Bibliography of Orthopaedic Problems in Developing Countries

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Global-HELP Publication

Bibliography of Selected Orthopaedic Problems in Developing Countries with Commentary

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Preface

The desire for a "literature based" approach to a subset of orthopaedic problems seen in developing countries began during several visits to the Hospital and Rehabilitation Centre for Disabled Children in Banepa, Nepal, and both the B&B hospital and the Tribhuvan Teaching Hospital in Kathmandu, Nepal. Here I had the opportunity to exchange ideas with a group of talented, dedicated surgeons who faced a large volume of complex problems within a setting of limited resources. These challenges are shared by all those who practice, or volunteer, in developing countries. From the perspective of a visitor from a developed country, one sees both the common presentation of uncommon problems (tuberculosis, polio, untreated joint sepsis, rickets), and the uncommon presentation of common problems (untreated traumatic dislocations, osteomyelitis, tumors at an advanced stage). Where can one find practical, yet detailed, information on how to treat these problems? Many of these topics receive minimal coverage in the more recent editions of orthopaedic textbooks, especially the management of cases with delayed presentation, such as the neglected clubfoot or chronic osteomyelitis. In addition, treatment recommendations cannot solely be based upon published materials. A further challenge is how to manage these problems in a practical, cost-effective, and culturally appropriate manner, within the confines of the resources available at a given location.

The goal of this project was to compile and summarize a "core" group of references on conditions seen with frequency in developing countries. One assumption is that the reader will not have access to the original articles, so each has been summarized in detail. I recognize that a subset of important references may have been overlooked, and that references from journals within developing countries have not been accessed. There is a wealth of knowledge to be gained from surgeons practicing in developing countries, and it my hope that their expertise may be incorporated in future publications aimed at improving orthopaedic care in developing countries. I hope that these references will be of use to surgeons in developing countries, and to volunteers participating in missions for teaching, service, or both.

Author and Donors for this publication

Irving and Judity Spiegel and their son Dr. David Spiegel.

The author attended Duke University for his undergraduate studies, for medical school, and for his orthopaedic residency. He went on to complete both a basic science research and a clinical fellowship in pediatric orthopaedics at the Children's Hospital of Philadelphia/University of Pennsylvania School of Medicine in 1998. He currently practices at the Shriners Hospitals for Children/Twin Cities, and is an Associate Clinical Professor at the University of Minnesota.

Financial support for the printing of this bibliography has been provided by Irving and Judith Spiegel, who live in Edison, New Jersey, and have been active volunteers in their community. They are committed to supporting the mission of Global-HELP in providing free educational materials for developing countries.

Introduction

There are enormous disparities between developed and developing nations in the provision of health care services. Surgeon General David Satcher stated that "89% of the world's population lives in developing countries that bear 93% of the world's disease burden. However, they account for only 11% of the world's health spending". The United States is responsible for approximately 40% of health care expenditure worldwide. The World Health Report (2000) indicates that "Three-fifths of the world's people in the poorest 61 countries receive 6 percent of the world's income—less than $2 a day". Across the globe, approximately 1.2 billion people live on less than $1 per day.

Estimates suggest that two thirds of the world's population may not have access to orthopaedic care, and that 80% of trained orthopaedic surgeons practice in developed countries. In developing countries, potential obstacles to the delivery of orthopaedic care include inadequate resources, a lack of trained providers, and difficulties in accessing health care services due to geographic constraints. In addition, surgeons practicing in developing countries often lack access to educational materials. Furthermore, most recent editions of textbooks published in developed countries have limited coverage of conditions seen with greater frequency in developing countries, for example tuberculosis, the sequelae of other infectious processes such as septic arthritis or osteomyelitis, the management of untreated clubfeet in older children, and the management of neglected traumatic dislocations.

In studies of international health, one traditional measure used to assess disease burden is mortality, which makes it impossible to gauge the impact of most musculoskeletal conditions. More recently, the DALY (disability adjusted life year) has been developed to better reflect the burden of disease for nonfatal conditions. This statistic includes the years of life lost due to premature death, and the years of life lived with a disability. The Global Burden of Disease study, sponsored by the World Health Organization and the World Bank, emphasized the importance of nonfatal outcomes for a host of conditions throughout the world. A large number of conditions have been ranked to better define their global impact, based on DALY's. The top 20 conditions have been listed for both the world as a whole, and for the developing world, based upon data collected in 1990. Projections were then made for 2020. Table 1 lists musculoskeletal conditions ranked in the Global Burden of Disease Study, for both the world and the developing world, in1990 and projected to 2020. Tuberculosis will remain a major source of morbidity. The most notable trend is for an increase in traumatic injuries. Road traffic accidents are projected to be the third leading cause of disability in the world by 2020 (2nd in the developing world). Priorities in global health care over the past few decades have appropriately been focused upon primary care measures such as immunization programs, the provision of safe water and sanitation, improving nutrition, as well as educational efforts directed against hazards such as landmines. These strategies have undoubtably impacted upon certain musculoskeletal problems. However, the world's burden of musculoskeletal disease is projected to increase over the next few decades, and a shift in pathology is expected as well. While both medical and orthopaedic problems associated with malnutrition and infectious diseases may decrease, the burden of disease from traumatic causes and from conditions associated with an ageing population will increase. The projected increase in trauma coincides with a trend towards urbanization in many societies, and injuries associated with armed conflicts are also expected to increase. Improvements in health care have led to an increase in mean life expectancy from the 1950's (40 years) to the 1990's (63 years), and problems such as osteoporosis and femoral neck fractures will likely become much more prevalent worldwide.

Condition	World		Developing World	
	1990	2020	1990	2020
Tuberculosis	7	7	5	6
Road Traffic Accidents	9	3	11	2
Congenital Anomalies	10	13	9	NE
Falls	13	19	13	NE
War	16	8	16	8
Violence	19	12	18	NE
Self Inflicted Injuries	17	14	19	NE
Osteoarthritis	24	NE	30	NE
Polio	60	NE	56	NE
Rheumatoid Arthritis	61	NE	NR	NE

Table 1: Musculoskeletal conditions in the Global Burden of Disease Study. NE = not estimated, NR = not reported.

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II. General Considerations

Badran A. The future of health care and medical education in the region. Global overview: State of health education in the world. ***Medical Education*** **29:16-23, 1995.**

Improvements in health care in developing countries has led to an increase in the mean life expectancy from the 1950's (40 years) to the 1990's (63 years), however enormous challenges in health care remain. The child mortality rate is 10% for those less than 5 years of age, and leading causes include diarrhea and respiratory diseases. Global problems include tuberculosis, malaria, AIDS, tobacco abuse, heart disease, cancer, and complications during child birth. Many of these may be improved or prevented by better education and public health measures. The socioeconomic gap between developed and underdeveloped countries continues to grow. In terms of aid, the richest 40% receive twice as much as the poorest 40% of developing countries. Seventy percent of aid is at least partially based upon military and political considerations rather than pure need. The developing world has 80% of the world's population, but only accounts for 4% of the expenditure on research and development worldwide. The developed nations spent 90% of the global budget for health services in 1990, and the USA accounted for 40% of the total. Developing countries spent 4% of their gross national product on health care, less than one thirtieth of the developed countries. The population is expected to increase by 3 billion people over the next few decades, and 80% of this growth will be in the developing world. Education is critical, and a recommended approach to enhancing care at the population level calls for a shift from tertiary care to primary care (complete package of public health). The need for particular services should be defined within each country based upon epidemiologic studies, and should include family planning services, prenatal through postnatal care, care of common diseases (malnutrition, measles, diarrhea, respiratory diseases, malaria), tuberculosis control, and prevention of sexually transmitted diseases. In parallel with this philosophy, medical education should be modified to include training in the social and behavioral sciences, to provide clinical rotations away from the teaching hospitals, and to vary with the needs of a given population.

Basch PF. Technology transfer to the developing world: Does new technology have any relevance for developing countries? ***Tubercle and Lung Disease*** **74:353-358, 1993.**

The author reviews important issues relating to the transfer of technologies to the developing world. Technology is defined not only as equipment and supplies, but "know-how, understanding and the ability to control and exploit underlying principles and processes". Topics addressed include the definition and scope of technology (nonmedical factors such as motor transport or the construction of buildings may have an indirect impact upon medical care), and issues relating to the transfer of technology (assessment of feasibility and effectiveness, research to determine more effective ways to improve care, routes of transfer, and costs/benefits). The relevance of a particular technology involves "direct application to reducing risk of infection and disease; affordability and cost-effectiveness; saving foreign exchange; satisfying public demand with benefit to the political government; and promotion of social equity".

Mukherjee AK, Mokashi MG. Epidemiology. The incidence and management of joint contracture in India. ***Clin Orthop Rel Res*** **219:87-92, 1987.**

This study documented that 50% of severely disabled patients in India (1.8% of population) had a disorder of the locomotor system, and that there were sigificant differences between urban and rural populations. Major causes include the residua of poliomyelitis, pyogenic/tuberculous osteomyelitis or arthritis, and trauma. In the rural areas, polio was most frequent, whereas in the city of Bombay more than 60% of cases were posttraumatic (only 1% polio). In addition, patients in the rural setting were younger (50% less than 12 years of age). The duration of disability prior to seeking medical treatment varied as well; 76% of rural patients waited 5 years, while 84% of urban patients sought treatment within 6 months. The distribution of pathology in a rural center included the following:

polio (53.5%), amputations (9.6%), adult hemiplegia (3.6%), cerebral palsy (13.5%), congenital (5.2%), and miscellaneous (14.6%). At a hospital in Bombay, the distribution was as follows: trauma (64.6%), rheumatoid arthritis (3%), osteoarthritis (10.2%), back pain (6.4%), tuberculosis or osteomyelitis (4.4%), polio (1%), and miscellaneous (11%).

Eyre-Brook AL. An appropriate approach to orthopaedics in developing countries. *International Orthopaedics (SICOT)* 10:5-10, 1986.

The author presents a thoughtful approach to orthopaedic problems in the developing world based upon an extensive personal experience. In contrast to the western world, the spectrum of disease is different, and the resources available to treat these conditions are often minimal. It may be "harmful" to train a surgeon from the developing world in the developed world, and efforts to train local providers should be completed in the home country, based upon the pathology and resources available in that country. Donations are only useful if they can be maintained locally. The desires and expectations of patients may be quite different in developing countries, and may impact upon treatment planning. The author also provides examples of how orthopaedic supplies may be constructed using materials available locally, such as calipers, shoes, crutches, wheelchairs, and prostheses.

Garst RJ. Surgical implants for use in developing countries. *Contemporary Orthopaedics* 17:25-28, 1988.

The author describes techniques used in the local production of orthopaedic implants. Pure 316L stainless steel can be supplied in bulk, and various sized stainless steel rods can be purchased and used to produce K-wires (1/16 inch rod), Steinmann pins (1/8 inch rods), and intramedullary nails (3/16 or ¼ inch rods). Plates may also be made from 1/8 inch thick plate metal (either ½ or 5/8 inches wide). A bolt cutter is used to cut the rods to the selected length, and an electric grinder can be used to sharpen the ends and smooth off the edges of plates. Rush rods can be made by bending the ends of the appropriately sized rods. A blade plate can also be made. Threaded pins can be made from 3/16 inch stainless steel rods, and bone screws can be produced with the aid of a lathe, dies, lathe cutting tools, thread cutting oil, and ¼ inch stainless steel rod.

Pulate A, Olivier LC, Agashe S, Rallan R, et al. Adaptation of Ilizarov ring fixator to the economic situation of developing countries. *Arch Orthop Trauma Surg* 121:79-82, 2001.

A ring fixator was developed from local materials and employed in the treatment of 25 open tibial fractures, 7 tibial nonunions, and 3 patients with chronic osteomyelitis. The rings were made from scrap aluminum, which was casted into drums from which the rings were cut. Holes (6.5 mm) were placed circumferentially. K-wires (1.5, 1.8 mm) were made from 316L stainless steel, and threaded rods were made in the workshop by cutting threads into 6 mm stainless steel rods with a hand held die. The bolts, nuts, and washers were purchased at a hardware store. Four rings were placed with 2-3 wires per ring. For the tibial fractures, all but one united after an average of 6 months. All of the nonunions healed at an average of 7.5 months. Pin tract problems were seen in 9.1%, and 5.7% of wires required replacement under local anaesthesia. Loosening occured in 1.7% of wires, and superficial infection was observed in 27.5%. Each fixator costs approximately $40, and less than $14 if reused 3 times.

Tuli SM. The art and science of orthopaedics in developing countries. *J Bone Joint Surg* 67b:840-842, 1985.

This lecture was given as the presidential address to the Indian Orthopaedic Association. Topics include the scope of pathology in developing countries, and the author reviews of a host of topics including infectious diseases and their prevention, trauma, "essential" surgery, rehabilitation, and training/education. The author documents the spectrum of pathology seen at a single institution during the course of a single year, which included tuberculosis (10.8%), osteomyelitis or septic arthritis (2.4%), polio (4.4%), deformities associated with malnutrition (3.3%), malunited or delayed presentation of fractures (14.5%), acute trauma (14.6%), neoplasm (1.7%), congenital deformities (6.5%), and miscellaneous (41.8%, inlcudes inflammatory, degenerative, and other conditions).

Many infectious problems, including tuberculosis, are becoming global due to patterns of migration, and in developing countries are related to social issues including crowding, poor sanitation, and poor nutrition. New cases of polio, despite widespread efforts at vaccination, often result from loss of refrigeration during transport. Most traumatic cases should be managed nonoperatively, and indications for surgery should be limited to irreducible fractures, cases in which alignment cannot be maintained using closed technqiues, and neglected or malunited fractures. Ninety percent of cases of osteoarticular tuberculosis should be amenable to outpatient chemotherapy, and surgery should be reserved for patients with persistent or recurrent paraplegia, for the prevention and correction of spinal deformities (especially in those at risk for progression), and for mobilization or arthrodesis of joints.

III. Trauma

A significant percentage of the pathology in any developing world hospital will be traumatic, especially in an urban setting. Although the most recent implants and radiologic equipment may not be available, the basic principles of fracture care can be modified based upon local resources. Nonoperative treatment methods are preferable in most settings. Open reduction and internal fixation may potentially be associated with a higher rate of complications due to inadequate sterility in the operating room and host variables (compromised patient population due to malnutrition, anemia, chronic disease). When surgical treatment is planned, the simplest, most cost effective technique should be chosen. Techniques such as traction, pins and plaster, intramedullary fixation with Rush rods, and external fixation are usually be employed with local resources. Traction is especially useful for lower extremity fractures, and available methods include longitudinal traction with a Bohler-Braun frame, balanced suspension traction (Thomas splint), the Perkins method, and Neufeld or roller traction. If resources are available, reconstruction of intraarticular fractures or other fractures expected to have a poor outcome using nonoperative approaches is appropriate. However, severe intraarticular fractures about the elbow and knee have been managed successfully with splinting and early range of motion exercises. Many fractures present days to months following injury, often complicated by osteomyelitis. Principles of open fracture management are important. Boiled or distilled water are effective irrigants. Stabilization of femoral neck fractures in the abscence of an image intensifier is technically challenging, and it remains unclear whether the outcome is better than nonoperative treatment. Excisional arthroplasty or prosthetic replacement (if available) may be better alternatives in some settings.

The treatment of unreduced dislocations of both the hip and the elbow has been described in a number of studies. It remains difficult to make absolute recommendations based on the literature, as a host of variables must be considered including age, the duration of joint dislocation, the available resources, and the patients level of function and symptoms at the time of evaluation. Options for the hip include no treatment, the "heavy traction" method, open reduction, proximal femoral osteotomy to reposition the limb, and in some settings prosthetic reconstruction. The reported incidence of AVN has varied following these methods, and the time from injury after which salvage by traction or open reduction is possible remains unclear. In general, the natural history is extremely poor if such cases are left untreated (or if a nonconcentric reduction is obtained), and the results following either both closed or open reduction may deteriorate as the time from the original injury to reduction increases. In the elbow, most studies suggest that open reduction should be considered, although the results following this procedure may deteriorate with a greater length of time between the injury and the treatment. Early range of motion is critical, and many authors recommend pin fixation for a short period following reduction. It remains unclear whether lengthening of the triceps should be routinely performed. A more functional arc of motion is usually achieved, although the absolute range is always diminished. Residual flexion contracture may be increased in the triceps are lengthened. In cases in which the articular surfaces have been damaged, either fascial/gelfoam arthroplasty or prosthetic reconstruction (if feasable) may represent the best option.

III A. General Considerations

Krug EG, Sharma GK, Lozano R. The global burden of injuries. *Am J Publ Health* 90:523-526, 2000.

