mild injuries may be much more difficult to resolve as the symptomatology may be obscure and mixed. Many symptoms can be non-specific, such as tachycardia, tachypnoea, chest pain, sweating and confusion[1,14]. All such patients should be held under supervision and appropriate supportive treatment.

Many chemical substances have long-lasting effects. The morbidity and mortality rates among residents in contaminated areas rise significantly, especially with regard to chronic respiratory, liver and kidney disease. Genetic malformations may occur in the future[13].

Because of the complexity of the problem and the lethal risk to large populations, it is imperative to establish a comprehensive system to

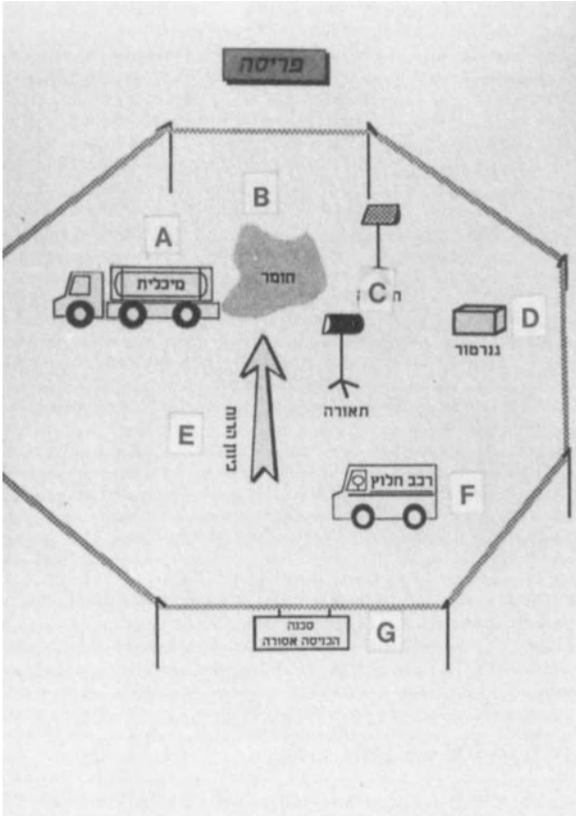


Figure 5. Management of chemical spillage. The contaminated zone is defined by a clearly visible perimeter established by the chemical factory rescue and intervention vehicle (from chemical factory manuals, see Fig. 4). (**A**) chemical tanker, (**B**) spilled chemicals, (**C**) lights, (**D**) electrical generator, (**E**) wind direction, (**F**) rescue and intervention vehicle, (**G**) perimeters of the contaminated zone

tackle chemical spillage. The different levels of such a system are as follows (Figures 4 and 5):

1. A front control group responsible for coordination of all matters involved in the incident (i.e. personnel, equipment, cooperation between teams, gathering and documenting information).
2. Diagnosis of the chemical agent and its toxic effect.
3. Safe evacuation of the endangered population and civilian management.
4. Prevention of expansion of the spillage.
5. Detoxification.
6. Fast and safe transportation of patients to hospital.
7. Comprehensive and appropriate medical treatment.
8. Dealing with the media.

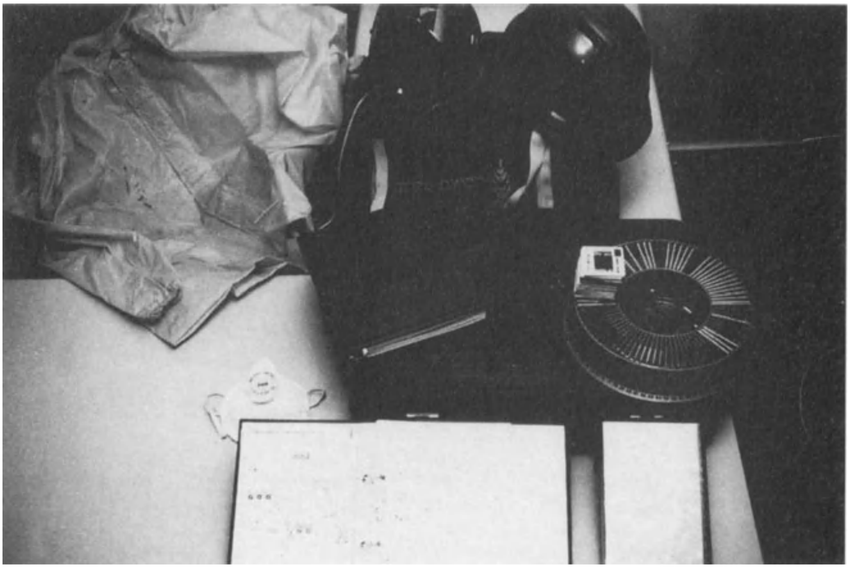


Figure 6. Some rescue and intervention vehicle manuals and educational materials (from chemical factory manuals, see Fig. 4)

The levels of hospital facilities are:

1. Evacuation, cleansing and triage of casualties (as performed in chemical warfare).
2. Reinforced task teams and medical staff during the emergency, all with adequate equipment and personnel.
3. Preparation and implementation of protocols for the medical staff (chemical substances, exposure, toxic signs and symptoms, antidotes and supportive treatment).
4. Training in various scenarios of chemical spillage incidents.

It must be borne in mind that no operative plan can give full protection to the population. Emergency plans can reduce the number of casualties and damage in the short and long term. But the best protection is prevention, which is provided by better and safer management of chemical depots, better protection for equipment and personnel, better insulation for chemical substances, removal of chemical plants and depots from populated areas and construction of safe by-pass routes for chemical transportation in populated areas and cities.

The vital questions that arise and must be answered by all concerned are do we have all these set-ups?, do we have similar or alternative means to handle cases of chemical spillage? and are we prepared?