Traumatic injuries rank among the highest causes of morbidity and mortality worldwide, and 16% of the global burden of disease. Road traffic accidents are the 10th leading cause of death, and overall rank 9th in burden of disease. In 1998, 5.8 million deaths were due to traumatic causes. The main injury-related causes of disability include road traffic accidents (17.5%), falls (12.2%), violence (10.1%), and self inflicted injuries (9.7%). A major goal in public health is to institute measures that lessen the impact of this preventable condition, and steps are outlined to address this issue. The magnitude and the scope of the problem should be determined, and the factors that lead to these injuries should be elucidated in order to identify which may be modified. Finally, preventive measures should be determined and instituted.

Odero W, Garner P, Zwi A. Road traffic accidents in developing countries: a comprehensive review of epidemiologic studies. *Tropical Medicine and International Health* 2:445-460, 1997.

The results from 73 studies (18 prospective) from 1966 to 1994 were combined to gain a greater perspective on the impact of road traffic accidents worldwide. These represent the leading cause of death for adolescents and young adults. 74% of the 856,000 yearly deaths from these accidents occur in the developing world, and significant increases have been observed in recent years. The estimated cost is 1-2% of each countries gross national product. Human error is the most common cause, and often vehicles carry many more passengers than can be safely supported. Inadequate safety features, poor road design, and the traffic mix on roads are also important. In three of four studies, pedestrian fatalities (41-75%) occured most often. In South-East Asia, cyclists comprise 39-63% of deaths. Accidents typically occur during the day and on weekends, and alcohol is frequently involved. Road traffic accidents account for 30-86% of all trauma admissions to the hospital. The problem is enormous from both a personal and societal perspective.

Mock C. Injury in the developing world. *West J Med* 175:372-374, 2001.

Road traffic injuries rank as the 2nd leading cause of mortality in patients from 15-44 years of age, and 3rd in children from 5-14 years of age in the developing world. In addition to creating difficulties for the delivery of health care, this represents a major economic burden. Despite this drain on resources, little effort has been put forth to prevention and to developing effective systems to deal with the burden of trauma in many countries. A scientific approach will be required to first identify risk factors and causes, and then to develop preventive strategies that can be evaluated in detail. Accurate recording of injuries is essential. In order to impact upon road traffic accidents, attention must be directed towards improving the roadways (engineering), the automobiles (safety features), and the drivers (speeding, alcohol, etc.). Each society will have to develop a basic level of services that may be applied to the entire population, similar to programs that have been developed for immunizations and tuberculosis.

Nantulya VM, Reich MR. The neglected epidemic: Road traffic injuries in developing countries. *BMJ* 324:1139-1141, 2002.

Road traffic injuries are the 9th leading cause of disability adjusted life years in the world, are projected to rank 3rd by the year 2020, and 90% occur in developing countries (85% of deaths as well). Children in low income countries have a more than 6 times greater risk of fatality in a developing country than in a develped country. In developed countries, deaths usually involve the drivers, whereas pedestrians, passengers, and cyclists are usually the victims in developing countries. These statistics can be explained by increases in the number of motor vehicles in developing countries, poor enforcement of safety regulations, more people injured or killed per accident, inadequacy of public health infrastructure, and poor access to health care services. For example, in Ghana only 60% of those sustaining series injuries in cities, and 38% of those injured in rural areas, received care.

III B. Traditional Bonesetters

Ofiaeli RO. Complications of methods of fracture treatment used by traditional healers: A report of three cases necessitating amputation in Ihiala, Nigeria. *Tropical Doctor* 21:182-183, 1991.

Tw closed distal radius fractures and one open proximal tibia fracture were initially managed by bamboo splints, and subsequently developed gangrene necessitating amputation. The author urges the development of primary surgical care centers in district hospitals to provide rural communities with access to more modern methods of treatment.

Onuminya JE, Obekpa PO, Ihezue HC, et al. Major amputations in Nigeria: A plea to educate traditional bone setters. *Tropical Doctor* 30:133-135, 2000.

Sixty of 100 amputations in Nigeria over a 10 year period resulted from mismanagement of fractures by traditional bonesetters. Most cases of gangrene were due to constriction by bamboo splints. In 15 of the 60, no fracture was identified by radiographs at the time of amputation. Only 25 patients ultimately ambulated using a prosthesis, and more than half used crutches for locomotion. Although these traditional methods of fracture care are well accepted regionally, they were also the leading cause of amputation. The authors recommend that the governments of developing countries establish policies on acute trauma management, and that the traditional setters receive additional training to limit the number of complications.

Oyebola DDO. Yoruba traditional bonesetters: The practice of orthopaedics in a primitive setting in Nigeria. *J Trauma* 20:312-322, 1980.

Three traditional bonesetters were interviewed, and treatment sessions were observed. After clinical diagnosis, the treatment protocol is instituted without analgesics or anaesthesia. The fracture is manipulated, and then a hot fomentation followed by a herbal solution is applied. The injured extremity is then bandaged and splinted, and this routine is completed two times per day. Limb mobilization is permitted following clinical union. The ingredients of the herbal solutions were not disclosed, and presumably the hot fomentation speeds healing by increasing local blood flow. The techniques and materials used vary between tribes. Other variations include placement of the injured extremity into a hole in the ground, or applying a hot nail to the skin overlying the fracture. In addition, some use chickens in their management approach. The fracture is first reproduced in a chicken. They believe that if the fracture heals in the chicken, then the patient will also heal. Interestingly, many of the patients had initially been managed in a medical facility, only to leave voluntarily and seek these traditional forms of treatment. Although overall results would be graded as poor in many cases by western standards, these traditional caregivers have the respect of their local communities, and treat many patients who would otherwise not receive care.

Roles NC. Tribal surgery in East Africa during the 19th century. *East Afr Med J* 44:15-20, 1967.

A host of techniques employed by different tribes for treating wounds, fractures, and other traumatic injuries are described. Superficial wounds might be covered in herbal medicines, hot butter or cow dung. Deeper wounds might be stitched, covered in hot sap or boiling fat, or left open. A variety of materials were used for suture, including thorns, hair from a cow's tail, tendons from the back of an ox, or bark fiber. Fractures were usually not reduced by manipulation, but were splinted until clinical union with sticks, cattle hide, or other materials. A herbal mixture was often applied to promote healing. Open fractures might be debrided and closed with thorns or strips of hyde. Heat was also employed to promote healing, whether by a hot iron or by making a fire over the extremity which was covered over by soil. For a severe rib fracture, a fragment might be excised and replaced by a sheep's rib. Sheep's fat is placed in the wound prior to closure.

III C. War Injuries

Brown PW. Wound closure - or not. *Techniques in Orthopaedics* 10:155-157, 1995.

Principles of management for war wounds include life support, accurate wound assessment, thorough exploration and debridement, decompression of compartments, open drainage

followed by delayed closure (by secondary intention or other method), and stabilization of the extremity. Closure over drains is not recommended, and primary closure should never be performed. Closure by secondary intention may be facilitated by extending wounds parallel to the axis of the extremity. Closed casting methods are be effective in most cases.

Cobey JC, Stover E, Fine J. Civilian injuries due to war mines. *Techniques in Orthopaedics* 10:259-264, 1995.

This article defines the magnitude of this worldwide problem, as millions of landmines have been placed in a host of countries since World War II. Antipersonnel mines are inexpensive, durable, easy to transport, and are readily available from a host of sources. Millions of unexploded mines remain across a countries such as Afghanistan and Cambodia. Three basic patterns of mine injuries exist. The first pattern occurs in those who step on a mine, and the blast usually mutilates the extremity below the knee, and may damage the contralateral extremity and the perineal region. Larger mines may result in loss of both limbs. The second pattern involves mines which are placed above the surface of the ground, and are activated by a wire. These send a blast that may damage any region of the body, and may injure those as far as 50 meters from the site. The third pattern involves damage to the face or upper extremity when picking up a mine. The zone of injury from the blast may result in an amputation much higher than the level of obvious injury. Many patients die as a result of inadequate transport or a lack of adequate medical facilities. The social and economic consequences are large.

Madenwald MB, Fisher RC. Experiences with war wounds in Afghanistan and Mozambique. *Techniques in Orthopaedics* 10:231-237, 1995.

Problems with care of war related musculoskeletal injuries in the developing world include inadequate transportation systems, limited surgical facilities, and a lack of trained personel. The pathology most often results from guns, knives or machetes, and land mines. Millions of landmines remain in countries such as Afghanistan, Cambodia, Laos, Somalia, Kuwait, and Mozambique. The principles of wound care are most important, including irrigation, adequate debridement, and open drainage. Antibiotics serve as a adjuvant to adequate wound management. In treating fractures, open reduction and internal fixation was associated with numerous complications, and the best approach involves closed reduction and casting, traction, or external fixation if available. Many severe intraarticular injuries were best treated by early mobilization rather than anatomic reconstruction. Wounds may heal adequately by secondary intention, and delayed primary closure, split thickness skin grafts, or a local muscle flaps may also be helpful. For amputees, the Red Cross has developed effective systems for prosthetic production using locally available materials and labor, often with fitting and discharge within 2-3 days. The authors treated femoral fractures with skeletal traction, initially with a tibial pin and a Bohler frame. They subsequently were placed in Perkins traction, which enables the patient to sit up for periods of time and to perform range of motion exercises at the knee. Long leg cast braces with a hinge at the knee were employed once healing was sufficient. Tibial fractures are generally treated with external fixation, and wires may be made from bicycle spokes. Simple frames composed of steel or wood may be attached to the pins using plaster. Nonunions were treated by posterolateral bone grafting. Intraarticular injuries were treated by frequent active range of motion exercises while in traction or splints, following wound debridement. These approaches were successful in taking care of a host of serious injuries in the setting of limited resources.

III D. Fractures

Alms M, Barnechea G, Cobey J, Fisher R, et al. Proximal femoral fractures. A perspective from developing countries. *Clin Orthop Rel Res* 2:890-96, 1987.

Anecdotal information on the management of proximal femoral fractures based on a large collective experience. Femoral neck fractures are difficult to manage, and an image intensifier will rarely be available. Closed reduction followed by a

single hip spica cast with the knee flexed has been successful in some settings. Pinning with threaded Steinmann pins, Knowles pins, or a triflanged nail has been performed through a lateral approach (extended anteriorly). Palpation or visualization of the femoral neck guides pin placement. Medial displacement osteotomy may be employed for nonunion, and excisional arthroplasty may be used for salvage. Prostheses are generally not available. Peritrochanteric fractures may be treated in tibial traction, and a plaster antirotation boot can help to maintain alignment. If radiographs are not available, measurements of extremity length may help to guide the amount of traction required. Roller traction has also been successful in a number of locations. Rush rods may be used to stabilize subtrochanteric fractures. Overall, "the advantages of internal stabilization of hip fractures are well accepted; however, the capability of carrying it out predictably and safely does not always exist in developing countries".

Bewes PC. Management of fractures in adverse circumstances. *Tropical Doctor* 17:67-73, 1987.

This review presents some practical yet unconventional methods of treating fractures, appropriate for inexperienced caretakers in a rural setting within the developing world. Although the methods would certainly be suboptimal in settings with trained orthopaedic surgeons, the results are worthy of mention. For olecranon fractures in patients with evidence of triceps function (even if the fragments are seperated), the results may still be successful following nonoperative treatment and early motion. Operative treatment is reserved for those with complete loss of triceps function. The same approach with early motion may be applied to Bennett's fractures. Fractures of the proximal phalanges may be immobilized by flexing the finger over a roll of bandage material, with a dorsal strap of tape applied from the dorsum of the hand to the palmar aspect of the distal forearm. Femur fractures may be treated by the Perkin's method. Tibial fractures with swelling or open wounds may be managed initially with traction using a calcaneal pin, with support from a gutter splint. When early healing is present, a weight bearing cast may be applied. This approach may serve as an alternative to external fixation. For fractures of the calcaneus, after a period of elevation, early weight bearing and range of motion has produced acceptable results in the authors experience, and neither open reduction nor casting is recommended.

Bewes PC. Fractures of the femur in a tropical context: A reevaluation of Perkin's traction. *Tropical Doctor* 2:64-68, 1974.

The Perkin's method was successful in 15 patients with fractures of the midshaft, the lower third, and the distal condyles of the femur. The apparatus requires a bed (in which the bedsprings can be removed in the lower half), blocks to raise the foot of the bed (12-20 inches), tibial pin, swivel hooks that can attach to a Steinmann pin, rope and weights, and fracture boards to go across the bed from side to side. After placing the tibial pin, the traction is begun with the foot of the bed elevated one inch for each pound of traction. If x-rays are unavailable, leg lengths are measured from the ASIS to the medial malleolus to ensure that excessive shortening is not present. After the first week or so in traction, the lower portion of the bed and mattress is flexed 90 degrees, which allows the patient to sit up and to perform range of motion exercises (10-30 minutes, 1-2 times per day). The patient continues to work on improving the range of motion at the knee until clinical union (no tenderness on palpation or attempted angulation at the fracture site). Then, traction is removed for several days while exercises are carried out. The pin is then removed, and the patient maintained on bedrest for an additional week. Then, crutch walking without weightbearing is begun. At twice the time that it took to achieve clinical union, the patient is permitted to begin weightbearing. The method does not require an extensive amount of equipment, but does require attention to detail.

Brueckmann FR. The art of effective fracture fixation with Rush pins. Thieme Medical Publishers, Inc. New York, 1990.

This technique manual gives a comprehensive overview of the rationale and principles behind intramedullary fixation with Rush pins for a host of fractures, and also provides detailed technical information.

Carballedo J, Schmauch M, Langa J, et al. Type III-B open tibia fractures in Mozambique. *International Orthopaedics (SICOT)* 20:300-304, 1996.

50 open tibial fractures (grade IIIb), mostly from road traffic accidents and gunshot wounds, were treated by debridement, external fixation, and antibiotics. The external fixator was removed at clinical union, and patients were kept in a PTB cast for an additional period of time. Overall, 49/50 united at an average of 5.6 months. In patients with bone loss, the average time to union was 12 months, and all 8 patients healed. The fixator was needed for 8 months. Significant bone loss was managed using several different strategies. Two cases underwent bone grafting between the tibia and fibula along the interosseous membrane, while 3 cases were treated by bone transport (9,7,11 cm), which required 350 days in the frame (310-430 days). Soft tissue coverage was provided by local rotation flaps (tibialis anterior, FDL, gastrocnemius or soleus). In 3 patients whose flap coverage failed, the bone was decorticated and drilled to stimulate granulation tissue. Malunion was encountered in 22%, equinus contracture at the ankle in 16%, and chronic osteomyelitis was found one year after injury in 5 patients (10%).

Fisher RC, Anderson MG. An orthopaedic and prosthetic program in Mozambique. *Contemporary Orthopaedics* 25:291-298, 1992.

A volunteer program was initiated in Mozambique with the goal of training local caregivers at the referral center in Maputo to manage selected problems, and then transferring the approaches for certain fractures to smaller facilities in rural areas. The spectrum of pathology in Mozambique included war injuries, other traumatic injuries, and infectious problems. Treatment methods were based upon local resources, and were developed for long bone fractures, open joint injuries, and proximal femoral fractures. For open femur fractures, debridement is followed by traction (Bohler frame at first, then the Perkins method), and a cast brace with knee hinges is applied when healing is sufficient. 41 patients were treated in this fashion, and all fractures healed. Wounds were left open to granulate, or were covered by split thickness skin grafts. A single patient had 2.5 cm. of shortening, and 6 cases healed with deformity (> 10°° varus or recurvatum). There were no cases of persistent infection. For open tibial shaft fractures in those who were candidates for limb salvage, treatment included debridement followed by external fixation. Twenty-seven patients with intraarticular fractures from high velocity gunshot wounds were treated by debridement and early range of motion exercises. A painless, functional range of motion was obtained in most patients at short term followup. Intertrochanteric hip fractures were treated in traction. Femoral neck fractures were extremely difficult to manage, and many presented late. Pinning without the use of flouro is technically difficult, and prosthetic replacement may be best in this setting (if implants are available). Resection arthroplasty is an excellent option in a setting of limited resources.

Galvagno S. External skeletal fixation: Experience in a small rural hospital in northern Kenya. *Tropical Doctor* 23:73-76, 1993.

Seven patients with neglected open fractures (1-7 months) were managed in a rural setting. Preoperative soaks with Dakins solution (3-5 days) were performed, and patients were given cloxacillin and erythromycin for 5 days following surgery. There were no laboratory facilities available for cultures. Under ketamine anaesthesia, debridement and stabilization with a locally made external fixator (TTM fixator) was performed. Five millimeter Steinmann pins (or Schanz screws) were used in adults (3 millimeters in children). The opposite leg was used as a reference for both length and angular/rotational alignment. Daily irrigation of the wound with 2 liters of boiled water was continued until adequate granulation tissue was present. An open cancellous bone graft from the iliac crest was then applied. Weightbearing was generally allowed after 3 weeks. All wounds healed, and the time to clinical union was 3.5-7 months in all but one case. A single pin tract infection occured (pin care was performed once per week).