REFERENCES

1. National Research Council: Criteria and Methods for Preparing Emergency Exposure Guidance Level (EEGL) Documents. May, 1985; Appendix D
2. Koplan, P. J., Falk, H. and Green G. (1990). Public health lessons from the Bhopal chemical disaster. *JAMA*, **264**, 2795–2796
3. Jasanoff, S. (1988). The Bhopal disaster and the right to know. *J. Sci. Med.*, **27**, 1113–1123
4. Lepkowski, W. (1985). Bhopal. *Chem. Eng. News*, **23**, Dec. 2
5. Bhandari, A. (1985). Aspects of the Bhopal tragedy. In: *Bhopal Industrial Genocide?*. Hong Kong, Arena Press, p. 104
6. Smiley, A. M. (1990). The Hinton train disaster. *Accid. Anal. Prev.*, **22**, 443–455
7. Kulyapin, A. V., Sakhahtdinov, V. G., Temerbulatov, V. M., Becker, W. K. and Waymack, J. P. (1990) The Bashhkiria train/gas pipeline disaster, June 1989 Bashkirian Republic. *Burns*, **16**, 339–342
8. Baxter, P. J. (1990). Responding to major toxic releases. *Ann. Occup. Hyg.*, **34**, 615–620
9. Mrvos, R., Dean, S. B. and Krenzelok, P. E. (1988). *Vet. Hum. Toxicol.*, **30**, 138–140
10. World Health Organization. (1990). *Emergency Preparedness and Response: Rapid Health Assessment in Chemical Emergencies.* Pub. ERO/EPR/90.1.9, Emergency Relief Operations. Geneva, WHO
11. Marshall, V. C. (1989). The predictions of human mortality from chemical accidents with especial reference to the lethal toxicity of chlorine. *J. Hazardous Mat.*, **22**, 13–56
12. Mehta, P. S., Mehta, A. S., Mehta, S. J. and Makhijani, A. B. (1990). The Bhopal tragedy's health effects: a review of methyl isocyanate toxicity. *JAMA*, **264**, 2781–2787
13. Baxter, P. J., Kapila, M. and Mfonfu, D. (1986). Lake Nyos disaster, Cameroon, 1986: the medical effects of large scale emission of carbon dioxide. *Br. Med. J.*, **298**, 1437–1441
14. Baxter, P. J. (1990). Review of major chemical incidents and their medical management. In: *Major chemical disasters – medical aspects of management.* London, Royal Society of Medicine
15. Naik, S. R., Acharya, V. N., Bhalerao, R. A. *et al.* (1986). Medical survey of methyl isocyanate gas – affected population of Bhopal, II: pulmonary effects in Bhopal victims as seen 15 weeks after MIC exposure. *J. Postgrad. Med.*, **32**, 185–91
16. Maskati, Q. B. (1986). Ophthalmic survey of Bhopal victims 104 days after the tragedy. *J. Postgrad. Med.*, **32**, 199–202

Section XVIII
International cooperation

97

European Union and national legislation regarding industrial activities involving the risk of serious accidents

EUGENIO CANNATA
Director, Central Technical Service, National Fire Brigade, Italy

---

The European Economic Community, in Directive 501/82 of 24 June 1982, indicated for the first time a number of guidelines to be followed in the Community in the sectors of public safety and health, also in relation to the protection of the environment from serious risks related to certain industrial activities. This latter aspect was a subject that had not previously been approached.

The Official Gazette of the EEC (now the EU), in issue NL 230 of 5 August 1982, 'On the risk of serious accidents related to certain industrial activities' defines 'serious accident' as follows: 'an event such as an important emission, fire or explosion due to uncontrolled development of an industrial activity which gives rise to serious, immediate or eventual danger to persons inside or outside the factory and/or to the environment and which involves the use of one or more dangerous substances'.

Problems related to fire and explosion risks and consequences such as toxic emissions are inevitably of direct interest to the National Fire Brigade, whose institutional role is to carry out action of prevention and control throughout the national territory in these important fields.

With unusual alacrity for the public sector, and long before the EEC guideline was recognized by the Italian state in 1988 by DPR (Decree of the President of the Republic) 175, this subject was the object of DPR 577 of 29 July 1982 relative to 'Approval of regulations concerning the provision of services of fire prevention and vigilance'. In the light of subsequent events, this Decree can be said to have shown great farsightedness, preceding international legislation.

DPR 577/82 paved the way for the Fire Prevention Organization to perform its onerous new tasks, with the creation, among other things, of

Regional Technical Committees for Fire Prevention. We would however point out in this regard, and not without a certain note of bitterness, that the Administration has not been placed in the position to operate as well as it might, as it has not yet been provided with the facilities necessary for it to fulfil its new, onerous and delicate responsibilities in Italy.

The Regional Technical Committee is a collective body comprising the Regional Inspector of the Fire Brigade responsible for the specific territory, who is the Chairman, together with other leading figures in the Brigade and external representatives from the Regional Government, the Association of Engineers and the Department of Labour.

DPR 577 also obliges factory owners to present a complete documentation with analytical studies of the safety and reliability of their processing plant and protection systems.

Article 19 of the DPR is perfectly in line with the EEC directive. It states: 'The Regional Inspectors of the National Brigade of Firemen proceed to the examination, from the viewpoint of fire prevention, of the construction projects; of important extensions or modifications to installations or plant, or any transformations which because of the technologies employed present high levels of risk as regards subsequent use, having consulted the Regional Technical Committee and in accordance with the regulations of the further EEC directive; for this purpose the projects must be accompanied by analytic studies of the safety and reliability of processing plants and protection systems'.

As can be seen, the revolutionary step was thus taken of abandoning the criterion of applying rigid fire standards, as hitherto was the case in high-risk industrial activities. Instead, complex safety studies and reliability analyses were to be used.

The last section of Article 19 provided for the emanation of a Ministerial Decree regulating the matter in its practical application.

This was duly realized by the Ministerial Decree of 16 November 1983, the object of which was as follows: 'List of activities, in the field of high risks, subject to examination by Regional or Interregional Inspectors of the National Fire Brigade according to Art. 19 of the DPR of 19 July 1982, No. 577'.

A subsequent Decree, of 2 August 1984, established: 'Standards and specifications for the formulation of the safety report related to fire prevention in activities involving the risk of serious accidents, as specified in the Ministerial Decree of 16 November 1983'.

Annex A of the above Decree provided specifications for the preparation of the safety report both in the phase of the 'authorization of feasibility' and in that of the 'detailed project'.

The above specifications require a probabilistic evaluation of risk in the following sequence:

- identification of possible accidents;
- evaluation of the probability and/or frequency rate of such accidents;
- calculation of the consequences of the occurrence of such accidents.

The safety report also has to demonstrate the adequacy of the projected measures for basic fire prevention, for active and passive protection, for protection from arson and external agents and for security.

The probabilistic evaluation of risk starts from a description of the site of the plant installation and the actual plant itself. We would here point out that the term 'technological risk' can be defined – even if not with absolute scientific precision – as the product of the predicted frequency of the accident F and of the magnitude M of the consequences, as expressed in the formula

$$\text{Risk} = F \times M$$

If F is expressed in cases per year and M in victims per year the product of the two gives the 'index of risk'.

The safety report must in particular specify the following:

- the subdivision of accidents according to whether they were caused by factors external or internal to the plant or were due to particular activities;
- the preventive measures and plant management criteria adopted in order to reduce the frequency of possible accidents;
- in the calculation of the consequences of the actual occurrence of accidents, the measures of active and passive protection adopted in order to reduce the extent of possible damage to persons or property;
- all other elements useful for the preparation of plans in the event of emergencies internal and external to the plant.

In the 'detailed project' phase it will clearly be necessary to modify the 'authorization of feasibility safety report', incorporating all the clarifications, integrations and variations that become necessary if at the moment of presenting the 'detailed project safety report' the conditions represented in the first phase have substantially changed.

Following these measures taken by the Ministry of the Interior at an early date and in line with EEC directives, the Ministry of Health also took an interest in the problem and in an ordinance dated 21 February 1985 promoted a nationwide census of industries performing high-risk activities.

However, as already said, it was only in 1988 that Italy recognized the EEC directive (commonly known as the 'Seveso directive') in its entirety, when DPR No. 175 of 17 May 1988 was issued. It will be useful to consider this decree, without going into excessive detail.

After indicating the field of application and the activities excluded, such as military and police establishments, the DPR, in Article 3, states clearly that factory owners are 'obliged to take all proper measures to prevent serious accidents and to limit their consequences to persons and the environment ...' and are furthermore 'obliged to demonstrate that they have taken steps to identify risks of serious accidents, adopted appropriate safety measures, and provided for the information, training and protective equipment for personnel and all those entering the factory for professional reasons'.

Article 4 obliges factory owners to notify the Ministries of the Environment and of Health if they perform any industrial activity involving the use of one or more of the dangerous substances specified in List III in the quantities indicated therein; they are also obliged to notify the same when the quantities stated are reached in total in different factories belonging to the same owner situated < 500 m from each other.

A copy of the notification also has to be sent to the Regional authority which, in the case of areas of high concentration of industrial activities, obliges the owners of factories situated < 500 m from each other to make the notification if the quantities stated are reached or exceeded.

Article 5, which prescribes how the safety report is to be prepared, is also of great importance. If the activity involves the use of one or more of the dangerous substances listed in Annex IV, factory owners are obliged to present to the Regional authority and to the Prefect a declaration to the effect that they have, in the manner specified, provided for:

- identification of risks of serious accidents;
- adoption of appropriate safety measures;
- information, training and provision of protective equipment for all persons working in the factory;
- insurance and security measures against risks of personal injury.

Article 7 considers existing industrial activities for which the directions indicated for new activities are as a rule valid, with the exception that the presentation of the notification could be made by 8 July 1989, while the deadline for the presentation of the declaration was 31 December 1991.

The notification has to be updated every 3 years or whenever there are substantial modifications that aggravate risk.

For new industrial activities falling within those at high risk, factory owners, after presentation of the notification or declaration according to the circumstance, may begin their activity 60 days after sending to the authorities receiving the notification a sworn report issued by an expert enrolled in the appropriate professional registers. This sworn report must attest to the veracity and the completeness of the information and to the compliance of the prescribed safety measures to the general regulations established by Art. 12 of Royal Decree No. 1265 of 27 July 1934.

Article 12 entrusts policy and coordination functions to the Ministries of Health and of the Environment, which also check on the effectiveness and the state of application of the regulations laid down in the DPR, identify areas with high concentration of activity that may involve greater risks, and indicate ways by which factory owners may be exempted from the obligation of making the declaration.

The following are designated as technical Organs for the performance of the prescribed institutional functions:

- the Higher Institute of Health;
- the Higher Institute for Industrial Accident Prevention and Safety;
- the National Research Council;
- the National Fire Brigade.

The consulting and proposing Organs are:

1. A Commission instituted by the Ministry of Health and integrated on each separate occasion by a representative of the region, commune or local health unit in whose territory the factory is situated, plus the Regional Fire Brigade Inspector and the Provincial Fire Brigade Commander in the territory.
2. A Committee for the coordination of safety measures in the industrial field instituted by the Prime Ministerial decree of 18 December 1985.

The tasks assigned to the Region are of great importance. The Regions have responsibility for receiving of the copy of the notification, participating in the preliminary investigative meeting regarding the safety reports and taking part in the consulting organs. They also have the power, as said above, to oblige owners of factories situated < 500 m from each other to prepare the safety report in areas of high concentration of risk.

The functions of the Regions with regard to other factories are even more significant and extensive. For these factories, which constitute the overwhelming majority of all those involved, the Regions have responsibility for receiving and investigating the declaration and for the examination of projects for new plant.

In all factories, in the event of failure to observe the prescribed regulations, the Region can order the cessation of activity in order to allow the necessary work to be carried out. Another very important task is to ensure the necessary liaison with the central organs of the state and the coordination of activities in the local area with other administrations, in the first instance with the Regional Departments and the Provincial Commands of the Fire Brigade, the port authorities and the Prefectures.

Article 18 is of particular importance. It refers to the manner in which the preliminary investigation is conducted. It provides as follows:

- the preliminary investigation is performed by the Ministry with the assistance of the technical and the consulting organs;
- the Ministry of the Environment, in concert with the Ministry of Health, nominates the Chairman of the preliminary investigation from the managerial or executive functionaries of the Ministries or of the technical organs;
- the Chairman of the preliminary investigation transmits the safety report to the technical organs, which then express their opinion;
- the Chairman of the preliminary investigation calls a service meeting, inviting the representatives of the technical organs and the other authorities involved, together with the representatives of the Regions and communes concerned; the opinions expressed are

placed on official record and a report is prepared by the Chairman and transmitted to the consulting organs, which are obliged to express their decision within 30 days.

Having taken cognizance of the documents relative to the preliminary investigation and of the opinions of the consulting organs, the Ministry of the Environment, in concert with the Ministry of Health, formulates the conclusions, indicating if appropriate the necessary integrative measures and the deadlines that the factory owner is obliged to respect.

The conclusions are then transmitted to the Regions, which are responsible for enforcing the prescribed vigilance in the performance of the industrial activity, and to the Prefects, who predispose plans for external emergencies.

Inspections are carried out by organs empowered to do so by other legislation and by functionaries from the Ministries of Health and of the Environment nominated for the purpose, also jointly with representatives from other administrations.

Although this description of current legislation in Italy regarding serious industrial risks is necessarily synthetic, we hope that we have given a sufficiently exhaustive account.

The most recent measure, which has not been mentioned so far, is the Prime Ministerial Decree of 31 March 1989. This was issued in order to apply DPR 175.

It should be pointed out that DPR 175 establishes that factory owners are obliged to observe not only the directives of the decree but also 'current standards of industrial safety and hygiene and of protection of the population and the environment'.

Article 1 of the Prime Ministerial Decree of 31 March 1989, regarding general safety standards expresses even more clearly the responsibilities of the National Fire Brigade where it states that factory owners are obliged to obtain from the local Fire Brigade Command 'authorizations concerning fire prevention as prescribed by current standards and to conform to the said standards'.