Gates DJ, Alms M, Cruz MM. Hinged cast and roller traction for fractured femur. A system of treatment for the third world. *J Bone Joint Surg* 67B:750-756, 1985.

121 patients in Uganda and the Dominican republic with fractures of the mid to distal femur were treated with Neufeld traction. The technique

is well illustrated, and involves a hinged cast (toes to groin with a single rope exerting traction) and a wooden or rubber roller attached to a beam. A tibial pin is used for traction (7-9 kg) for several days to a week, and then the hinged cast is applied. While applying the femoral section of the cast, a long shoehorn attached to a pullout string is placed posteriorly with the convex side up to restore the anterior bow of the femur. A short leg cast is then connected to the femoral segment by the hinges. Suspension of the casts is by loops attached to the anterior surface. Patients are able to maneuver while in bed, and after 2 weeks can often get out of bed for limited periods of time with crutches. Weights are adjusted based upon the clinical assessment of leg lengths. The time out of traction is increased gradually, and by 3-4 weeks the thigh cast may be tightened, and partial weight bearing allowed. The prescence of comminution will necessarily effect this timetable. Once in traction, the hospital stay should be approximately 1 month. Overall, all but one fracture united, and significant shortening was not observed The method can easily be taught to hospital staff including medical technicians. The roller traction can be set up with local materials, and patients can perform their own physical therapy. The apparatus can be set up an supervised by technicians or other staff.

Jongen VHWM. Alternative external fixation for open fractures of the lower leg. *Tropical Doctor* 25:173, 1995.

Seven patients with an open tibia fracture were treated by an external fixator comprised of two wooden splints (3.5 x 2 x 45 cm). Five millimeter holes were placed 1 centimeters apart throughout the length of each piece of wood, to accommodate Steinmann pins of a similar diameter. Two pins were placed in all patients. In 5 of these, they were drilled through the tibia, while in 2 cases one pin was placed through the tibia and one through the calcaneus. Wound care could easily be provided with the fixator in place. Once the soft tissues had stabilized, the device was replaced by a cast. Although such a device may not provide sufficient stability to mobilize patients, this may serve as a temporizing measure to facilitate management of open injuries. The cost is low, and the device can be made by local craftsmen.

Kugler C, Locher L. Low-cost external fracture fixator. *Tropical Doctor* 18:70-73, 1988.

An external fixation system (TTM fixator) was designed in Germany with the goal of being able to transfer this technology to developing countries. The principles of application are similar to commercial designs, yet the cost is low, and the production can be accomplished in developing nations. The device is attached to either Steinmann pins or Schanz screws (must be obtained seperately). Chromium-plated brass cylinders are used for adjustable clamps, which are attached to the pins or screws. A device is provided to preload the pins or screws, and all of the necessary equipment to apply the device is provided in the set.

Lourie JA. Low cost external fixator for compound tibial fractures. *Papua New Guinea Medical Journal* 26:62-63, 1983.

An open tibial fracture was effectively stabilized with a makeshift fixator. Two Denham pins were inserted both above and below the site of the fracture, and these were attached to Kuntscher nails with car body repair cement (PMMA can be used if available).

Rush LV. Atlas of Rush Pin Techniques. Mississippi, Berivon, 1955.

The original technique manual for intramedulary fixation of fractures with Rush pins.

Rush LV. Dynamic intramedullary fracture-fixation of the femur. Reflections on the use of the round rod after 30 years. *Clin Orthop Rel Res* 60: 21-27, 1968.

The author describes his experience managing 211 consecutive femoral shaft fractures from the lesser trochanter to the knee (35 closed pinning, 58 open reduction/pinning, and 115 with semiopen reduction and pinning) with intramedullary pinning. “Dynamic fixation” involves placement of the device to counteract the muscular forces which lead to malalignment. The rods are ¼ inch thick, and fixation is felt to be adequate except in elderly patients with significant osteopenia, and those with severely comminuted fractures. Cerclage wires were added for additional stabilization in those with comminution or spiral fractures. A single pin inserted laterally just distal to the tip of the greater trochanter was used most often, and for distal

fractures (including the femoral condyles) both medial and lateral retrograde pins were used with success. There were 2 nonunions in the series. Final alignment, degree of shortening, and function were not reported.

Sarmiento A. Functional bracing of tibial and femoral shaft fractures. *Clin Orthop Rel Res* 82: 2-13, 1972.

The author describes the technique and results of functional bracing for tibial and femoral shaft fractures. For the tibia, a long leg cast is initially applied, and maintained for approximately 2 weeks (depending upon age, fracture pattern, status of soft tissues, etc.). Some fractures may be amenable to a short leg cast initially. The patient is then converted into a short leg functional cast, and early weightbearing is begun if appropriate. The third stage involves a functional brace (made of thermoplastic materials) with both knee and the ankle free. 191 patients were treated in this fashion (16-86 years old), and union occured at an average of 14 weeks (18 weeks for open fractures). The maximum shortening was 2 cm. (mean 6.5 mm). For femoral fractures, sufficient healing must be present to ensure adequate stability. The brace is applied supine, with measurements taken of the thigh circumference (midline between ischium and patella) and the length of the femoral segment (ischial tuberosity to the middle of the patella). 2.5 centimeters are added to the transverse and longitudinal measurements to make up for shrinkage of the thermoplastic material. The results in 70 patients are presented. The brace was applied after a period in skeletal traction (4 weeks - 4 months), and an average of 8 weeks was required in the brace. All fractures united. The maximum amount of shortening was 3.8 cm, with an average of 1 cm. Angulation occured in a small subset after weightbearing was permitted, and close monitoring is required to identify this complication.

Spray P. Treatment of fractures of the femoral shaft with Rush pins. *Contemp Orthop* 6:39-56, 1983.

The author treated 40 femur fractures (9 open) over a ten year period with smooth intramedullary pins, and union was achieved in 38 cases. Proposed advantages of this technique include decreased expense and ease of insertion.

Strecker W, Elanga M, Fleischmann W. Indications for operative fracture treatment in tropical countries. *Tropical Doctor* 23:112, 1993.

The authors review 123 fractures treated operatively in Zaire, and present indications for the operative fixation of fractures in tropical countries. Thirty-seven patients were treated by external fixation (25 AO fixator, 12 "transfixational plaster casts"), while 86 patients were treated by internal fixation [intramedullary nails (8), plate and screws (28), screws (22), cerclage (7), and Kirschner wires (21)]. Nonunion occured in 4.1%, and 5.7% developed infection (8.1% for internal fixation, 21.4% of those with plates and screws). The authors suggest that absolute contraindications to internal fixation include pyogenic infections, sickle cell anemia, and HIV infection. Relative contraindications include a poor soft tissue envelope, metabolic deficiencies (chronic anemia, hypoproteinemia from chronic malnutrition, TB, malaria, schistosomiasis, or other causes), and lack of compliance. Conservative management should be used for most fractures in tropical countries, and open fractures may be treated effectively with external fixation. Indications for internal fixation include displaced patella or olecranon fractures, irreducible fractures, and those associated with neurovascular injuries.

Strecker W, Fleischmann W, Thorpe RG. The transfixational plaster cast technique. *Anal Soc Belge Med Trop* 71:129-137, 1991.

This technique is presented as an alternative to open reduction and internal fixation for unstable fractures, and is ideally suited for fractures of the forearm. For a fracture of the distal radius, the arm is placed in finger traction with 5-10 lbs of weight, and two K-wires (2 mm) are drilled through both bones away from the fracture site (through the 2nd and 3rd metacarpals if the fracture is distal). A cast is then applied with the wires incorporated, and the traction is released when the cast has dried. This technique may be applied to fractures of the distal humerus (pins through olecranon and midshaft of humerus), or the tibia and fibula.

III E. Neglected Dislocations

1.) Hip

Garrett JC, Epstein HC, Harris WH, et al. Treatment of unreduced traumatic posterior dislocations of the hip. *J Bone Joint Surg* 61:2-6, 1979.

39 dislocations in adults were treated following a delay of 3 days to 9 years [3 days to 3 weeks (16), 3 weeks to 3 months (9), and > 3 months (14)], with a followup of 4 years. The treatment approach included an attempt at closed reduction in the first group, open reduction in the second group, and reconstruction (6 cup arthroplasties, 3 arthrodeses, 2 total hip arthroplasties) in those with dislocations for > 3 months or if there was damage to the femoral or acetabular articular surface. The natural history of untreated dislocations was poor. Only 3 of 20 hips treated by closed (0/7) or open reduction (3/13) had good results, due to avascular necrosis (11) or concomitant fractures of the femoral head or medial acetabular wall. Primary reconstructive procedures were associated with the best results. The authors recommend total hip arthroplasty as the best option, should such technology be available.

Gupta RC, Shravat BP. Reduction of neglected traumatic dislocation of the hip by heavy traction. *J Bone Joint Surg* 59:249-251, 1977.

Seven adults with a neglected posterior hip dislocation (1-9 months old) were treated by the heavy traction method. Tbial traction (7-18 kg.) was applied for 5 days, and once the femoral head was brought down to the level of the acetabulum, the extremity was abducted gradually. The traction weight was then decreased gradually. Reduction was successful in six of these cases, and there was no evidence of avascular necrosis at 6 months to 3 years followup.

Hamada G. Unreduced anterior dislocation of the hip. *J Bone Joint Surg* 39b:471-476, 1957.

Four traumatic anterior hip dislocations presented from 5 months to 12 years following injury. The involved lower extremity was abducted, externally rotated, and flexed. The range of motion was limited. Surgery was performed to reorient the limb in space, and consisted of an osteotomy at the level of the base of the femoral neck. The leg is adducted, extended, and internally rotated, and the patient is placed in a spica cast. Healing occured within 3-4 months.

Nixon JR. Late open reduction of traumatic dislocation of the hip. Report of three cases. *J Bone Joint Surg* 58b:41-43, 1976.

Open reduction was performed at 28-93 days following injury, and cases were followed for 7-14 years. The three patients had minimal symptoms at followup, although radiographs showed loss of articular cartilage (1) and trabecular bony changes (3). The author recommends open reduction in cases when traction or closed reduction fails.

Pai VS. The management of unreduced traumatic dislocation of the hip in developing countries. *International Orthopaedics (SICOT)* 16:136-139, 1992.

29 neglected traumatic hip dislocations (26 posterior) were treated by 5 different methods. Patients were from 3-64 years of age, and the time of presentation was as follows: Group 1 = 3 days to 3 weeks (6), Group 2 = 3 weeks to 3 months (4), Group 3 = 3 months to 1 year (4), and Group 4 = more than one year (15). Treatment methods included closed reduction (attempted if the delay in presentation was < 3 weeks), heavy traction and abduction (skeletal traction with 5-7 lbs for 3 weeks), primary open reduction, or reconstruction (hemiarthroplasty, excision, or osteotomy). The followup was 2-6 years, and outcome was based upon pain, range of motion, and a radiographic evaluation. Closed reduction was successful in 3 of 6 cases, the other 3 had associated fractures of the femoral head and acetabulum. Abduction traction was successful in 4 of 8 patients in groups II and III, and the others were managed by open reduction. Achieving a concentric reduction is essential to avoid early degeneration. The Group IV patients were treated effectively with a valgus proximal femoral osteotomy. The authors conclude that for dislocations present for less than one year, closed or open reduction may yield satisfactory results if the femoral head is spherical and a concentric reduction can be obtained. For those who present more than one year following injury, limp and instability may be effectively treated by valgus osteotomy. The followup is relatively short, and the incidence of avascular necrosis was not reported.

Pai VS, Kumar B. Management of unreduced traumatic posterior dislocation of the hip: Heavy traction and abduction method. *Injury* 21:225-227, 1990.

Eight cases of neglected dislocations [3 days - 3 weeks (4), 3 months - 1 year (3), and > 1 year (1)] were treated in patients with a mean age of 11.6 years. Skeletal traction (lower femur or upper tibia) with 10-13 lbs was employed for 2-3 weeks, and the limb was then abducted while reducing the traction to 5-7 lbs over a period of 3 weeks. Patients were then managed in either a hip spica for 6 weeks (children) or by mobilization without weight bearing in adults. The followup was 3.5 years. There were no cases of AVN, and 4/8 achieved a concentric reduction. Two of the others had an open reduction, and buttonholing of the capsule was responsible for the inability to reduce the hip. The two other patients refused surgery, and were left with a nonconcentric reduction. The clinical results were excellent except for the two with a nonconcentric reduction, who went on to arthritic changes (1) and redislocation (1).

Stewart MJ, Milford LW. Fracture-dislocation of the hip. An end result study. *J Bone Joint Surg* 36:315-341, 1954.

128 patients (4-76 years of age) were treated by closed or open reduction for a traumatic dislocation of the hip (74% posterior), and had followup of greater than 1 year. Ninety were reduced with closed manipulation, and none of those treated after 24 hours delay had good results. The incidence of avascular necrosis was 15.5% following closed reduction, and 40% following open reduction (21.2% combined). In both groups, the time to diagnosis of avascular necrosis was 17 months. The time to reduction was 3 days in the closed reduction group, and 21 days in the open reduction group. The authors could not correlate patient age with the results.

Varma BP. Management of old unreduced traumatic dislocations of the hip. A study of twenty-nine cases. *Ind J Orthop* 9:69-80, 1975.

Twenty-nine neglected hip dislocations (26 posterior) were treated. Twenty-five of these were initially managed in traction (5-15 lbs) for 1-3 weeks, and once the hip was brought down to the level of the acetabulum, a closed reduction was attempted. This alone was successful in 4 cases, all of whom were dislocated for < 4 weeks. The remaining patients were treated by open reduction (iliofemoral approach). In addition to tenotomy of the adductors and iliopsoas, a contracted inferior capsule required release to affect reduction. Children were placed in a spica (30°° abduction, mild internal rotation) for 3-4 weeks, and at 6-8 weeks weight bearing was permitted. A caliper was used for 12-16 weeks. Adults were initially managed in a derotation boot on bedrest, and range of motion exercises were started after 4-6 days. Weightbearing was permitted at 3-4 weeks, and crutches were used for 8-12 weeks. One patient required excision of the femoral head for a coexisting fracture, while another was treated by primary osteotomy. The average followup was only 5 months, so the incidence of AVN could not be reliably documented. None of the cases reduced after a delay of > 4 months had an excellent result. The results following open reduction in adults (85.7% excellent or good) were better than in children (57% excellent or good) at this short term followup. For those who present at greater than 6 months from the time of injury, the authors recommend proximal femoral osteotomy for realignment.

2.) Elbow

Allende G, Freytes M. Old dislocation of the elbow. *J Bone Joint Surg* 26a:691-706, 1944.

Open reduction was performed in 35 neglected elbow dislocations (3 weeks to 5 months) in children and adults. Patients presented with the elbow held in extension with a arc of motion in the range of 20°. The articular cartilage was generally normal in cases that were delayed less than 5 months. A posterior approach was utilized, except in 2 cases when an osteotomy of the olecranon was performed. The triceps was split distally, leaving a central tongue on the distal aspect to facilitate closure. The ulnar nerve is mobilized, and the joint is cleared of fibrous tissue. Areas of ossification around the distal humerus (especially posteriorly) are excised, and the sigmoid notch is cleared of soft tissues. The triceps is repaired, and a long arm cast is applied at 40° flexion if the elbow is stable (90° if unstable). The ulnar nerve is not transposed anteriorly. The cast is worn for one month, however after 8-10 days it is bivalved to facilitate active range of motion exercises.

Arafiles RP. Neglected posterior dislocation of the elbow. A reconstruction operation. *J Bone Joint Surg* 69b:199-202, 1987.

11 patients (15-54 years old) with unreduced posterior elbow dislocations were treated from 1-48 months following injury (average 9 months). The preoperative arc of motion was 38°, and the average lateral instability was 32°. Reconstruction was accomplished through a posterior approach, and the joint was visualized medially and laterally along the borders of the triceps distally. Fibrous tissue was removed, and the joint was cleared of all debris. The common flexor origin was left intact. A free palmaris longus graft was harvested (ideally 22cm.) and weaved through 4 drill holes around the medial side of the joint. Two of these were through the distal humerus (one exits through the trochlea), and 2 were through the ulna. The graft is secured to the flexor origin, and then tensioned and sutured down over the olecranon (allowing a full range of flexion/extension, and 5° of medial/lateral motion). A tricepsplasty is performed if necessary. Active range of motion exercises were started as early as 6 days following the procedure. At a mean followup of 32 months, the average range of motion was 105°. Flexion contracture averaged 33° in the 6 patients who required tricepsplasty, and only 4° in the 5 that did not require this procedure. Subluxation at the radiocapitellar joint was observed in 7 cases, but this did not affect the outcome. Four patients had occasional pain, and the only complication was infection in a single patient. Myositis ossificans was not seen. The authors suggest that the immediate stability achieved through this reconstruction enabled early motion, and the results did not correlate with the timing of reconstruction following injury.

Billett DM. Unreduced posterior dislocation of the elbow. *J Trauma* 19:186-188, 1979.