The responsibilities of the Regional Inspectors and of the Regional Fire Prevention Committees therefore remain in force, also as regards the examination of the safety reports for the authorization of feasibility and the detailed project.

The procedure for the issue by the territorially responsible Provincial Fire Brigade Commandant of the certificate of fire prevention is in two stages (authorization of feasibility and detailed project), in different moments but in similar manner:

- presentation by the factory owner to the Provincial Fire Brigade Command of the safety report for the authorization of feasibility
- transmission of the report, with substantiated opinion, to the Regional Department
- preliminary investigation by the Regional Department
- examination by the Regional Fire Prevention Committee
- opinion of the Regional Department.

The safety report for the detailed project is analogous, concluding with a visit by a special Commission composed of three experts appointed in accordance with Article 14 of DPR 577.

The Provincial Fire Brigade Commandant, having been informed by the Regional Department of the favourable outcome of the Commission's investigations, issues the fire prevention certificate, which is the sole authorizing document prescribed by current legislation.

It would go beyond the limits of this chapter to express opinions and considerations regarding inconsistencies between the various administrations which may appear, and indeed have already appeared, in the application of the various regulations and of the protracted bureaucratic procedures laid down by DPR 175. Indeed, the administrations which promoted the decree are themselves convinced of the need to set in motion procedures for the rapid revision of current norms, a process in which the Ministry of the Interior will inevitably be involved. Hopefully current directives and procedures will be revised and harmonized within the EU, with due attention to the country's general interest and to the necessity for national industry – with all due guarantees for safety – to become more powerful and more efficient, in full respect of clear and rapid authorizing procedures.

REFERENCES

Paolini, F. (1992). The action of the European Community for civil defence. In *The Management of Mass Burn Casualties and Fire Disasters,* M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers

Cannata, E. and Di Benedetto, F. (1992). Safety regulations in high-risk industries. In *The Management of Mass Burn Casualties and Fire Disasters,* M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers

98
The role of the World Health Organization in disasters

A. TEKLE
Director, Emergency Relief Operations, WHO, Switzerland

The social objective of WHO is health for all by the year 2000 through primary health care. This means that by the year 2000 people should lead economically and socially acceptable lives. The elements of primary health care are: essential drugs, water supply and sanitation; nutrition; immunization; and control of epidemics and endemic diseases. These elements will help us attain the social objective mentioned above. The elements should however be affordable, acceptable and accessible to the people concerned.

The World Health Organization has a constitutional mandate 'to act as the directing and co-ordinating authority on international health work' and 'to furnish appropriate technical assistance and, in emergencies, necessary aid upon the request or acceptance of Governments'. It is also mandated 'to provide, or assist in providing, upon the request of the United Nations, health services and facilities to special groups, such as the peoples of trust territories'.

With an increase in the number of disasters, more humanitarian assistance is being requested and provided. For example, between 1978 and 1988, more than one million lives were lost in disasters; over 420 million people were affected. Some 40 million refugees and displaced persons were driven from their homes. These disasters have an impact on health. For example, 1.75 billion people lack basic health services, 1.5 billion people have no access to drinking water, and 1.5 million children under the age of 5 suffer from serious malnutrition.

Although humanitarian assistance is in the constitution of WHO, it was only in the 1970s that WHO established its first emergency unit to co-ordinate technical work related to emergencies. In the 1980s, with the increase of disasters, Member States voted overwhelmingly to adopt several resolutions for WHO to take a more active and leading role in health-related emergency response. As a result the Emergency Relief Operations was enlarged in 1989 and has co-ordinated a wide range of activities related to emergency preparedness and response in the Horn of Africa, Afghanistan, the Gulf area, Occupied Arab Territories, Namibia, Cambodia, Slovenia, Croatia, Serbia, Bosnia, southern Africa, and other troubled countries.

WHO believes that in order to have comprehensive national emergency preparedness programmes for health a four-step sequence of activities is a prerequisite:

- Risk mapping, which determines natural and man-made health hazards for the country;
- Health assessment, which assesses the country's vulnerability to these hazards;
- Co-ordination and planning, which develops logistical plans and builds national co-ordinating committees to respond to emergencies and manage post-disaster assistance;
- Education, training and promotion, which ensure that plans are properly understood by officials and the community at large in the most disaster-prone areas.

In addition WHO develops and publishes emergency preparedness standards and guidelines. It conducts workshops and seminars in health emergency mitigation, preparedness and response.

It also undertakes applied research in emergency health issues, particularly those relating to large population displacements and refugees.

In order to respond immediately, WHO has an emergency response fund, stand-by expertise and emergency supplies.

Emergency response fund

This US$ 1 million fund enables WHO to provide disaster-stricken countries with the necessary technical assistance and with seed money to pay for desperately needed services before international assistance arrives.

Stand-by expertise

Additionally health experts are provided. At the WHO headquarters there are 26 divisions dealing with various aspects of technical sectors, such as environmental health, drug action, etc. This know-how is also present in WHO's six regions. Additionally and essentially the action takes place at the country level.

Stockpiling drugs and supplies

WHO has developed standardized Emergency Health Kits and a global network of drug warehouses and suppliers to ensure that the right drugs are delivered on time during emergencies. Each WHO Health Kit contains enough essential drugs and material to support 10 000 people for 3 months. The cost is about US$ 10 000. This initiative was started by Dr William Gunn, when he was in charge of emergency operations in WHO, and I am pleased to continue it.

Recently, with less tension among the major powers, the international community is expecting from the United Nations more involvement on humanitarian action and development. The United Nations resolution 46/182 states: 'There is a clear link between emergency, rehabilitation and development ... emergency assistance should be provided in ways that will be supportive of recovery and long-term development ... Humanitarian assistance should be accompanied by a renewal of commitment to economic growth and sustainable development of developing countries'.

The adoption of the resolution on humanitarian assistance necessitates new strategies for rapid response. These involve issues such as central emergency revolving fund, central register of specialists, supplies and services, consolidated appeals and emergency stockpiles.

The WHO strategy for emergency management can be summarized as follows:

- WHO has a specific role in international emergency management: to reduce the impact of disasters on health.
- WHO works in partnership with the international community and disaster-vulnerable countries to prepare for and respond to disasters.
- WHO's goal is to promote the self-reliance of Member Countries in dealing with major emergencies.

The preceding remarks concern the wide field of health and WHO's work in health disasters, but the Organization is also involved in the management of specific disasters. Which brings me to burns.

BURNS IN COMPLEX EMERGENCIES

Unlike most natural disasters, technological disasters often occur suddenly, preceded by little or no warning (e.g. the disasters at Seveso, Bhopal and Chernobyl). Although many types of technological disaster can occur, the most common involve fires or explosions. Many challenges will then face first-aid, medical and public health workers in responding and attempting to prevent such catastrophes. Although management of burns is sophisticated when it comes to very few cases, in emergencies with a large number of casualties some basic complex rules have to be respected in order to be able to treat as many patients as possible.

Epidemiological surveys after such emergencies, including chemical catastrophes, have shown that emergency health decisions are often based on insufficient information, no information, or even false information; as a result intended aid is frequently insufficient, unnecessary or inappopriate and possibly harmful. An effective public health response to technological disasters, which are likely to produce large numbers of burn patients, therefore depends on good community preparedness efforts and the rapid systematic collection of accurate data on health effects as soon as possible after the disaster occurs. This highlights the need to have an efficient emergency surveillance system as part of the overall community contingency planning.

Public health authorities cannot respond effectively to complex emergencies including fires and chemical disasters if they operate strictly on their own. Efforts should be made to integrate their efforts within the overall community preparedness and response set-up.

Finally, the importance of prevention must be re-emphasized. Unlike natural disasters, technological disasters are often preventable. We can control where chemical and similar plants are built, how close they are located to population centres, and how hazardous materials are stored and transported. This will help in the assessment of risk and consequently in the achievement of better community awareness, preparedness and response.

This Conference is an essential element in managing these kinds of disasters more effectively.

REFERENCES

Gunn, S. W. A. (1983). Actions of the World Health Organization and the United Nations in Disasters. *Prehospital and Disaster Medicine*, **1**, 297

Wasunna, A. (1992). Clinical technology in small hospitals; the WHO programme. *In: Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers

World Health Organization (1988). *Basic Documents*. The WHO constitution, Article 2a, d, e. WHO, Geneva

World Health Organization (1984). *WHO Emergency Health Kit. Standard Drugs and Clinic Emergency for 10000 Persons for 3 Months*. WHO, Geneva

99
Protection of health and humanitarian services in time of armed conflict: The role of the International Committee of the Red Cross

JACQUES MEURANT
International Committee of the Red Cross, Geneva, Switzerland

EFFECTS OF WAR ON HEALTH AND MEDICAL SERVICES

The internal conflict in the former Yugoslavia is a terrible example of a conflict situation which is escalating into all-out war. The social and economic balance is suddenly disrupted, civilians – especially those already living in precarious circumstances – risk losing what they need to remain in relatively good health, or even to survive; and population movements represent a major threat to health, since they are always accompanied by serious damage to the environment in which essentially vulnerable people are living.

When war is raging the medical services, generally disorganized and partly destroyed, are overwhelmed by the number of wounded and sick. All public health activities, vaccination programmes, maternal and child health care and campaigns to control major endemic diseases grind to a halt in the same way as curative services, and this in turn leads to an increase in the incidence of disease.

In extreme cases, such as the present situation in Somalia, chaos reigns when all facilities are destroyed and no single authority is in charge; power is split up between small groups that indulge in plunder and arbitrary violence among themselves and against the people, already suffering the effects of a severe famine.

THE ROLE OF THE INTERNATIONAL COMMITTEE OF THE RED CROSS (ICRC)

As a neutral and independent organization, the ICRC has a very special part to play in health protection during armed conflicts. The mandate conferred upon it by the States party to the Geneva Conventions and their Additional Protocols, its right of initiative and its role as a neutral intermediary enable it to approach health problems from several different angles.

Some general statistics

At present the ICRC has some 52 delegations in 80 countries, with a total staff of 880 expatriates assisted by some 6000 local employees, working on behalf of prisoners of war, war wounded, security detainees, deportees, separated families and civilians affected by bombing, shelling and other acts of war, by famine and by all forms of armed repression.

Over 80% of the ICRC's field budget (610 million Swiss francs in 1991) go to assistance and protection for civilians, many of them displaced persons and refugees.

Direct medical action

This involves war surgery; dispensary work; nutritional surveys and distribution of food aid; environmental sanitation or water supply programmes; and orthopaedic rehabilitation programmes. All these measures are based on a careful survey of the situation and definition of priorities.

Examples

The ICRC has set up war-surgery hospitals for civilian and military casualties in several countries of Africa and Asia: in northern Kenya for the population of southern Sudan, in northern Somalia, in Pakistan and Afghanistan, on the Thai-Cambodian border and in Cambodia itself. Some 20 000 wounded people – over half of them civilians – were treated in 12 ICRC surgical hospitals in 1991. The services provided by these hospitals are supplemented by first-aid and evacuation posts in the combat zones, often deep in areas held by rebels. In the same period, orthopaedic centres in 13 countries enabled 11 000 military and civilian amputees to walk again.

Food and material assistance

Emergency food and material aid has developed substantially, especially in Africa, and more particularly since the start of relief operations in Angola, Ethiopia and Somalia. One of the working principles of the ICRC, which in 1991 distributed some 90 000 tonnes of relief to civilians affected by war, is to come to the aid of population groups which, for political or security reasons, other organizations cannot reach. The ICRC distributes its assistance directly to the beneficiaries after detailed assessment of their requirements on the spot. It never delegates its work in the field to anyone else; this is to ensure strict control over the use of food aid and prevent its being diverted or used for political ends by the armed forces or other armed groups.

Seed-distribution and vaccination programmes have been launched to provide some degree of self-sufficiency to the resident or displaced population groups whose agriculture resources have been destroyed by war. On the Angolan Planalto and in Mozambique, for instance, this combination of medical assistance, material aid and emergency rehabilitation has contributed to greater stability and has helped prevent or limit mass population movements and the formation of new concentrations of refugees.

Negotiating health protection measures

All the parties concerned are involved. This is one of the ICRC's more specific tasks. Agreements to call a truce, lift a blockade, allow farmers to return to their fields or guarantee due respect for hospitals and medical personnel can have far-reaching effects.

Example

On several occasions the ICRC has brought the parties involved in the Yugoslav conflict together around the same table in Geneva. The main aims of these meetings have been to work out practical mechanisms for intervention on behalf of the victims. Between late 1991 and spring 1992, plenipotentiary representatives of the parties concerned held four such meetings under ICRC auspices. Among the results of the meetings, there is the establishment of protected zones placed under ICRC supervision, with the agreement of all the parties to the conflict, afforded special protection to the sick and wounded and other particularly vulnerable groups of non-combatants. The hospital and the Franciscan convent in Dubrovnik were declared protected zones in mid-December 1991 and the Osijek hospital became protected in early January 1992.