Six patients with unreduced posterior dislocations were treated by open reduction at 1-3 months following injury. Through a posterolateral incision, the triceps was elevated as a flap, and the joint was exposed. Fibrous tissue was removed, and the collateral ligaments were divided. The elbow was manually reduced and stabilized with a Kirschner wire placed through the olecranon into the humerus. A V-Y lengthening of the triceps was performed, and was necessary to facilitate reduction. A posterior splint was then applied. After 2 weeks, the wire was removed and rehabilitation was started. Redislocation occured in the single case in which a Kirchner wire was not employed. The range of motion at 3-12 months followup ranged from 5-85° flexion. In this small group, the final range of motion seemed to correlate with the length of time from injury to reduction.

Fowles JV, Kassab MT, Douik M. Untreated posterior dislocation of the elbow in children. *J Bone Joint Surg* 66a:921-926, 1984.

Fifteen children with untreated posterior or posterolateral elbow dislocations were treated by open reduction at 3 weeks to 3 years following injury. Three patients with a mean of 80° flexion were left untreated, and functioned relatively well. The posterior approach (Speed) was employed in most patients, and the collateral ligaments were detached off the distal humerus. Fibrous tissue was excised, and subperiostial new bone was removed from the posterior aspect of the distal humerus. A V-Y tricepsplasty was only performed if triceps contracture interfered with the reduction, or if flexion was limited to around 30° following reduction. If the elbow was stable at 90° flexion, a long arm cast was applied. If there was instability, then one or two Kirschner wires were placed through the olecranon and into the distal humerus. The cast, and K-wires, were removed after 2-3 weeks. Active range of motion exercises were then begun. Complications included 2 superficial infections, one tourniquet paralysis (resloved after several days), and 2 cases of myositis ossificans. At 12-79 months followup, the average arc of motion was from 63-113° flexion. Frearm rotation was also improved and averaged 84°. Based on the fact that several patients had a useful range of motion and were not treated by open reduction, the authors recommend waiting at least 3 to 8 weeks following injury to determine if open reduction is necessary.

Jupiter JB, Ring D. Treatment of unreduced elbow dislocations with hinged external fixation. *J Bone Joint Surg* 84a:1630-1635, 2002.

5 patients with a mean age of 49 years were treated by open reduction and external fixation. The average time from injury to treatment was 11 weeks (6-30 weeks), and there were 3 posterolateral

dislocations and 2 posteromedial dislocations. A posterior approach was employed in 4 of 5 patients, and the joint was exposed medially and laterally. The ulnar nerve was mobilized, and transposed anteriorly in 3 cases. Collateral ligaments could not be identified, and the articular cartilage was found to be in good condition after the joint was debrided of fibrous and granulation tissue. The origin of the flexor-pronator group of muscles was found to be intact in all patients, and was left undisturbed during the surgery. On the lateral side, the origin of the extensor muscles was disrupted in 3 cases, and was reattached through drill holes or with suture anchors. A capsulotomy was performed, and no attempt was made to remoce heterotopic bone. The joint was reduced, and an external fixator was placed with 2 pins in the humerus (5 mm, proximal lateral and distal medial) and 2 pins in the ulna (4 mm, proximal lateral and distal medial). Gentle passive range of motion exercises were started the next morning, and active exercises were begun 10-14 days later. The fixator was removed after an average of 5 weeks, and a turnbuckle orthosis was then used several times per day in an attempt to gain further extension. Complications included one ulnar neurapraxia, one broken pin, and one case of blistering around the medial skin flap. The mean followup was 38 months, and a detailed cinical and radiographic review was performed. The outcome was satisfactory in all patients, although 3 patients had occasional mild pain. All elbows were stable, at the average arc of flexion was 123°. The average flexion contracture was 13°, and all patients had full forearm rotation. All patients were able to complete their activities of daily living. Mild joint space narrowing was identified in 4 patients, and periarticular calcifications at the origin of the collateral ligaments was seen in all cases. These results suggest that a stable reduction can be achieved without reconstruction of the collateral ligaments, and the authors suggest that maintenance of the reduction with the external fixator facilitates healing of these structures to the epicondyles while enabling range of motion exercises to commence.

Krishnamoorthy S, Bose K, Wong KP. Treatment of old unreduced dislocation of the elbow. *Injury* 8:39-42.

26 patients (6-60 years of age) were treated for posterior or posterolateral dislocation of the elbow, and 9 had associated fractures. Patients were initially managed by traditional bone setters, and they presented from 2 weeks to 8 months following injury (average 7 weeks). Patients presented with the elbow in extension, and the preoperative arc of motion was only 10-15 degrees. All patients were treated surgically, 18 through a combined medial and lateral approach, and 8 through a posterolateral approach. The interval between the triceps and brachioradialis was used, and the extensor origin was detached. Medially, the epicondyle was exposed by releasing the attached soft tissues. Removal of scar tissue, capsule, and new bone (myositis) was required to reduce the joint, and in 4 patients resection of the radial head was also performed to facilitate reduction. The elbow was immobilized at 90°° for 2-4 weeks, and then active range of motion exercises were started. Complications were limited to 3 nerve palsies (2 ulnar, 1 radial) which resolved. At followup, 9 patients had more than 90 degrees flexion with a flexion contracture less than 30 degrees, and all were asymptomatic with a stable elbow. Eleven patients had more than 60 degrees flexion, with 30-60 degrees of flexion contracture, and no pain or instability. Only 3 patients had a poor result with pain and instability.

Laupattarakasem W, Mahaisavariya B, Mahakkanukrauh C, et al. Old elbow dislocation: Joint mobility after open reduction. *J Med Assoc Thai* 71:289-292, 1988.

Fifty-six patients with unreduced posterior elbow dislocations of greater than 1 months duration were treated by open reduction, 41 of whom had no associated inraarticular fractures. The mean age was 27 years (7 -76 years), and the mean delay in treatment was 7.6 months. The mean followup was 16 months. The Speed technique was employed, and a crucial component of the procedure was exposure of the radial head and collateral ligament. Pin fixation (10-14 days) was employed for instability following reduction, and active motion was begun after 10-14 days. The collateral ligaments were repaired, and ulnar nerve transposition was occasionally performed. The triceps was lengthened by V-Y plasty. The mean preoperative arc of motion was from 7-25°, while the mean postoperative arc was 35-116° flexion. Motion was improved at the expense of flexion contracture. When comparing

results in those with a delay in treatment less than 3 months versus more than 3 months, the former had a small but significant increase in flexion. Overall, the range of motion at followup was felt to justify the use of open reduction, although the long term results remain to be determined.

Mahaisavariya B, Laupattarakasem W, Supachutikul A, et al. Late reduction of dislocated elbow. Need triceps be lengthened? *J Bone Joint Surg* 75b:426-428, 1993.

70 patients with untreated posterior elbow dislocations were treated by open reduction with or without triceps lengthening. The mean age was 24.5 years, and most had a delay in diagnosis/treatment from 1-3 months. 36 patients underwent reduction by a posterior approach (Speed's technique) with a V-Y tricepsplasty, and Kirschner wires were placed across the ulnohumeral or radiocapitellar joints. The pins were removed after 2-3 weeks, and active range of motion exercises were started. 34 patients underwent open reduction without triceps lengthening, 29 of whom required only a lateral incision, while the other 5 had both a medial and a lateral approach. Only 6 patients required placement of a Kirschner wire for instability. Active motion was started after 1-2 weeks. Patients treated by reduction without tricepsplasty had a better arc of motion (115° versus 89°) and a smaller flexion contracture (7° versus 38°) at 16-30 months followup. Poor results (arc < 60°, flexion contracture > 60°, pain/instability) were observed in 5 patients undergoing tricepsplasty and in 2 patients who did not have lengthening of the triceps. A single patient in each group developed a wound infection, and there were no cases of myositis ossificans. There were 2 cases of ulnar neuritis which resolved. The rehabilitation program was more difficult for those treated by tricepsplasty. Tricepsplasty is recommended only when needed to facilitate reduction, and significant contracture of the triceps becomes more likely as the interval between injury and treatment increases.

Naidoo KS. Unreduced posterior dislocation of the elbow. *J Bone Joint Surg* 64b:603-606, 1982.

23 patients with chronic posterior dislocations were treated by open reduction. The mean age was 30 years, and the delay in treatment ranged from 1 month to more than 2 years. The Speed technique was employed through a posterior approach. An inverted V-flap of the triceps was performed, and the ulnar nerve was mobilized. All scar tissue is removed, and a complete release is performed including the capsule and the collateral ligaments. Articular destruction was not seen. The joint was gently reduced, and the reduction maintained with a Kirschner wire through the olecranon and into the distal humerus with the elbow at 90° flexion. An inverted V-Y repair of the triceps was necessary depending upon the degree of contracture. The wire is removed after 12-14 days, and active range of motion exercises were started. A collar and cuff were worn for 6-12 weeks. Wound closure could not be completed in 3 cases, and healing was by secondary intention. A single postoperative infection occured, while 5 patients had ulnar neuritis (3 fully recovered, 2 partially recovered). The arc of motion at followup was > 90° in 10 patients, between 60 and 90° in 5 patients, and less than 60° in 8 patients. The degree of motion did not seem to correlate with the time between injury and definitive treatment. Overall, the authors felt that the procedure was beneficial irrespective of patient age and the delay in seeking treatment.

Shahriaree H, Sajadi K, Silver CM, et al. Excisional arthroplasty of the elbow. *J Bone Joint Surg* 61a:922-927, 1979.

Thirty patients with bony or fibrous ankylosis of the elbow due to trauma (22), inflammatory disease (7) or osteoarthritis (1) were treated by excisional arthroplasty of the elbow with interposition of gelfoam. The age range was 11-58 years, and the minimum followup was 18 months. A posterior approach was employed, which was curved laterally across the olecranon. The triceps is split, and the ulnar nerve is not routinely exposed. Capsular attachments are divided, and the distal humerus is exposed subperiostially. The radial head is excised, and the medial and lateral condyles are excised. A notch is created in the trochlea, and gelfoam sutured through drill holes across the surface of the distal humerus. A Steinmann pin is placed from the olecranon into the distal humerus, and a posterior splint is used for immobilization with the elbow in 90° flexion. The pin is removed after 2 weeks, and active range of motion exercises are started. A sling was worn for 6 weeks. At the time of latest followup, 77% were pain free, and all but one

patients had a mean arc of motion of 80°. Lateral instability was found in all but one patient, however this did not interfere with work. The best results were in younger patients with good muscle strength and a posttraumatic etiology.

Silva JF. Old dislocations of the elbow. *Ann Roy Coll Surg Engl* 22:363-381, 1958.

The management of 44 cases of chronic (4 weeks to 15 years) elbow dislocation is presented (25 open reductions, 11 arthroplasties with fascia lata, and 8 distal humeral prostheses). Patients typically present with the elbow fixed in extension. Pathologic changes include myositis ossificans, scattered deposits of osteoid tissue around the bony structures, contracture of the collateral ligaments, thickening of the capsule, shortening of the ulnar nerve, loosening of articular cartilage, and contracture of the triceps. Results were graded according to motion. Only 8% of those treated by open reduction achieved more than 90 degrees of motion, and 72% had less than 55 degrees total motion. The results were similar in those treated by fascial arthroplasty. Of the 8 patients treated with prosthetic replacement of the distal humerus, 5 achieved greater than 60 degrees motion. The authors recommend prosthetic reconstruction if resources are available.

Speed JS. An operation for unreduced posterior dislocation of the elbow. *South Med J* 18:193-198, 1925.

The author describes a technique for open reduction of unreduced posterior elbow dislocations. A longitudinal posterior approach is employed, and this is curved laterally across the radiocapitellar joint. The triceps tendon is detached at the musculotendinous junction, and the muscle belly is split exposing the posterior aspect of the humerus. A circumferential capsulotomy is performed. The distal humerus is completely freed of soft tissue attachments, and periostial new bone is resected posteriorly. The radial head is also exposed. Fibrous tissue is removed from the joint surfaces. The joint is reduced, and the triceps muscle and posterior periostium are repaired. The fascia is repaired around the radial head, and the triceps tendon is reattached anatomically. The elbow is splinted at 90° flexion for 7-10 days, and gentle range of motion exercises are started.

IV. Chronic Osteomyelitis

Chronic osteomyelitis is a major contributor to the global burden of musculoskeletal disease, and most cases occur in the developing world. Predisposing factors include poor hygienic conditions, malnutrition, bacteremia from skin ulcers/secondary skin infections, and sickle cell disease. Limited access to medical facilities often results in inadequate management of acute osteomyelitis, and patients often present at an advanced stage with extensive involvement. Appropriate treatment includes the aggressive debridement of all infected/devitalized tissue, in addition to antibiotics (although cases have been managed successfully in centers where antibiotics were not available). The “Paprika” sign (punctate bleeding) may help to define the appropriate extent of bony debridement. Related concerns include dead space management, providing adequate soft tissue coverage, treating segmental bone loss and/or angular deformity, and finally addressing any leg length discrepancy. With modern treatment methods, more than 80% of such cases may be controlled. Although more sophisticated approaches (vascularized soft tissue and composite grafts, bone transport using the Ilizarov approach) have been applied with success in recent years, older methods including debridement followed by conventional bone grafting or the Papineau technique may also be successful.

Although most cases of chronic osteomyelitis in the western world are secondary to trauma (open fractures, gunshot wounds), in developing countries chronic osteomyelitis often begins as acute hematogenous osteomyelitis. Abscess formation is accompanied by necrosis of bone, and the avascular segment is defined as the sequestrum. When the periostium remains viable, bone formation is stimulated and significant regeneration is possible, particularly in children less than 8 years of age. In fact, complete regeneration has been documented following sequestration of the tibial shaft. This periostial response gives rise to the involucrum, and the status of the periostium helps to predict the outcome. The sequestrum serves as a nidus of infection, and commonly leads to recurrent episodes of infection and drainage. Since controlling the disease process requires removal of the focus of

infection, sequestrectomy is a major component of any debridement procedure. Most authors recommend that sequestrectomy be delayed until an adequate involucrum has formed in order to maintain stability. Early sequestrectomy may compromise stability, and an infected nonunion is certainly more difficult to manage than an infected union. If there is concern regarding stability after this procedure, the limb can be protected in a cast until the involucrum has become more mature. In contrast, several reports have suggested that sequestra may be reincorporated following antibiotic treatment, and that sequestrectomy is not always required.

The Cierny-Mader classification has been devised for adults with chronic osteomyelitis, and in addition to defining different anatomic/radiographic patterns of involvement, this scheme also recognizes the importance of host variables. The anatomic component includes four major types, namely medullary, superficial, localized, and diffuse. The patient or "host" is classified as A (healthy), B (local and or systemic compromise), and C (not a candidate for treatment). In general, the "A" and "B" hosts are candidates for an aggressive "limb salvage" approach. Although perhaps less useful in children, this highlights the importance of host variables in the overall treatment approach. Adequate nutritional support is essential for success, especially in developing countries where malnutrition and chronic illness are prevalent.

Unfortunately, severe or untreated acute infections may destroy the periostium, eliminating the potential for regeneration and resulting in segmental bone loss. After debridement and stabilization of the soft tissue envelope, conventional bone grafting represents one option for managing segmental bone loss. External fixation may facilitate grafting procedures, and bone transport represents an alternative to conventional grafting if the technology is available. In the lower leg and the forearm, transference procedures have been used effectively to bridge extensive defects in the tibia, the radius, or the ulna. Numerous techniques have been described for using the ipsilateral fibula as a bypass graft for extensive loss of the tibial diaphysis. Creation of a single bone forearm may adequately treat cases of chronic osteomyelitis in the forearm, as long as the radiocarpal and ulnohumeral joints are intact.

Abdel-Rahman HA, El Com S. Treatment of tibial osteomyelitic defects and infected pseudarthroses by the Huntington Fibular Transference Operation. *J Bone Joint Surg* 63a: 814-819, 1981.

Six patients (5-18 years old) with tibial defects from chronic osteomyelitis were treated by the two-stage Huntington fibular transference procedure. In the first stage, two incisions are employed to expose the proximal tibia and the proximal fibula at the site of osteotomy (through healthy tissue rather than the infected zone). The lateral surface of the tibia is subperiostially exposed, and a trough (angled upward and inward) is created in which to place the fibula. Through an anterolateral incision (interval between the peroneal muscles and the soleus), the fibula is osteotomized and translated into the trough (screw fixation). The limb is immobilized in a cast for 10-12 weeks, and the second stage is performed after healing. The distal transference is similar, and is performed through 2 incisions in the middle of the leg and a single incision distally. A cast is then reapplied until healing. Patients are allowed to bear partial weight for 8 weeks following union, after which they bear weight as tolerated. The theory behind the two stage transfer is that the fibula acts as a pedicle graft, and maintains it's blood supply throughout the treatment period. The fibula hypertrophies over time, and the outcomes were adequate in all cases. The procedure is recommended for children with defects that cannot be managed by conventional bone grafting.