CONSTRAINTS

The numerous constraints inherent in situations of armed conflict make it very difficult to safeguard the health of the population. First, an international embargo may hamper the dispatch of certain articles which are essential to health. Second media over-reaction to certain situations may also disrupt medical relief work by triggering a disproportionate response on the part of the donors. The most serious problem, however, is undoubtedly the difficulty of gaining access to the victims, because it holds up every phase of the operation, from the initial assessment right up to the end result. This may be due to the lack of financial, material and human resources as well as of means of transportation, especially when armed conflict breaks out in an impoverished area. But too often the holders of political and military power are reluctant to allow humanitarian assistance; their reasons range from reference to the State sovereignty and security considerations to the statement that sufficient aid is already available and that no outside help is needed, not to mention bureaucratic objections. In most cases, however, these reasons conceal the concern of military and political authorities that humanitarian helpers and unwelcome witnesses will hinder the prosecution of war, the means of which are considered effective but not necessarily praiseworthy.

For this reason discussions on humanitarian aid in recent years have focused on the demand that a 'right to intervene on humanitarian grounds' (le droit d'ingérence humanitaire) be created. Claiming this right to intervene – or to interfere – is to demand a paradox. Neither so-called 'common sense' nor ethical considerations allow us to view the assistance which we provide to persons in need as an unjustified interference. On the contrary, providing assistance is a duty. International humanitarian law likewise does not view help as interference. The Geneva Conventions and their Additional Protocols contain more than twenty provisions on medical and other material assistance to which victims of armed conflict are entitled.

For example, Article 70 of Additional Protocol I states clearly in relation to aid to civilian populations in need that 'Offers of such relief shall not be regarded as interference in the armed conflict or as unfriendly acts. (...) The Parties to the conflict and each High Contracting Party shall allow and facilitate the rapid and unimpeded passage of all relief consignments, equipment and personnel (...) even if such assistance is destined for the civilian population of the adverse Party'. What are the conditions which govern the entitlement to unimpeded assistance? There are two: the actual needs of the civilian population and the humanitarian and impartial nature of the assistance. While it is true that under the same Article 70, relief operations require the consent of the State concerned, the context and the discussion on the formulation of these provisions at the 1974–1977 Diplomatic Conference nonetheless clearly show that consent must be given if the above-mentioned conditions are met. In this way, consent becomes an expression of the sovereignty of the State, which is thereby fulfilling obligations it has accepted, for by ratifying the Geneva Conventions the Contracting Parties have undertaken, in the free exercise of their sovereign rights, to respect the right of victims to be assisted.

The consent of the authorities in an area in which a humanitarian operation is being conducted also has a very practical value, for how can one in actual fact impose assistance on a country, in an area controlled by the government, against its will? Or how is it possible to provide this help, in all its cultural, social, logistic and administrative aspects, without the cooperation of the local people in command or even against their resistance?

This latter point is to be stressed: it is not the formal consent of the government that we seek to go somewhere in the country where it is not in control. In such cases we require the consent of those exerting effective power in the specific region where there are humanitarian needs.

There is of course one answer if there is no consent, namely the use of force as it was the case with the 'Provide comfort' operation carried out in 1991 in Iraqi Kurdistan. However, any armed intervention even for reputedly humanitarian purposes, gives rise to doubts as to its genuinely humanitarian and impartial character. Such doubts are but accentuated by the slogan of 'humanitarian interference' and appear to confirm a suspicion, long held by many recipients of humanitarian aid, as to whether the help so generously given is really disinterested? Is it not rather a particularly artful, indeed devious form of political intervention? If we refuse force, are we going to let people die or go without care?

This is why assistance to victims of armed conflict must be provided in an impartial manner by a neutral and independent organization, such as the ICRC. The evacuation of injured persons from a besieged town, visits to prisoners of war or the distribution of relief supplies must be negotiated with all parties to an armed conflict. All this is possible if the ICRC's independence is credible to its partners and to all military and political powers.

Let us take Iraq as an example to illustrate the importance of this credibility. After the UN's imposition of the embargo and threat of military intervention, the representatives of most international organizations and the diplomats of most States gradually withdrew from Baghdad. The ICRC kept its delegation there throughout the entire Gulf War. Whilst the anti-Iraq Coalition and the Western media were reporting a quick, clean war against Saddam Hussein, the ICRC continued to warn about the distressing consequences of armed intervention, calling on the parties to the conflict to respect international humanitarian law. When the suffering of the civilian population following the international war and the uprisings in the south and the north of the country became known, ICRC delegates were already on the spot: they knew the country and the people, at whose side they had endured the war, and they knew the different persons in command. And the authorities knew the ICRC: independent of the United Nations, which had declared the embargo, independent of the Swiss Government, which had autonomously aligned itself with the UN sanctions, but an ICRC which was ready to act. The first shipments of aid reached Baghdad whilst the war was still continuing, and when the question how to help the hundreds of thousands of displaced Kurds arose, the first delegates, with the consent of the Iraqi authorities, set off for the mountains of Kurdistan to survey the situation and deliver the first relief supplies. Aid by the Allies against Iraqi resistance conversely had to be brought in using enormous military resources and in very difficult logistic conditions. The ICRC, with the help of personnel from West European Red Cross Societies, is still there to this day, working alongside UNHCR operations, conducted under the protection of UN guards.

CONCLUSION

Humanitarian assistance is a balancing act in which effective protection and active assistance depend on credible impartiality and independence.

REFERENCE

Meurant, J. (1992). Communications in the prevention of disasters; the role of the national and international Red Cross and Red Crescent. *In*: *Management of Mass Burn Casualties and Fire Disasters*, M. Masellis and S. W. A. Gunn, eds. Dordrecht, Boston, London: Kluwer Academic Publishers

100
Considerations on a collaborative international health project for guerilla warfare burn victims in Angola

F. BASSETTO, B. AZZENA, G. SANDRI, E. FRACCALANZA, M. SCHIAVON, F. MAZZOLENI
Istituto di Chirurgia Plastica, Università di Padova, Padua, Italy

INTRODUCTION

In the period 1990–1992 the Plastic Surgery Institute of Padua University was given by the International Centre of Cooperation for Development in Rome the task of conducting a special health mission in Luanda, the capital of Angola, in the general framework of an EEC Health Project to assist guerilla warfare burn victims in this developing country.

This operation proceeded in three phases: 1) discussion regarding the planning and creation of an Intensive Care Unit for burn victims; 2) a 6-month training period in Italy at the Padua Burns Centre for an Angolan physician who after the initial year of collaboration would take responsibility; 3) direct management of the new Centre by the Italian team for 12 months.

Angola was devastated, starting in the early 1950s, first by the struggle for independence from Portugal, which was obtained in 1975, and then by 15 years of guerilla warfare between different political factions, interrupted in June 1991 by the Lisbon peace agreement and tragically resumed in October 1992, after the country's first democratic elections. The long war reduced the country to a state of absolute poverty (despite its abundance of petroleum, diamonds and uranium) and total disorganization, with a large proportion of the population concentrated in the capital: 25% of the 10 million inhabitants live in Luanda or its suburbs. Some measure of health organization exists only in the cities, and only the capital possesses multispecialized hospital facilities, which however operate in difficult conditions owing to a shortage of trained health operators, financial resources and drugs. Inevitably, in such circumstances, only the most important specialities could be developed by the

Public Administration (General Medicine, Infective Diseases, Paediatrics), while the costly and complex care of burn patients has not yet been adequately approached. Post-burn mortality was thus extremely high and the survivors were usually left with severe scar sequelae.

ORGANIZATION OF THE CENTRE

The Centre was set up at the Neves Bandinha Hospital in the capital, Luanda, and was organized as follows:

- an Intensive Care Unit (ICU) with eight beds (six adults, two children);
- a section for the treatment of minor burns with 46 beds (33 adults, 13 children);
- an independent operating theatre;
- two medication rooms;
- a physiotherapy and rehabilitation gymnasium.

RESULTS AND CONSIDERATIONS

Between 1 June 1991 and 31 May 1992 1625 patients were treated, of whom 638 were admitted (mean bed occupation rate: 86.4%) and 987 were treated on an out-patient basis for minor burns.

The mean age of the patients was 15.7 years (range 2 months to 78 years). Of the patients, 58.4% were 14 years old or less, 32.3% were under 5 years of age and 4.4% were less than 1 year old.

Altogether, 212 surgical operations were performed, of which 60% were for acute burns, 29.2% for burns sequelae, 2.3% for neoplastic pathology secondary to burns and the remainder for plastic surgery procedures such as trauma, syndactyly, pharmacotherapy necrosis, tropical ulcers and skin neoformations.

The mortality rate was 22% (141 patients out of 638); 116 (42%) out of the 275 patients admitted immediately to the ICU died, with a mean burned body surface area (BSA) of 46%. Of these 49 were aged over 14 years (mean burned BSA 48%), 67 were aged less than 14 years (mean burned BSA 45%).

The various difficulties encountered can be summarized as follows:

- excessive number of patients treated (1625), considering the limited number of physicians and paramedical staff assigned to the Centre
- high percentage of paediatric patients (58%)
- frequent simultaneous arrival of several patients (sometimes whole families and groups of workers)
- shortage of drugs and means of diagnosis
- poor level of basic training and unreliability of paramedical staff, at least in the early stages

- logistic difficulties in water and electricity supply
- coexistence of previous and concomitant tropical diseases presenting difficulties of diagnosis and treatment
- difficulty of establishing a balance between the resuscitation/ surgical treatment phase and the rehabilitation phase in burn patients.

CONCLUSIONS

Our experience in the realization of this project has enabled us to make some considerations that may prove useful with regard to analogous projects of Cooperation for Development in third-world countries.

One basic point to bear in mind in this kind of project is the high burn rate in such countries, owing to inadequate preventive measures against domestic and professional accidents.

As this is a field of medicine that requires enormous commitments of equipment and drugs, the projects must be based on accurate study of the country and the precise point of realization, taking into account all the intrinsic difficulties (e.g. water and electricity supply, safety conditions, international links). There must be a reliable logistic support organization to guarantee the initial phase and the continuation of the work and to handle at short notice any shortages typical of the country or whatever difficulties may arise from the political situation or international communications.

The objective of the organizers of these programmes must be twofold: to assist and to teach, in order to win over the confidence of the local people. This is a prerequisite for the continuation of programmes in the future. It is not always easy, as one comes up against the natural diffidence of populations that have experienced only the colonialist spirit and therefore tend to distrust the principles of Cooperation for Development. Knowledge of the country and the people are essential.

In particular, this type of programme must be based on team work inspired by a spirit of collaboration between teacher and learner, with a great deal of goodwill between the two. Because of the difficulties of treatment and the frequency of serious unexpected complications the team must be led by a physician of proven experience in burns therapy who is able to manage the course of the burns disease on the basis of clinical observation, without recourse to instrumental diagnostic means, which are likely to be inadequate or unreliable in the country in question.

This specific experience must also be associated with detailed knowledge of tropical diseases and their treatment. Plastic surgery specialists are certainly best suited for the role both because of their expertise in the field of burns therapy and because surgical therapy is indispensable in local conditions where there is a prevalence of very deep third-degree burns.

We are convinced that an experience of this kind can be extremely useful in the clinical and professional training of young surgeons. The great number and wide variety of cases, together with the diagnostic and logistic difficulties of therapy, rapidly enable less experienced surgeons to acquire experience of various techniques and methods and the fundamental principles of medical ethics.

Central to any programme aimed at treating patients and teaching how to treat patients is the development of collaboration with the local academic authorities, which have to be encouraged to carry on the work of training medical personnel capable of performing types of surgery that are so necessary in countries with high rates of disabled persons.

We consider it a superfluous and unnecessary expense to have a training period of foreign personnel in the country which will later carry out the programme. It is more advisable that this kind of approach should be spread out over as long a period of time as possible, as it has been observed that although it may be simple enough to teach therapeutic techniques and principles, it is difficult to instil the medical culture and mentality that guarantee continuity and efficiency. In addition, the training of local personnel should be completed by short stays in more developed countries, at a later phase, when the learning of new techniques is based on consolidated specific basic training.

101
Treating the paediatric burn patients of the Bashkiria disaster

S. ASTROZHNIKOVA, A. BULETOVA and L. VASILIEVA
Children's Clinical Hospital #9, Moscow, Russia

INTRODUCTION

Emergency admission of a large number of paediatric burn patients in a mass casualty situation can be an organizational nightmare. It requires highly qualified and dedicated staff to ensure the best possible outcome for the patients.

In June 1989, 26 children with severe burns were admitted to Children's Hospital #9 after a train accident/natural gas explosion in Bashkiria, Russia. Later two more children were admitted to our hospital from other hospitals in Moscow. Specialists from the Shriners Burn Institute (USA) under the leadership of Professor J. P. Remensnyder, took part in the treatment and follow-up examinations of the patients. Twenty-four children recovered and were discharged. Four other children died.

In February 1990 all the surviving children returned to Children's Hospital #9 for follow-up examinations. We also continued follow-up examinations on these patients in 1991 and 1992. This is apparently the first time such a long-term follow-up examination and care has been provided for a large group of patients in Russia.