Aronson J, Johnson E, Harp JH. Local bone transportation for treatment of intercalary defects by the Ilizarov technique. Biomechanical and clinical considerations. *Clin Orthop Rel Res* 243:71-79, 1988.

This review article outlines the basic science principles and technical considerations behind the use of bone transport for segmental defects. Mechanical forces can stimulate production of bone by two mechanisms. Distraction osteogenesis describes the production of new bone between corticotomy surfaces subject to gradual distraction, while transformational osteogenesis involves the stimulation of healing at a pathologic bony interface by mechanical stimulation (both compression

and distraction). Bone transport relies on both of these mechanisms. The technique of corticotomy is important. Only the cortex should be divided, which preserves the periostial and the medullary blood supply. Delaying the process of distraction by 3-7 days allows time for local neovascularization. There are three basic goals involved in transport. First, stability and alignment must be maintained, and a ring fixator allows fixation of the proximal segment, the segment to be transported, and the segment to which the transport will dock. Second, the transported segment must be oriented correctly, and distraction must be applied at a rate that will promote osteogenesis. Third, the site of docking must be loaded in compression to stimulate healing (transformational osteogenesis). The external fixator also enables correction of angular deformities, and a bifocal transport may also be accomplished (distraction osteogenesis at two sites within the bone). Technical considerations are also outlined in this excellent review.

Bassey LO, Antia-Obong OE, Antia UE. Sequestrectomy and local muscle flap implantation for chronic osteomyelitis in children and adolescents. *East Afr Med J* 72:787-790, 1995.

Forty-one children (average age 11.9 years) with chronic osteomyelitis were treated by sequestrectomy and local muscle flap implantation. Sites of involvement included the femur (56%), tibia (15%), humerus (14%), and clavicle (5%). Patients were started on antibiotics for 3-7 days (augmentin), and any sinusus or discharge was cultured. After an adequate debridement down to bleeding bone, a local muscle flap was sutured over the area of bony involvement. Suction drainage was employed postoperatively. For the femur, either sartorius or vastus lateralis was used. Other muscle groups included the gastrocnemius, soleus, tibialis anterior, biceps brachii, pectoralis major, and the supinator. Pathologic fractures were stabilized with some form of external fixation. Wound dehiscence was encountered in 19.5%. Overall, all cases had healed without recurrence at 3 years followup. Other complications included joint stiffness (6), pathologic fracture (3), and limb shortening (3). Sequestrectomy alone was associated with complications in 47%, thus the addition of the muscle flap was felt to improve the outcome.

Bosworth DM, Liebler WA, Natstasi AA, Hamada K. Resection of the tibial shaft for osteomyelitis in children. *J Bone Joint Surg* 48a:1328-1338, 1966.

Six children with extensive involvement of the tibia were treated by subperiostial resection of the tibial shaft. This led to control of the infection, improvement in other sites of involvement, and there was no recurrence at 32 year followup. Excellent regeneration of the tibial shaft occured in younger patients (2,6, and 7 years old), but not in older patients (9,11,and 16 years old). Delayed regeneration occured in a single 8 year old. Shortening (1-7 inches) was seen in several patients, and appeared to result from physeal damage by the infection. All patients were working at the time of followup. Fibular transfer is suggested for cases in which regeneration fails to occur. Of note, these patients were managed prior to the availability of antibiotics.

Campanacci M, Zanoli S. Double tibiofibular synostosis (Fibula pro Tibia) for non-union and delayed union of the tibia. End result review of one hundred and seventy-one cases. *J Bone Joint Surg* 48:44-56, 1966.

The single stage fibular transference procedure was employed for nonunion or delayed union of tibial fractures in 171 cases. The proximal portion is exposed through a lateral incision extending from above the fibular head to the lateral aspect of the anterior tibia, and the peroneal nerve is dissected free and protected. The cartilage of the proximal tibiofibular joint is excised (with care to avoid the physis in children), and the proximal fibula is subperiostially exposed and translated medially into a trough in the proximal tibia. Fixation is with screws, and the periostial flap with the insertion of the biceps is reattached. Next, a distal longitudinal incision between the tibia and fibula is performed, and the bones are subperiostially exposed. A transverse osteotomy of the fibula is performed, and transferred to a trough in the distal tibia. Screws are used for fixation. A long leg cast is applied, and weightbearing is encouraged. The ages ranged from 10-65 years, and only 6 patients were children. 112 patients had open fractures, and 58 were infected. The procedure was performed from 1-3 years after the initial injury in most patients. Followup ranged from 1-10 years. Union was achieved in 98% (<

8 months in 86%). There were 5 peroneal palsies identified early in the study. Range of motion was maintained, and no patient had recurrence of infection. The site of pseudarthrosis is not exposed, unless it is necessary to correct angular deformities.

Chacha PB, Ahmed M, Daruwalla JS. Vascular pedicle graft of the ipsilateral fibula for non-union of the tibia with a large defect. An experimental and clinical study. *J Bone Joint Surg* 63B:244-253, 1981.

Transfer of the ipsilateral fibula as a vascularized pedicle graft is described in both a basic science and a clinical study. In contrast to other techniques for fibular transfer, the fibula is aligned along the central axis of the tibia, which avoids eccentric loading, and theoretically decreases the risk of fracture. An experimental study was in monkeys revealed that the muscle pedicle grafts remained viable, in contrast to free grafts. The clinical study included 11 patients (2-62 years old) with a defect of 2.5-12.5 cm (average 4.5 cm). The entire fibula is exposed through the interval between the peronei and the soleus. The peroneal vessels are protected, and all but one centimeter of the FHL is detached. Similarly, the FDL and tibialis posterior are left attached over a one centimeter segment. The tibialis posterior is elevated off the interosseous membrane to expose the tibia. The posterior tibia is decorticated, and the fibular graft (osteotomized proximally and distally) is brought over and secured to the posterior surface of the tibia and secured with 3 screws above and below the defect. A short leg cast was applied for 8-10 weeks. After this, a caliper or PTB cast is used, and weight bearing is permitted. A caliper was used for 18 months to avoid stress fracture. All but one patient healed within 4-6months, and 2 had stress fractures of the graft. Sepsis should be well controlled prior to reconstruction.

Cierny G. Chronic osteomyelitis: Results of treatment. *Instr Course Lect* 39:495-508, 1990.

This instructional course summarizes important principles in the management of chronic osteomyelitis in adults. Treatment is not only based upon the site and degree of involvement, but also on host factors (comorbidities, nutritional status, etc.), and the resources and expertise of local caregivers. An anatomic classification is reviewed, which includes four major types (medullary, superficial, localized, and diffuse). Medullary lesions arise within the endostium, while superficial lesions involve the outer surface of the bone and are associated with a defect in the soft tissue envelope. Localized chronic osteomyelitis involves a well defined sequestered region of cortical bone. In these first three types, the infected bone can be resected without causing structural compromise. The fourth type is permeative, involves an entire segment of the bone, and results in instability both before and after resection. The patient or "host" is classified as A (healthy), B (local and or systemic compromise), and C (not a candidate for treatment). In the author's experience, 82% of patients were candidates for limb salvage using a variety of techniques. Several options are available for dead space management following an adequate debridement, and the best choice may be coverage with muscle transposition or free flaps. Antibiotic beads are helpful in staged dead space management. The Papineau technique, involving open cancellous bone grafting, represents the simplest method. It is recommended that the patient be an "A" host, that the bone be subcutaneous, and that the wound be adequately contoured to receive the grafts. The thickness should be less than 2 centimeters to prevent necrosis of the central portion of the graft. Overall, 70-80% of patients achieve an adequate result with this technique alone. Bone grafting is generally required for infected nonunions, and options include cancellous grafts, pedicled osseous transfers, free bone flaps, and bone transport using an external fixator. The more complex methods of reconstruction require specialized training and equipment, and may not be appropriate in many settings.

Cierny G. Infected tibial nonunions (1981-1995). The evolution of change. *Clin Orthop Rel Res* 360: 97-105, 1999.

The author reviews advances in the management of infected tibial nonunions in a series of 150 cases treated over a 15 year period. Older methods (still appropriate for most of the developing world) included sequential debridements, healing by secondary intention, and bypass bone grafting. Changes in philosophy and techniques have revolved around the development of rigid external

fixation, techniques for soft tissue reconstruction (muscle transposition, free flaps, composite transfers), and local antibiotic depots. Earlier wound stabilization promotes functional recovery, and decreases complications. The 150 cases described were managed by a specialized protocol, and limb salvage was attempted in 89% of patients. Deep cultures (preoperative) helped to guide the choice of antibiotics, and all isolates were treated. Intravenous agents were used for four days, and patients were converted to oral agents which were continued for a total treatment time of 6 weeks. Debridement was performed, and closure was achieved over antibiotic beads. Seventy-five percent of cases were placed in an external fixator, and coverage was achieved within 7 days. Dead space management included antibiotic beads, cancellous grafts, flaps, or combinations of these. 49 patients during the first 5 years of the study were managed in this fashion. In the next 10 years of the study, 101 patients were treated by more complex reconstructions (bone transport, internal fixation, free flaps). The more complex reconstructions resulted in a decrease in the rate of amputation (19% to 6%), with no compromise in the rate of success.

Cierny G, Zorn K. Segmental tibial defects. Comparing conventional and Ilizarov methodologies. *Clin Orthop Rel Res* 301:118-123, 1994.

Of 44 patients with segmental tibial defects following debridement of infected tibial nonunions were treated by either cancellous bone grafting/ tissue transfers (21 pt) or bone transport using the Ilizarov method (23 pt). In the former, the average defect was 8.5 centimeters, and 57% of infections were polymicrobial. A total of 83 additional procedures were required (77% need soft tissue reconstruction), and the complication rate was 60% (6 fractures, 5 infections, 3 flap losses). The success rate was 74%. Twenty-four patients required tissue transfers to obtain coverage, and 19 fibular (contralateral) transpositions were employed in addition to the cancellous grafting. In the latter, the average defect was 6.5 centimeters, and 17 additional procedures were required (14% require soft tissue reconstruction). The success rate was 71%. Complications were seen in 33% (4 stress fractures, 1 delay in regenerate). This group had fewer procedures, a shorter time in the hospital, and a shorter disability time. There was also a savings in cost. The authors feel that in order to avoid complications, the length of regenerate should be kept below 6 centimeters in the adult tibia. Overall, the final outcome was the same using either of these approaches, but the Ilizarov strategy was felt to be superior in Cierny B hosts, in addition to being easier, faster, and more cost effective. Conventional methods may be better in those with larger zones of injury.

Daoud A, Saighi-Bouaouina A. Treatment of sequestra, pseudarthroses, and defects in the long bones of children who have chronic hematogenous osteomyelitis. *J Bone Joint Surg* 71a:1448-1468, 1989.

The authors review the management and outcome in 34 patients (mean age 7 years, mean duration of infection 13 months) with chronic osteomyelitis complicated by sequestration and pseudarthrosis or segmental bone loss. Patients were divided based upon the prescence of an involucrum. The status of the periostium is crucial in predicting outcome and determining the most appropriate treatment. If the periostial sleeve remains viable (an involucrum has formed), the diaphysis has the potential to regenerate and management is aimed at preventing fracture while the bone heals. Grafting is not required in this circumstance. Pseudarthrosis, with or without segmental bone loss, reflects damage to the periostial tube. This may potentially relate to ischemia from compression of periostial vessels by an abscess. Surgical recommendations should be based upon the status of the involucrum. A staged approach is recommended, beginning with sequestrectomy and debridement, antibiotics, and immobilization. The clinical course and sed rate are followed to determine the appropriate timing for the second stage, which involves corticocancellous bone grafting and immobilization, and any deformity is also addressed at this time. Fixation was with intramedullary K-wires and/or screws. Fibular osteotomy may allow easier correction of angulation, and may promote healing of the tibia. The delay was up to 6 months. Cancellous chips (Papineau) were used if there was a skin defect, or the skin could not be closed. The authors recommend early sequestrectomy, rather than delaying this until an involucrum has formed, based upon the argument that a persistent sequestrum (ongoing infection)

inhibits formation of the involucrum. The fibular transference procedure was attempted in 8 cases, and all had complications. The major problem was with healing of the proximal segment, and a single patient developed a peroneal palsy. Overall, at 37 months followup, all but one patient healed. An average of 1.8 procedures/patient was required.

Dibbell DG, Edstrom LE. The gastrocnemius myocutaneous flap. *Clin Plast Surg* 7:45-50, 1980.

The authors describe this versatile flap which may be useful both in cases of trauma and osteomyelitis. The flap can extend in length from the midpoint of the superior politeal fossa to within 5 centimeters of the medial malleolus. Coverage may be achieved from the anterior and medial knee joint to the junction of the middle and distal thirds of the tibia. The medial gastrocnemius flap is used much more commonly than the lateral flap, and both may be employed simultaneously. The technique for harvesting the medial flap is described in detail, and injection with flourescein is suggested to assess vascularity. The blood supply arises high in the popliteal fossa, and this area is not routinely exposed during mobilization of the flap. The donor site must be skin grafted.

Eckardt JJ, Wirganowicz PZ, Mar T. An aggressive surgical approach to the management of chronic osteomyelitis. *Clin Orthop Rel Res* 298: 229-239, 1994.

Thirteen adults (19-76 years old) with a mean duration of infection of 12.8 years were treated for chronic osteomyelitis. Debridement was performed at 2-3 day intervals until a healthy granulation bed was present, and intraoperative cultures were negative. Empiric antibiotic therapy was begun at the time of initial debridement, and the agent was modified based on the culture results. Delayed closure was performed after adequate debridement. Intravenous antibiotics were continued for an average of 5 weeks, and some patients were treated with oral agents for 2-6 additional weeks. Iliac crest bone grafting was performed in cases of bone loss or a compromise of structural integrity, and a local muscle flap with skin grafting was performed if necessary. Patients required an average of 4.2 debridements (2-8), and 7 underwent bone grafting while 2 required flaps. There were no recurrences at 58 months followup, and both function and cosmesis were felt to be acceptable in all but one patient, who ultimately underwent hip disarticulation.

Emami A, Mjoberg B, Larsson S. Infected tibial nonunion. Good results after open cancellous grafting in 37 cases. *Acta Orthop Scand* 66:447-451, 1995.

The Papineau technique was employed in 37 infected tibial nonunions, 6 months to 2 years after the primary procedure. Twenty-two cases had a gap from 1.5- 3 cm, and the others had a large bony defect with some cortical contact. After complete debridement (12 patients required 2 procedures), patients were stabilized with an external fixator. The wound was covered for 5 days, then inspected and redressed. Daily dressing changes were then completed until granulation tissue was present (8-14 days), and the defect was grafted with autogenous iliac crest. Five days following grafting, the dressing was changed, and daily irrigation was performed until the graft was covered with granulation tissue. Six patients required a second grafting procedure, and a split thickness skin graft was performed in 20 patients (2-4 months following the initial grafting). In those who achieved closure without skin grafting, the overlying skin was often adherent to the underlying bone, but no further intervention was necessary. All patients achieved union, and coverage was achieved by 5 months in all patients. Complications included 2 refractures, one following a high energy injury. The authors recommend an orthosis or splint to avoid this. Debridement is critical, and nearly 1/3 of patients were debrided a second time prior to grafting.

Fitzgerald RH, Ruttle PE, Arnold PG, et al. Local muscle flaps in the treatment of chronic osteomyelitis. *J Bone Joint Surg* 67a:175-185, 1985.

Forty-two patients (mean age 39 years) treated for chronic osteomyelitis were reviewed at a mean of 2.7 years following treatment. The etiology was post-traumatic (28), soft tissue trauma without fracture (8), elective surgery (3), and hematogenous (3). All patients had a sinus tract. Nine of these patients had an infected nonunion, and the tibia was involved in 62%. Pseudomonas was isolated in 38%, and 44% had gram negative organisms isolated. Eleven of fourteen staphylococcal species isolated were resistant to penicillin. The first stage

involved debridement, and 28 patients required multiple procedures to achieve a clean wound. Local muscle flaps were applied 2 days after the final debridement, mainly a soleus or gastrocnemius flap for tibial defects. Other local muscle flaps included the flexor digitorum communis, the extensor pollicis brevis, the extensor digitorum communis, the extensor hallucis longus, and the vastus medialis. Five patients were covered with a combination of muscles, and a split thickness skin graft was applied 48 hours after the muscle flap. The mean duration of intravenous antibiotic (based on deep cultures) therapy was 24 days, and 12 patients were treated with oral agents for 10-80 additional days. Additional procedures included revision of the muscle flap in 4 patients, and additiona; split thickness skin grafting in 9 patients. Nine patients had a nonunion following treatment, and were treated with bone grafting. At followup, 39 patients had no signs of recurrent infection , 3 patients had recurrent infection, and a single patient chose to have an amputation for persistent nonunion. There were no functional deficits resulting from the muscle flaps. Overall, this approach resulted in adequate salvage in patients with chronic osteomyelitis.