THE BURN UNIT IN CHILDREN'S HOSPITAL #9

Children's Hospital #9 in Moscow, Russia is a 1000-bed multi-profiled facility which also serves as the base of the Moscow Scientific Research Institute of Paediatrics and Children's Surgery. The 60-bed burn unit is divided into two areas, a 30-bed unit for children from birth to 3 years old and a 30-bed unit for children 3–15 years old. Every year we have 1200–1300 admissions to the burn centre, any admissions considered to be in shock going directly to the ICU. Admissions are accepted not only from Moscow but also the remainder of Russia and the CIS countries.

Standard wound care (dressing changes with topical antibiotic ointments) is performed in all patients. In patients with third-degree or greater burns, our usual procedure is early excision with immediate autodermoplasty within 2–3 days post-burn. We rarely excise more than 30% of the body surface area. During a normal year we perform between 440 and 470 burn-related surgical procedures. Clinitron fluidized airbeds are used for patients with burns on the back/buttocks or patients who will be bedridden for long periods of time, in order to prevent tissue breakdown. Besides early excision and air-bed therapy, we also use plasmapheresis and haemosorption as necessary. The average stay for a severely burned child is 1.5–2 months, with a mortality rate of 1.2–1.4%. Pressure garments are worn by the children after healing with follow-up physiotherapy in the polyclinics and health resorts.

MATERIALS AND METHODS

In this chapter we will review the treatment and rehabilitation of 28 children who were injured in the Bashkiria train accident and treated at our hospital in 1989.

When our hospital was requested to assist in the care of the disaster victims, a medical team was immediately assembled and sent to the accident site, leaving the remainder of the hospital staff 2 days to prepare for the arrival of the first patients. Duty schedules for both the doctors and nurses were arranged for extra cover on all shifts. Along with this, additional beds were made available for burn patients, and additional supplies, including dressings, intravenous fluids and medications, were assembled.

American specialists from the Shrines Burn Center in Boston took part in the treatment and examinations. Children were admitted over a 2-day period. Triage was rapid because our medical team had examined the patients prior to their transfer to our facility.

The majority of the patients were in a very serious condition. Total body surface area (TBSA) burns were as follows: 20%, one child; 21–30%, six; 31–40%, 4; 41–50%, 10; 51–80%, 7. Twenty-one children presented respiratory injuries and 12 children were suffering from combined thermal and chemical burns. All of the children received combined treatment, including blood transfusions and blood substitutes, plasmapheresis and haemosorption. All wounds which were not excised were treated with topical antibiotics.

The massive admittance caused organizational, medical and psychological difficulties. Every day we changed dressings under anaesthesia in 18–20 children, performed early excisions in 15–17 children, and carried out 7–8 autodermoplasty operations, twice as many as usual. All but four of the children had their wounds covered within 8–10 days post-burn. The four delays were due to the patients' having very little unburned skin to use as donor sites.

The complex situation was worsened by the psychological climate, which was difficult because the young patients' parents were also burned and were admitted to hospitals. Psychological trauma was complicated by the death of parents: 10 patients lost 15 family members. It became necessary for the psychologists to work with both children and parents. It was very difficult for the staff to work, because they had to tell children that their parents died. Four children died: three had burns in 51–80% TBSA and died during the first days after admittance, and one girl, with 80% burns, died on post-burn day 53.

We discharged 24 children, of whom 21 received health-resort treatment.

ANALYSIS OF LONG TERM RESULTS

In February 1990 we examined 24 recovered children (plus two others treated in other hospitals in Moscow), after reviewing their medical charts (extensive care was taken to thoroughly document all care received by the patients at Children's Hospital #9 along with their condition at discharge).

After examining the patients and interviewing them and their families, we identified multiple complaints and problems: 19 children complained of irritability which appeared after the accident; seven children of increased tiredness, 13 were easily offended; and 15 cried a lot. Three of them had become very reserved. Eight had difficulty sleeping. Two children complained of heartache and nine of pains in the epigastric area. The memory of two children had become worse, two suffered from dizziness, and eight from headaches; one had a constant feeling of fear. Seven had rashes on their scars.

No major abnormalities were found in the children. Fourteen had the same weight as before. Twelve had minor abnormalities for their age group. Rheoencephalographical examinations showed in 22 out of the 26 children abnormalities such as increased tonus of small arteries and difficult venous flow in all parts of the brain. During consultations with neuropathologists and psychoneurologists we found psychological abnormalities of different degree in all the children.

On EKG, 18 children presented ventricular myocarditis, sinus arrhythmia, tachycardia, and low voltage abnormalities. On echocardiography, 15 children showed cardiac insufficiency in the stage of compensation and cardiomyopathy (a slight decrease in the oxygen transport function of blood and a moderate decrease in cardiac output). The functional condition of external breathing did not present abnormalities in the majority of the children.

Scar formation was assessed on 3-scale system. We found good results in 11 of the 26 children. Three presented some cosmetic defects such as minor scar deformity of the ears or local alopecia. All the children received some conservative and health-resort treatment.

Fifteen children had a positive outcome. They have soft, light, moderately hypertrophic scars. Four had face scars which presented considerable cosmetic problems. Seven had scars in the hands and feet which were complicated by scar tissue in the web spaces of some digits. Six children were operated on in February 1990 by surgeons of our hospital, aided by American physicians. In spring 1990 we operated on five more children: three were operated on in England and two in our hospital. Initially they were operated on in February 1990. Four operations were delayed because it was initially considered that after conservative treatment no operative procedures would be necessary. Three of the 15 children did not need any scar revision. Out-patient examination in 1991–1992 showed the effectiveness of our treatment – all results were acceptable.

DISCUSSION

Our survey showed that six months after the trauma the children still present pleomorphic pathologies, the cerebro-asthenic syndrome prevailing. For this reason we think that children who suffer burn injuries or other accidents should have a prolonged rehabilitational period of about one year. It is necessary to establish special education–rehabilitation centres where children can simultaneously receive operative, conservative and health-resort treatment. During the period of the asthenic syndrome, cosmetic scars and inferiority feelings will disappear and the children will be able to get back to school.

We also believe that a burn centre should always have a reserve of equipment, instruments and medications. We also need to train paediatric surgeons to work with burn patients and to cooperate with foreign colleagues.

CONCLUSION

We have summarized the experience of treating 28 children suffering from severe burns sustained in a train accident/natural gas explosion in Bashkiria, Russia in 1989. We found that the treatment of the burned children involved in the accident was different from the usual work in the unit. It requires special self-discipline on the part of the staff and collaboration between different specialists in the framework of the burn unit, as well as with international organizations.

Index of Authors