Fowles JV, Lehoux J, Kassab M, et al. Tibial defect due to acute hematogenous osteomyelitis. Treatment and results in twenty-one children. *J Bone Joint Surg* 61b:77-81, 1979.

In this group of children, defects averaging 4 centimeters (0.5-14 cm.) occured following acute tibial osteomyelitis, due to either the infection or to early sequestrectomy (< 1 year, most removed within the first 3 months). Only 4 children had spontaneous regeneration of the shaft. Reconstruction was delayed until sinuses had healed and the infection had cleared. Eleven patients were treated by a tibiofibular graft through a posterolateral approach, and six had fibular transference. Fibular transference was selected when there was < 5 centimeters of the tibial metaphysis present, or in the case of a fixed deformity from an irreducible dislocation of the tibiofibular joint or bowing of the fibula. Initially a two stage transfer (Huntington) was employed, but later the procedure was completed in a single stage. Complications included 2 peroneal palsies (resolved) and 4 recurrent infections which were treated effectively with drainage and antibiotics. Grafts healed within four months. At 3 years followup, all were free of infection and ambulating. Leg length discrepancy from physeal damage, and joint ankylosis from coexisting septic arthritis, were seen in a subset of patients. The fibula was hypertrophied, and the articular relationship at the ankle was preserved in all but 3 patients. The authors recommend delaying sequestrectomy for 6-12 months, and if necessary performing the reconstruction shortly after sequestrectomy.

Ger R, Efron G. New operative approach in the treatment of chronic osteomyelitis of the tibial diaphysis. A preliminary report. *Clin Orthop Rel Res* 70:165-169, 1970.

One important issue in the management of chronic osteomyelitis is the provision of adequate tissue coverage, and local muscle transposition followed by split thickness skin grafting (6 days after) is described in 9 patients. The soleus flap is useful to achieve coverage of the tibia in chronic infections.

Ger R. Muscle transposition for treatment and prevention of chronic post-traumatic osteomyelitis of the tibia. *J Bone Joint Surg* 59: 784-791, 1977.

Local muscle flaps may be helpful in treating acute tibial fractures with soft tissue loss, or post traumatic chronic osteomyelitis of the tibia. Techniques for coverage of defects in the proximal, middle, and distal thirds of the tibia are presented. After local muscle transposition, the patient is placed in a cast, and is brought back approximately 6 days later for split thickness skin grafting over the flap. For proximal defects, the medial head of the gastrocnemius can be utilized. For the middle third of the tibia, the soleus muscle is used, and for distal lesions either the flexor hallucis longus or the abductor hallucis are the best options. The tendoachilles may also be used if the ankle has been severely injured or is ankylosed. Forty-three patients were treated using this approach. For those treated within 30 days of their injury (22), there were no cases of post traumatic osteomyelitis, and all fractures healed. There were 3 complications, including minor loss of a skin graft, major loss of a skin graft, and deep vein thrombosis. In patients previousely treated who presented with loss of coverage at more than 5 month following their

injuries, all but one was slavaged. Patients who presented with chronic osteomyelitis (17) did well overall. Seven of these had complications, but at final followup all but one healed. Complications included malalignment (1), refracture (1), sepsis requiring amputation (1), temporary (1) or chronic (1) sinuses, and partial loss of muscles (2). There were no significant functional limitations at followup.

Ger R. Transposition of the tendo calcaneus for post-traumatic bone defects of the tibia. *J Bone Joint Surg* 59:366-369, 1978.

The author presents several options for treating supramalleolar soft tissue defects associated with tibial fractures or other pathology. Transposition of the soleus is the best choice, but if the lesion is too distal then the tendoachilles may be substituted. Due to the anticipated functional morbidity, the procedure should be considered as a salvage when amputation is the next choice, when the ankle is ankylosed, or when loss of the tendon is preferable to chronic ulceration with or without osteomyelitis. Subcutaneous tenotomy is used to release the muscle distally, and the tendon (with it's paratenon intact) is delivered up into the wound. A gutter may need to be cut into the tibia to enable coverage. The muscle/tendon unit is sutured to the edges of the defect. If greater coverage is required, the flexor digitorum longus can be mobilized. The soleus should not be mobilized, as this will compromise the vascularity of the tendoachilles flap. A split thickness skin graft may then be applied. Ten adults were treated succesfully using this approach.

Green SA, Dlabal TA. The open bone graft for septic nonunion. *Clin Orthop Rel Res* 180:117-124, 1983.

Fifteen patients with septic nonunion (mean age 38 years) were treated by a two-stage protocol. In the first stage, following debridement (one or more times), an external fixator is applied to stabilize the limb. Dressing changes were then completed three times per day until granulation tissue was present (mean 4 weeks). In the second stage a cancellous bone graft (iliac crest or upper femur), and postoperatively the wound was covered in gauze and kept moist with saline. Daily dressing changes were continued until the wound had epithelialized. Patients were hospitalized for an average of 8 weeks. The fixator was removed at an average of 7.5 months, and patients then used a cast/orthosis for 2 years. At 3.5 years followup, thirteen cases united, and below knee amputation was performed in the two patients with persistent nonunion. Both had undergone multiple procedures prior to this two-stage approach. Technical points include keeping the graft no greater than 1.5 centimeters from the exposed granulation tissue, and maintaining the patient at bedrest for at least 10 days after the grafting procedure. Either posterolateral bone grafting, or incorporating the fibula into the graft mass, may improve the ultimate stability. While in the fixator, patients should minimize weightbearing. This approach may be applied to defects up to 9 centimeters in length, otherwise fibular transposition may be required.

Griffiths JC. Defects in long bones from severe neglected osteitis. *J Bone Joint Surg* 50B:813-820, 1968.

Twelve cases of severe chronic osteomyelitis are reviewed, all of which presented with segmental bone defects, or large sequestra without any involucrum. If no involucrum has formed, conservative management is likely to fail, and early sequestrectomy to eradicate infection and affect healing of the surrounding soft tissues (including sinuses) is recommended. Reconstruction at most sites involves bone grafting, however in the forearm and the lower leg bone transference may restore stability. Numerous techniques have been described for fibular transfer, and in the forearm synostosis between the distal radius and the proximal ulna represents the best option. If possible, transference is more practical than grafting unless the defect is small. Coexisting growth disturbance from physeal damage may be severe, and many patients may ultimately benefit from amputation for large discrepancies. Even if amputation is required for shortening associated with tibial involvement, reconstruction by fibular transference preserves a stable lower limb segment and allows the surgeon to perform a Syme rather than a below or through knee amputation.

Harmon PH. A simplified surgical approach to the posterior tibia for bone-grafting and fibular transference. *J Bone Joint Surg* 27:496-498, 1945.

A posterolateral approach to the tibia is described,

in which the interval in between the soleus/FHL and the peroneals is used to gain access to the posterior surface of the fibula. The soleus and FHL are retracted medially, and the tibialis posterior is dissected from the interosseous membrane. The posterior muscle mass can then be retracted medially to expose the posterior tibia. This approach is helpful when there is significant scarring in the anterior compartment, and can be used for fibular transference as well as posterolateral bone grafting.

Jain AK, Sharma DK, Kumar S, Sethi A, et al. Incorporation of diaphyseal sequestra in chronic haematogenous osteomyelitis. *International Orthopaedics (SICOT)* 19:238-241, 1995.

Seventeen patients with large diaphyseal sequestra, and a variable degree of involucrum formation, were treated by surgical drainage, immobilization in plaster, and 6-8 weeks of antibiotics (IV and oral). Cases presented within 2-6 weeks of the onset of symptoms, and 10/17 had draining sinuses. Sixteen of seventeen demonstrated incorporation of more than 60% of the sequestrum, and 7 had near complete incorporation. In this setting, the authors do not recommend early sequestrectomy. In children with chronic osteomyelitis, the authors recommend surgical drainage, immobilization and antibiotics as the initial management. In those who do not show evidence of incorporation, sequestrectomy may be performed later.

Langenskiold A. Hahn's operation for pseudarthrosis after osteomyelitis of the tibia in children. A Report of three cases. *Acta Orthop Scand* 54:714-720, 1983.

Three patients with chronic osteomyelitis and extensive sequestration of the tibia were managed by fibular transfer (Hahn technique). Excision of scar tissue and bony debridement were performed through a longitudinal incision. The dissection continued along the anterior interosseous membrane until the fibula was encountered. The fibular periostium was split longitudinally (medially), and after subperiostial exposure was completed, the bone was osteotomized just proximal to the level of the residual tibia at each end. The fibula was implanted into the tibial metaphysis, and secured with a screw. Local bone graft was added, and after closure patients were placed in a long leg cast. Limb length discrepancy was treated by epiphysiodesis.

Lauschke FHM, Frey CT. Hematogenous osteomyelitis in infants and children in the northwestern region of Namibia. Management and two-year results. *J Bone Joint Surg* 76:502-510, 1994.

The management of osteomyelitis is reviewed in 55 patients (7 days - 14 years) who were classified as early acute (≤ 3 days from the onset of symptoms), late acute (4-6 days), and chronic (> 6 days). Predisposing factors such as poor hygiene, malnutrition, and other infectious diseases were seen in two thirds of patients. Staphylococcus aureus (penicillin resistent) was found in 29/32 positive cultures, and Escherichia coli, proteus mirabilis, and enterobacter were isolated in 3 other patients. The femur and the tibia were most commonly involved, and 4 patients had more than one site of involvement. Thirteen patients had reactive effusions at neighboring joints. Antibiotics alone were successful in all patients with early acute disease, and in 4/8 with a late acute presentation. Antibiotics included cloxacillin or flucloxacillin, and gentamicin was added if there was persistent fever or sepsis. The duration of antibiotics depended upon the clinical response, including the white blood cell count and the sed rate. In general, intavenous therapy was required for 1-2 weeks in early acute, 2-3 weeks in late acute, and 3-4 weeks in those with chronic osteomyelitis. Oral antibiotics were continued for 2 weeks (early acute), 3-4 weeks (late acute), and 1-2 months (chronic). Surgical treatment was required in half of the patients with late acute and all of the patients with chronic osteomyelitis. Abscesses were drained acutely (often with cortical fenestration), and debridement/sequestrectomy were performed early if needed. Local skin or muscle flaps were required in 7 patients to obtain coverage. Thirteen patients with bony instability following debridement were managed with a cast or an external fixator, and fibular transference was helpful in several patients. At 2 year followup, six of seven early acute cases had a good result, while the last developed recurrence of infection at the same site. In the late acute group, 19 of 23 patients had an adequate result. Poor results were seen with development of chronic osteomyelitis associated with osteolysis of the femoral head (2), and osteolysis of the tibia (1), and a single valgus

deformity from necrosis and collapse of the lateral femoral condyle. In the chronic group, at 2 years followup,15 of 26 had excellent motion with no recurrence of disease (good result). Six patients had a poor result owing to recurrence of infection, or limb shortening associated with avascular necrosis of the femoral head or complicating fibular transposition.

Lowe HG. Radio-ulnar fusion for defects in the forearm bones. *J Bone Joint Surg* 45B:351-359, 1963.

Seven patients (5-48 years old) with segmental bone loss in the radius or the ulna (3 due to chronic osteomyelitis) were treated by creation of a single bone forearm. A prerequisite is stability at the radiocarpal and ulnohumeral joints. Although forearm shortening should be expected, and forearm rotation is limited, overall the results were adequate both functionally and cosmetically.

Mackowiak PA, Jones SR, Smith JW. Diagnostic value of sinus-tract cultures in chronic osteomyelitis. *JAMA* 239:2772-2775, 1978.

Cultures obtained from sinus tracts and from operative biopsies were compared in 40 patients with chronic osteomyelitis. Only 44% of organisms isolated from sinus tracts were also identified from the operative cultures. Staphylococcus aureus was isolated from 60% of operative specimens, while 23% had species of Enterobacteriaceae, and 9% had pseudomonas. Twelve percent were polymicrobial. A correlation was established between the isolation of staphylococcus aureus from a sinus tract and the same organism from the operative culture. The authors suggest that appropriate cultures may be obtained from bone biopsy specimens, aspirations of pus, and implants. Cultures obtained during a debridement procedure, including sequestra, may be contaminated by sinus tract material. Other than staphylococcus aureus, isolates from sinus tracts cannot predict the organism responsible for the infection.

Mader JT, Mohan D, Calhoun J. A practical guide to the diagnosis and management of bone and joint infections. *Drugs* 54:253-264, 1997.

This review article considers the evaluation and treatment of septic arthritis (gonococcal and nongonococcal) and osteomyelitis, including recommendations for antibiotics. For osteomyelitis, recommendations are based upon the Cierny-Mader classification, which defines the disease process independent of etiology, location, or chronicity. Each case is stratified by anatomic class (medullary, superficial, localized, diffuse) and physiologic class (A = normal host, B = systemic compromise, local compromise, or both, C = treatment is worse than the disease). In cases of hematogenous osteomyelitis (stage 1), positive blood cultures or joint aspirates may guide therapy, and a bone biopsy may then be unnecessary. Identification of the organism is paramount, and bone aspiration of biopsy may be required to make the diagnosis. The most common pathogen is staphylococcus aureus. Specimens should ideally be obtained prior to starting antibiotics. Sinus tract cultures do not correlate with deep cultures from bone. Radiographic changes lag several weeks behind clinical changes. In stage 2 the outer cortex of the bone is involved, while stages 3 and 4 will include soft tissue changes, lytic changes, sclerosis, and sequestra may be evident. Components of treatment include adequate drainage/debridement, dead space management, wound coverage, and culture specific antibiotics. The recommended duration of intravenous therapy is always followed by an oral agent for an additional period of time. Stage 1 involvement in children can usually be treated by a 2 week course of intravenous antibiotics. In adults, the same stage is treated by both surgery and antibiotics (4 weeks intravenous). With stage 2 involvement, a 2 week course of intravenous antibiotics is indicated after debridement/soft tissue coverage. For stages 3 and 4, 4 weeks of intravenous therapy are recommended following an adequate debridement. Additionally, it may be possible to modify host factors. Cessation of smoking, nutritional supplementation, and other measures may be helpful.

Recommended antibiotics for the most common pathogens include the following (*first choice):

1. Staphylococcus aureus (*Nafcillin or *Clindamycin, alternatives Vancomycin or Cefazolin)
2. Methicillin resistent staphylococcus aureus (*vancomycin, Cotrimazole and rifampicin, imipenem)
3. Group A and B streptococcus (*Penicillin G, Clindamycin or Cefazolin)

4. Staphylococcus epidermidis (*Vancomycin, cefazolin, clindamycin)
5. Enterococcus (*Ampicillin, vancomycin)
6. Escherichia coli (*Ampicillin, cefazolin, tobramycin)
7. Proteus mirabilis (*Ampicillin, cefazolin, gentamicin)
8. Serratia marcescens (*Cefotaxime and Gentamicin, Mezlocillin and Gentamicin)
9. Pseudomonas aeruginosa (*Piperacillin or Ceftazedime and Tobramycin, Ciprofloxacin, Amikacin)
10. Bacteroides fragilis (*Clindamycin, Metronidazole, Amecillin-Sulbactam)
11. Peptostreptococcus (*Clindamycin, Penicillin, Metronidazole, Ampecillin-Sulbactam)
12. Proteus vulgaris, Proteus rettgeri, Morganella morganii (*Cefotaxime ± Gentamicin, Mezlocillin and Gentamicin)

Marsh JL, Prokuski L, Biermann JS. Chronic infected tibial nonunions with bone loss. Conventional techniques versus bone transport. *Clin Orthop Rel Res* 301:139-146, 1994.

Twenty-five patients with infected tibial nonunion and a gap of greater than 2.5 centimeters were treated by "conventional" treatment or bone transport. Fifteen patients were treated by the conventional approach, which included application of a monolateral fixator following debridement. Four patients required a muscle flap for soft tissue coverage, and 13 required bone grafting (13 received an open cancellous graft). Ten patients were treated by bone transport using a monolateral fixator. There were no significant differences between these groups with respect to rate of union, eradication of infection, number of complications, treatment time, number of surgical procedures, or alignment at followup. The number of complications per patient requiring surgical treatment averaged 0.7 in the conventional group and 1.1 in the bone transport group, while complications requiring nonsurgical management were 0.9 and 1.1 per patient, respectively. The most common complications were pin tract infections and late loss of alignment. The limb length discrepancy at followup was less in the bone transport group, and 12/13 patients treated by the conventional technique had a discrepancy of greater than 1 centimeter.

McNally MA, Small JO, Tofighi HG, et al. Two-stage management of chronic osteomyelitis of the long bones. The Belfast technique. *J Bone Joint Surg* 75b:375-380, 1992.

This Belfast technique was employed in the treatment of chronic osteomyelitis of the tibia (25), femur (9), radius (2), and humerus (1). Followup was 49 months. The first stage involves excision of sinuses, and radical debridement of devitalized tissue and bone until bleeding tissues are observed. Cultures are sent, and antibiotic impregnated beads were sometimes implanted. The skin was closed in some patients, while others were treated with microvascular transfer or local flaps. A cast was then applied, or an external fixator if instability was present. Bedrest was employed for 5 days, and then patients were mobilized. Antibiotics were based upon the culture results, and patients were discharged on oral agents. The second stage was performed after an average delay of 33 days, and involved debridement if necessary, followed by a cancellous bone graft from the iliac crest. Using this approach, union without recurrent infection was achieved in 92%. Wound problems were encountered in 4 cases following the second stage, and were treated effectively with an additional wound coverage procedure. Recurrance was treated by repeating the two-stage procedure.

Meier DE, Tarpley JL, Olaolorun DA, et al. Hematogenous osteomyelitis in the developing world: A practical approach to classification and treatment with limited resources. *Contemporary Orthopaedics* 26:495-505, 1993.

Osteomyelitis is a major source of morbidity and mortality in the developing world, and predisposing factors include malnutrition, bacteremia from poor hygienic conditions, skin ulcers/secondary skin infections (trauma, insect bites), sickle cell disease (Africa), and delayed presentation/treatment. 161 patients (average 10 years old) were classified and treated according to a set protocol. Seventy percent of cases occured in the femur or tibia, and 22% had multiple sites of involvement. Four classes are included in their scheme: acute (x-rays normal, < 2 week history)(27%), acute with radiographic changes (2-8 week history, extensive

bone destruction without sequestration)(22%), chronic localized (persistent drainage, symptoms for several months)(40%), and chronic systemic (chronic osteomyelitis with systemic illness)(10%). All patients were treated surgically under ketamine anaesthesia, and antibiotics were often unavailable. If available, antibiotics were used for all but the chronic localized type. Acute cases were treated by irrigation through a 3 cm. oval window, while chronic cases underwent sequestrectomy and drainage of all involved regions. Wounds were left open, and managed with daily irrigation and dressing changes. Families were shown how to irrigate the wounds with water sterilized by chlorine bleach, and patients were allowed to bear weight if stability was maintained. Although 57% were lost to followup, 43% healed over 4.4 months. Only 5/74 patients followed for more than 4 years exhibited a recurrence.

Paley D, Catagni MA, Argnani F, et al. Ilizarov treatment of tibial nonunions with bone loss. *Clin Orthop Rel Res* 241:146-165, 1988.

Twenty-five patients were treated for tibial nonunion with bone loss, and thirteen of these had chronic osteomyelitis. Eighty-eight percent of cases were atrophic. The Ilizarov device allows one to treat nonunion, limb length discrepancy, angular deformity, and bony defects. No bone grafts were necessary, and all cases united. The mean time to union was 13.6 months, and good or excellent results with regard to bone healing and alignment were observed in 92%. The infection was eradicated in 10/13 with chronic osteomyelitis. Ultimately, 4 patients had residual deformity while one had a significant leg length inequality. The functional results were excellent or good in 92%. The authors discuss the biologic basis of this methodology, and the technical considerations in treating these difficult problems, based on their classification of pseudarthroses. Four points of fixation are applied above and below the site of involvement. Two circular rings may be applied above and below, and in very short segments a single ring with a fine wires, with or without half pins suspended by posts or half rings, may be applied to achieve the four points of fixation. The rings are placed parallel to the knee and the ankle joints, and are connected by four threaded rods. Four threaded rods (or telescopic rods) are used to connect each pair of parallel rings, and hinges can be added if an angular deformity must also be corrected. This basic design may be modified to deal with bone loss or fixed deformity. Angular deformities may be corrected gradually through the use of hinges between the rings. For bony gaps following adequate debridement in chronic osteomyelitis, internal lengthening (bone transport) may be performed. A tibial corticotomy is performed (either proximally or distally) and completed by manual osteoclasis. After a latency period of 7-10 days, distraction may performed at 1 mm/day (4 turns of 0.25 mm). This transports a segment of bone through the gap. Fibular osteotomy is performed when the transported segment has been brought across the gap, to aid with healing at the docking site. Loss of length without bone loss is treated by external lengthening, and in this case the fibular osteotomy is performed at the same time as corticotomy. Bone loss and loss of length may be treated simultaneously. "Bifocal" treatment involves distraction at one level to gain length, and compression at another level to heal a pseudarthrosis, while "trifocal" lengthening involves corticotomy and distraction at two levels with compression at a third location. The Ilizarov method is comprehensive, and can successfuly manage the host of problems that may be encountered in tibial nonunion (bone loss, angular deformity, limb shortening, pseudarthrosis).

Panda M, Ntungila N, Kalunda M, et al. Treatment of chronic osteomyelitis using the Papineau technique. *Int Orthop* 22:37-40, 1998.

41 cases (7-78 years old) in Kinshasa were treated by a 3 stage technique including debridement, grafting, and finally skin grafting if necessary. The etiology was traumatic in 53% and hematogenous in 44%, and 83% of cases were in the femur or tibia. External fixation was used in 44%, and casting in 39%. Control of infection and bony healing were observed in 89% at short term followup. Initially, multiple drill holes were used to facilitate saucerization, and the cavity was cleansed with Dakin's solution and packed with vaseline gauze impregnated with 1% framycetine. The wound was evaluated after 12 days, cleaned again with Dakin's solution, and another dressing applied. The cancellous grafting (proximal tibia) was then performed, usually within 10 days. Five days after grafting, daily drip irrigation with 1

liter of saline was performed. If necessary, a skin graft was applied after consolidation (3-7 months). Complications included a single recurrence, and a single case of pseudarthrosis. Of note, antibiotics were often unavailable, and there was a lack of laboratory support.

Patzakis MJ, Abdollani K, Sherman R, et al. Treatment of chronic osteomyelitis with muscle flaps. *Ortho Clin North Am* 24:505-509, 1993.

Local muscle flaps are an important adjunct in the management of chronic osteomyelitis, and are typically employed once an adequate debridement has been performed. The flaps improve the vascularity at the host site, which helps improve the delivery of antibiotics, promotes healing, and improves host defense mechanisms. 36 patients (36 years old) were reviewed, and 31 had involvement of the tibia. 86% had stage IIIa or IVa using the Cierny classification. Staphylococcus aureus was cultured from 25 patients, pseudomonas from 16 patients, and 20 patients had a polymicrobial infection. Preoperative cultures were obtained, and a second set of cultures were sent at the time of debridement. Wounds were left open and managed with daily dressing changes and irrigation with normal saline, and patients were maintained on antibiotics. Another set of cultures were obtained 24 hours after debridement. If followup cultures were negative, patients were returned to the operating room for redebridement and a soft tissue coverage procedure (3-9 days). Muscle flaps (24 local, 12 free vascularized) included the gastrocnemius (14), soleus (9), rectus abdominis (10), latissimus dorsi (1), pectoralis major (1), and gracilis (1). 70% of patients required bone grafting, which was completed 6 weeks following soft tissue transfer. Antibiotics were maintained for a mean of 21 days, and patients were then placed on oral antibiotics. All flaps were successful, and complications included four pin site infections, and partial loss of a skin graft or flap in 3 cases. A single patient had persistent drainage.

Sachs B, Shaffer JW. A staged Papineau protocol for chronic osteomyelitis. *Clin Orthop Rel Res* 184:256-263, 1984.

A 3-stage Papineau protocol was applied to 13 patients (18-66 years old) with chronic osteomyelitis. Sites of involvement included the femur (2), the tibia (10), and both the femur and tibia (1). Stage one involved debridement, and apllication of a cast (12) or an external fixator (1). The wound was dressed in gauze soaked in betadine, and gressing changes were made every 2-5 days (cultures also obtained). After 3 weeks, if nonviable tissue remained, another debridement was performed. If the wound was clean, then a cancellous bone graft from the iliac crest was applied (average 3-9 weeks after debridement). A petroleum gauze dressing was applied and changed every 2-4 days. Repeat grafting was performed in additional stages if necessary. The third stage involved skin coverage (average of 5 weeks following stage 2), which was by epithelialization (7), split thickness skin graft (5), or muscle transposition (1). Oral antibiotics were continued throughout this course. The infection was eradicated in 12/13, and the bony defect healed in every patient. The only patient managed with an external fixator had a refracture 5 months after healing. Cultures from sinus tracts did not correlate with those from the area of deep infection.

Simpson AHR, Deakin M, Latham JM. Chronic osteomyelitis. The effect of the extent of surgical resection on infection-free survival. *J Bone Joint Surg* 83B:403-407, 2001.

This prospective study in 50 patients (mean age 49 years) compared recurrence in patients treated by wide resection (> 5 mm), marginal resection, and intralesional biopsy. All patients received 6 weeks of intravenous antibiotics. Diagnoses included post-traumatic (62%), hematogenous (24%), and spread from an overlying ulcer (14%). Wide resection resulted in no recurrence of disease, while the rate of recurrence was 28% for marginal excision and 100% for intralesional surgery, at a mean followup of 26 months (12-48 months). Of the patients treated by marginal excision, no Cierny type A hosts had recurrence, while 8 type B hosts had a recurrence. The extent of surgical resection seems to be the critical factor in the successful management of chronic osteomyelitis.

Swiontkowski MF, Hanel DP, Bedder NB, Schwappach JR. A comparison of short and long term intravenous antibiotic therapy in the post operative management of adult osteomyelitis. *J Bone Joint Surg* 81B: 1046-1050, 1999.

This retrospective study evaluated antibiotic

therapy in 93 adults treated for chronic osteomyelitis (71 posttraumatic, 15 following wound breakdown, and 7 hematogenous). In addition to an aggressive debridement and early soft tissue coverage, patients were treated with intravenous antibiotics (based on culture results) for 5-7 days, and then a 6 week course of oral antibiotics. Oral agents included Trimethoprim (160 mg) and Sulfamethoxazole (800 mg) twice per day, or Ciprofloxacin (750 mg) twice per day. One third of patients had multiple organisms, and staphylococcus aureus was found in 54/93. Other common organisms included Pseudomonas (21), staphylococcus epidermidis (10), and other gram negative organisms (13). Antibiotic beads were used to temporarily manage the dead space, and both local (20) and free (33) tissue transfers were used to obtain coverage. Three amputations were performed, one for a squamous cell carcinoma at a sinus, and two for persistent infection. The approach was successful in 91% of patients, including 27/31 Cierny grade 4 hosts.

Tetsworth K, Cierny G. Osteomyelitis debridement techniques. *Clin Orthop Rel Res* 360: 87-96, 1999.

With modern techniques including radical debridement, antibiotic beads, soft tissue coverage procedures (including mscovascular free flaps), and the use of the Ilizarov or similar devices, eradication should be possible in more than 90% of cases. A staged protocol is most commonly employed, beginning with an aggressive debridement of all devitalized tissue and foreign material (critical component of the entire process). Comorbid conditions should be recognized preoperatively and addressed if possible. Most clinical decisions can be made on plain radiographs, and the intraoperative findings are most important in determining the margins of debridement. An estimation of the amount of soft tissue and bone to be removed should be made preoperatively, so that secondary procedures can be planned in advance. Prior scars should be used if possible, and the edges should be excised. Otherwise, the incision should be perpendicular as it crosses any previous incisions or scars. Scar tissue, especially with questionable vascularity, should be excised. Only the involved segment of bone should be subperiostially exposed, and extraperiostial dissection can aid exposure of the region. Sinus tracts removed from the region of debridement may often be left alone. Braided or absorbable sutures should be avoided. The wound closure should be free of tension, and if necessary the plane in between the subcutaneous tissue and the fascia can be mobilized with care to help achieve skin closure. Local advancement flaps may also be helpful. Bony debridement should include the sequestrum, but not the involucrum. The combination of periostial stripping and intramedullary debridement may disrupt the local blood supply, resulting in an iatrogenic sequestrum. Prescence of the "paprika sign", which refers to punctate bleeding from the exposed bone, helps to define the appropriate margins of debridement. If 70% or more of the cortical volume is left after debridement, the risk of fracture is felt to be low, and stabilization may not be required. Should a segmental resection be required, stabilization with a fixator will be required prior to reconstruction. Dead space management is also important, and antibiotic beads have become popular. Bone grafting, or bone transport, may ultimately be required to complete the reconstruction.

Van Gurp G, Kila R, Hutchinson T. Management of childhood hematogenous osteomyelitis in a rural Papua New Guinean hospital. *PNG Med J* 32:117-122, 1989.

An approach to treating chronic osteomyelitis in a rural setting within a developing country is discussed. Most cases of acute and chronic osteomyelitis require surgical intervention. Surgical treatment of acute osteomyelitis involves open drainage of abscesses, and the authors recommend drilling of the cortex when there is a subperiostial abscess. The indications for antibiotics alone are limited, and include infections present for < 48 hours. For chronic osteomyelitis, sequestrectomy is recommended once an adequate involucrum has formed, and the medullary canal is curretted. The wound is closed over a drain, as long as there is no excessive tension on the skin. The indications for antibiotics in chronic osteomyelitis include an associated soft tissue infection, perioperatively for sequestrectomy, and radiological evidence of ongoing bone destruction with systemic signs of infection. Intravenous cloxacillin and probenecid were recommended while awaiting the results of cultures.

Varma BP, Tuli SM, Srivastava TP, et al. Reincorporation of early diaphyseal sequestra and bone remodelling in extensive haematogenous osteomyelitis in children. *Indian J Orthop* 8:39-44, 1974.

Six cases of chronic osteomyelitis with extensive sequestration of the diaphysis of the tibia (3), the femur (2), and the radius and ulna (1) are presented. With an inadequate involucrum, they were managed by antibiotics and immobilization in plaster. Antibiotics were given for 4-8 weeks, and then again for any recurrence of infection. All cases demonstrated excellent reincorporation of large sequestra, and remodelling was apparent with extended followup in children less than 5 years of age. Two cases had curettage of sinuses with removal of small sequestra, while one required removal of a small piece of sequestered cortex 3 years after treatment. Several additional cases in which the bone was exposed due to skin necrosis did not show evidence of reincorporation, and were treated by sequestrectomy and a fibular transference procedure.

Vitale CC. Reconstructive surgery for defects in the shaft of the ulna in children. *J Bone Joint Surg* 34:804-810, 1952.

Two children with large defects in the shaft of the ulna were treated by radio-ulnar fusion. The single bone forearm is stable, cosmetically acceptable, and patients achieved adequate function without symptoms. Forearm rotation is lost, but patients seem to compensate adequately. Prerequisites include a functional wrist and elbow joint.

Wilson PD. A simple method of two-stage transplantation of the fibula for use in cases of complicated and congenital pseudarthrosis of the tibia. *J Bone Joint Surg* 23:639-675, 1941.

Nine patients were treated by a 2 stage fibular transference procedure, which is recommended for chronic osteomyelitis with segmental tibial bone loss and congenital pseudarthrosis of the tibia. The first stage is performed proximally, and a lateral incision allows mobilization and protection of the peroneal nerve. The anterior compartment musculature is elevated, and stripped off both the interosseous membrane and the fibula. The anterior tibial artery and vein were ligated to facilitate transfer of the fibula. The fibula is divided at the level of the neck, and then translated medially and inserted into a window in the proximal tibia. If excessive force is required to translate the fibula, a more distal fibular osteotomy (greenstick) may be required. The second stage is performed 4 weeks later, or when union has occured. The site of transference is distally, above the malleoli. A longitudinal incision is made over the anterior compartment, and the fibular shaft is exposed subperiostially and osteotomized obliquely. The fibula is then brought through a plane between the interosseous membrane and the anterior compartment musculature, and keyed in to a slot in the lateral surface of the tibia. Patients were immobilized in a long leg cast for 3 months, and a walking brace was applied. In those with congenital pseudarthrosis, a walking cast was maintained for at least one year. The authors recognized that the fibula may be involved in congenital pseudarthrosis of the tibia (4/5 cases), yet healing occured, and in several cases the tibial pseudarthrosis healed as well. Overall, union was achieved initially in 6/9, and the other 3 cases united after additional grafting (1-3 procedures). Function and alignment were not quantified at followup, but union was achieved which avoids the need for amputation.

Zahiri CA, Zahiri H, Tehrany F. Limb salvage in advanced chronic osteomyelitis in children. *International Orthopaedics (SICOT)* 21:249-252, 1997.

Nine children with chronic osteomyelitis involving the entire shaft of the tibia were effectively treated with a 3 stage protocol. The average age was 7 years, and the followup was 8 years. The infection was present for an average of 13 months, and all had draining sinuses. The first stage involved a resection of the tibial shaft, with debridement of any periostium and reactive tissue. Typically, this extended into the metaphysis, where healthy cancellous bone was identified. The wound was closed over drains, and the second stage involved systemic antibiotics. Once 3 successive cultures of the drainage material demonstrated no growth, the patient underwent fibular transfer through the same anterior incision. The periostium was incised over the proximal and distal thirds, and osteotomy was performed at the level of the metaphysis both proximally and distally. The ends of the fibula were translated under the metaphyseal regions of the

tibia. Proximally, the graft was keyed in to the tibia, while distally fixation was achieved with a smooth Steinmann pin through the calcaneus across the talus and tibia into the fibular graft. A long leg cast was applied. The cast was converted to a functional brace once healing was adequate. Physical therapy was then employed. All patients healed, and there were no recurrent infections. Shortening from 1-3 cm was universal, and anterior bowing was seen in 4 patients. Overall, patients were functional.

V. Sequelae of Septic Arthritis

Neglected cases of septic arthritis of the hip are rare in the United States, but are frequently observed in developing countries. The infection may directly damage both sides of the joint, and may also have indirect consequences through avascular necrosis and physeal disturbance in both the femoral head/neck and acetabulum. Residual deformities of the femoral head and neck include partial or complete destruction, coxa magna, coxa breva, coxa vara or coxa valga. Greater trochanteric overgrowth results in abductor insufficiency, while subluxation or dislocation may be associated with both instability and leg length discrepancy. Some patients may develop fibrous or bony ankylosis of the joint, and a subset of these extremities will be malaligned. Although bony ankylosis is usually not associated with symptoms, fibrous ankylosis will often cause pain in the affected hip. Leg length discrepancy results from damage to the proximal femoral physis, from subluxation or dislocation, and in some cases from coexisting physeal damage in other areas in those patients with multiple sites of involvement. This spectrum of pathologic changes has been represented in the classification systems by Hunka et al, and Choi et al. Both of these authors have made treatment recommendations based upon the pathological findings.

Symptoms vary depending upon the severity of the initial insult. A limp is universal, and relates to leg length discrepancy, abductor insufficiency, and often pistoning from subluxation or dislocation. Pain is a less common finding, even at mid range followup, except in cases progressing to fibrous ankylosis. Most studies have followed patients who had infantile hip sepsis, and there may be differences between these younger patients and those affected during the childhood years. Cases diagnosed in infants seem to be associated with better motion, while those diagnosed in childhood are more commonly associated with stiffness and often ankylosis.

There is some controversy in the literature regarding when and how to treat these residual deformities, and whether certain interventions will improve the natural history. Several reports including patients with varying degrees of involvement have found that most patients remain pain free and have reasonable function at mid range followup.

Perhaps the best approach is to approach each patient individually. The radiographic deformities should be classified, and correlated with the patients symptoms and findings on physical examination. The literature supports treating the leg length discrepancy by epiphysiodesis, and at least one paper has reported success with limb lengthening. If the involved femur is to be lengthened, a stable articulation is a prerequisite. A pseudarthrosis of the femoral neck is rare but has responded poorly to bone grafting, and either valgus osteotomy or resection of the head and neck (+/- greater trochanteric arthroplasty) may be required. Greater trochanteric arthroplasty (Colonna and variations) has been associated with mixed results, and the results may deteriorate with time. Proposed benefits of this procedure include enhanced stability (no pistoning), improvement in the abductor lurch, and a smaller discrepancy in leg lengths. It has also been suggested that restoration of an articulation at the hip may facilitate future prosthetic reconstruction. However, some hips may lose motion or progress to subluxation or dislocation, which may result in pain. It appears that adding a varus osteotomy of the proximal femur improves the overall results. Arthrodesis always remains a good option for painful hips, although this solution may be unattractive from a cultural standpoint, particularly in areas such as East Asia where patients need to squat for many activities of daily living.

Axer A, Aner A. A new technique for greater trochanteric hip arthroplasty. *J Bone Joint Surg* 66B:331-333, 1984.

This case report describes a technique for greater trochanteric arthroplasty in which the proximal femur is rotated 180°° following subtrochanteric osteotomy. Fixation was achieved with a short

intramedullary nail. Shortening of the femoral shaft was avoided (no varus required). Several years later the limb was lengthened 5 cm. Despite fragmentation of the apophyseal fragment, presumably due to avascular insult, the fragment healed, remodelled, and contributed to longitudinal growth. At 20 years of age, the patient was pain free and had a mild limp.

Betz RR, Cooperman DR, Wopperer JM, Sutherland RD, et al. Late sequelae of septic arthritis of the hip in infancy and childhood. *J Ped Ortho* 10:365-372, 1990.

This multicenter review (32 hips in 28 patients) evaluated the Harris hip scores and leg length inequality, based on the Hunka classification, in 2 groups (< 3 months, > 3 months of age). The followup was 42 years. For those in the younger group, 10/19 were pain free, while 5 had mild pain and 4 had moderate pain. In the older group, 9/10 were pain free, 3 had mild pain, and 1 required a THA for severe pain. Hips in the infantile group were usually mobile, whereas those patients with a later onset of the disease tended to have stiffer hips, many of which were ankylosed. Despite Harris scores were in the fair range (70-80), 59% of these hips were pain free. Leg length discrepancy is a significant problem, and averaged 3.3 cm. in located hips, and 5.6 cm. in dislocated hips. The authors recommend avoiding reconstructive surgery in most cases. Femoral osteotomy to reposition a hip which has autofused may be helpful. Leg length discrepancy should be treated.

Bryson AF. Treatment of pathological dislocation of the hip joint after suppurative arthritis in infants. *J Bone Joint Surg* 30B:449-453, 1947.

A review of 16 cases treated by Colonna arthroplasty (1), subtrochanteric osteotomy (4), and arthrodesis (11) was performed. Subtrochanteric osteotomy was successful in 1 of 4 cases, and this patient had a painless fibrous ankylosis of the hip. The Colonna arthroplasty failed in a single patient. Arthrodesis was the most successful treatment. Given reasonably good function in childhood, and the tendency for flexion/adduction conracture to develop in patients fused early, the authors recommend waiting until the patient is 12-13 years of age.

Chang CH, Huang SC. Reconstruction for sequelae of septic hip in children. *J Formos Med Assoc* 96(5):353-358, 1997.

13 hips were reconstructed [Hunka IIb (6), Iva (4), IVb (2), V (1)] at an average age of 6 years with the goal of achieving containment, and later equalizing leg length discrepancy. Procedures included open reduction, femoral and pelvic osteotomy for containment, and valgus osteotomy and limb lengthening for LLD. Preoperatively, patients had a painless limp and an average leg length discrepancy of 3.3 centimeters. Although 4 patients required secondary procedures for resubluxation, all were stable at 6 year followup. The authors recommend early surgical stabilization of the hips, and equalization of limb lengths at a later time.

Cheng JCY, Aguilar J, Leung PC. Hip reconstruction for femoral head loss from septic arthritis in children. A preliminary report. *Clin Orthop Rel Res* 314: 214-224, 1995.

8 patients with complete loss of the femoral head and neck (Choi IVb) were treated by a vascularized iliac crest pedicle graft. The cartilagenous side of the crest is aligned superiorly to contact the acetabulum. Patients were all pain free at 7 year followup, and 7 of 8 cases exhibited vertical stability at the hip. Severe resorption was seen in one graft, and 5/8 did not consolidate fully. Ultrasound suggested a mobile fibrocartilagenous mass within the acetabulum. Those which healed completely did show evidence of remodelling at followup. Achieving stability in this manner may facilitate later limb lengthening procedures.

Cheng JCY, Lam TM. Femoral lengthening after type IV B septic arthritis of the hip in children. *J Ped Ortho* 16:533-539, 1996.

Four patients with loss of the femoral head and neck (Choi IVb) underwent successful femoral lengthening from 4.5 to 13 cm., without loss of hip stability or range of motion of the hip or knee. All had multiple joint sepsis, which contributed to the magnitude of their discrepancy. Three of four were treated by a vascularized iliac crest pedicle graft to reconstruct the absent femoral head and neck prior to their lengthening.

Choi IH, Pizzutillo PD, Bowen JR, Dragann R, et al. Sequelae and reconstruction after septic arthritis of the hip in infants. *J Bone Joint Surg* 72a:1150-1165, 1990.

34 patients with residual deformities from septic arthritis (< 1 year old) were retrospectively reviewed. A classification scheme was presented, and treatment results were presented. Sequelae include LLD, premature complete or asymmetric closure of the proximal femoral physis, partial or complete destruction of the femoral head and neck, pseudarthrosis of the femoral neck, avascular necrosis, subluxation or dislocation, acetabular dysplasia, and premature closure of the triradiate cartilage. This classification is a modification of the Hunka classification. The different classes, and their recommended treatment, are as follows:

I (5) = No residual deformity, radiographic features of AVN Containment until reossification with an abduction orthosis or cast.

IIa (7) = Coxa breva + deformed head treat avascular changes with containment, apophysiodesis or transfer of the greater trochanter for abductor insufficiency, pelvic osteotomy for coverage, epiphysiodesis for LLD.

IIb (4) = Progressive coxa vara or valga from asymmetric premature physeal closure partial epiphysiodesis of the femoral physis +/- greater trochanteric apophysis, proximal femoral osteotomy.

IIIa (4) = Slipping at the femoral neck into coxa vara or coxa valga Proximal femoral osteotomy.

IIIb (1) = Femoral neck pseudarthrosis Bone grafting (usually fails), valgus osteotomy

IVa (2) = Destruction of femoral head with small neck segment Reduction of femoral neck fails, procedures include pelvic osteotomy, trochanteric arthroplasty, arthrodesis, and epipysiodesis, and lengthening.

IVb (11)= Destruction of femoral head and neck, dislocation Trochanteric arthroplasty + varus, pelvic osteotomy, epiphysiodesis

The functional result was acceptable in all patients with Type I deformity, in 7/11 with Type II, in ¾ with Type III, and in 4/13 with Type IV. These treatment strategies, especially for the more severe deformities, may serve as temporizing measures prior to definitive reconstruction in adulthood.

Colonna PC. A new type of reconstruction operation for old ununited fracture of the neck of the femur. *J Bone Joint Surg* 17:110-122, 1935.

Six cases of greater trochanteric arthroplasty are described for femoral neck nonunion in older patients. The technique involves circumferential muscle release around the trochanter, with care to avoid subperiostial dissection. The neck is debrided to be flush with the femoral shaft, and the trochanter is placed within the acetabulum. The abductors are advanced and sutured to a trough in the lateral aspect of the femur (tensioned at 20 degrees abduction). The vastus lateralis is reefed over the new insertion of the glutei. The patient is placed in a spica with the hip in extension and 20 degrees abduction.

Fabry G, Meire E. Septic arthritis of the hip in children: Poor results after late and inadequate treatment. *J Ped Ortho* 3:461-466, 1983.

29 children with septic arthritis +/- osteomyelitis were followed for > 12 years. Patients were divided into two groups (< 1 month, 1 month-3 years old). The prognosis was worse in younger children, and in those with coexisting osteomyelitis. As for most series, symptoms and functional parameters do not necessarily correlate with the degree of changes on radiographs. Trochanterplasty (technique not described) was of limited success, due to stiffness and/or dislocation. In general, reconstructive procedures were not felt to be successful.

Freeland AE, Sullivan DJ, Westin GW. Greater trochanteric hip arthroplasty in children with loss of the femoral head. *J Bone Joint Surg* 62a: 1351-1361, 1980.

The Colonna greater trochanteric arthroplasty was performed in 17 children, 7 of whom had sequelae of septic arthritis. Followup was 11 years. For those with septic arthritis, in addition to greater trochanteric arthroplasty, 5/7 underwent a pelvic osteotomy (Salter or Pemberton) and 3/7 had a varus proximal femoral osteotomy. One was also treated with an acetabuloplasty, in which the acetabulum was reamed to accept the greater trochanter. Four patients were treated by epiphysiodesis at a later time. At followup, 1/7 had required a total hip arthroplasty, and fobrous ankylosis was seen in 2. Two patients had completely fused. In the group as a whole, greater trochanteric arthroplasty alone resulted in stability initially, but this deteriorated to subluxation, stiffness, and degenerative changes. Results in those also treated by pelvic osteotomy were similar, although containment was improved. The best results were achieved in those having a varus proximal femoral osteotomy as a component of the procedure.

Hallel T, Salvati EA. Septic arthritis of the hip in infancy: End result study. *Clin Orthop Rel Res* 132: 115-128, 1978.

24 hips in 21 patients with septic arthritis within the first 7 months of life were reviewed at 17 year followup. Abduction splinting or casting failed uniformly if the femoral head and neck were absent, but was successful in 10/14 with at least a small head and neck remnant present. Arthrography is not helpful in determining the proximal femoral anatomy due to scarring. The study was prior to MRI, and surgical exploration was performed to assess the status of the femoral head and neck, and an open reduction is recommended in the prescence of a stable head and neck. Trochanteric arthroplasty was performed in 6 patients, 3 of whom remained located. Benefits of successful arthroplasty include stability, a decrease in abductor lurch, and less LLD. However, those that failed were stiffer, and some progress to subluxation/dislocation and have pain. Another possible benefit of trochanteric arthroplasty is to promote more favorable conditiions for prosthetic reconstruction later in life.

Hunka L, Said SE, MacKenzie DA, Rogala EJ, et al. Classification and surgical management of the severe sequelae of septic hips in children. *Clin Orthop Rel Res* 171:30-36, 1982.

A classification system, and treatment recommendations, are presented based upon a review of 10 cases with 11 year followup. All patients had septic arthritis before 18 months of age. Irrespective of the degree of involvement, most children were pain free.

I = Absent or minimal changes (no patients identified)
- No treatment suggested

II = Femoral head deformity +/- damage to the femoral physis (no patients identified)
- If identified, such patients will require management of trochanteric overgrowth, leg length discrepancy, and possibly malalignment.

III = Pseudarthrosis of the femoral neck (2 patients)
- Poor response to grafting only recommend grafting if there remains a large, viable femoral head. Results remained unsatisfactory following other reconstructive procedures including soft tissue release, and trochanteric arthroplasty/pelvic osteotomy/varus femoral osteotomy. The poor results occurred due to fibrous ankylosis and persistent subluxation. The authors suggest that excising the neck segment and then treating the patient as a Type V may be the best choice.

IVa = Complete destruction of the proximal femoral epiphysis with a stable neck
- Problems include trochanteric overgrowth/LLD Recommend distal trochanteric transfer and epiphysiodesis.

IVb = Complete destruction of the proximal femoral epiphysis with a small, unstable neck
- Problems include trochanteric overgrowth, LLD, and instability Recommend Distal transfer of greater trochanter, LL equalization, and proximal femoral osteotomy/pelvic osteotomy.

V = Complete destruction of the head/neck to the intertrochanteric line
- Problems include Instability, LLD recommend early trochanteric arthroplasty with varus proximal

femoral osteotomy (3 years of age) and distal transfer of the abductors (preliminary adductor release and traction).

Krumins M, Kalnins J, Lacis G. Reconstruction of the proximal end of the femur after hematogenous osteomyelitis. *J Ped Ortho* 13:63-67, 1993.

7 children with severe changes (loss of head and neck) were treated by proximal femoral osteotomy with external fixation. The proximal femoral segment (head and neck remnants) is gradually medialized into the acetabulum using the fixator. The gap created eventually consolidates. Hip stability and ambulation improved at short term followup (< 5years).

Weintroub S, Lloyd-Roberts GC, Fraser M. The prognostic significance of the triradiate cartilage in suppurative arthritis of the hip in infancy and early childhood. *J Bone Joint Surg* 63B:190-193, 1981.

Septic arthritis of the hip may be associated with damage the triradiate cartilage, which may result in growth arrest. Radiographic narrowing and irregularity of the triradiate reliably predicts severe involvement of the femoral head, and acetabular dysplasia may develop over time. In the abscence of such changes, a mobile femoral head will usually be found in the acetabulum.

Weissman SL. Transplantation of the trochanteric epiphysis into the acetabulum after septic arthritis of the hip. *J Bone Joint Surg* 49a: 1647, 1967.

This case report describes a technique for greater trochanteric arthroplasty in a 3 year old with complete destruction of the head and neck of the femur. Findings included interposition of fibrous tissue in between the actabulum and the femoral neck remnant. After removal of all fibrous tissue, in addition to release of the psoas and detachment of the short external rotators and the gluteus medius and minimus, the greater trochanter is sutured down into the acetabulum. A varus osteotomy (100°°) was then performed. At nearly seven years followup, remodelling of the apophysis was seen, and the hip remained stable.

Wopperer JM, White JJ, Gillespie R, Obletz BE. Long-term follow-up of infantile hip sepsis. *J Ped Ortho* 8:322-325, 1988.

The natural history of infantile hip sepsis (< 3 mos) in 8 patients (9 hips) is reported at 31 year followup. The spectrum of pathology included mild deformity (3), absent or deficient femoral head and neck without dislocation (3), and an absent or deficient head/neck with dislocation. Results based upon Harris hip scores included 6 excellent, 1 good, and 2 poor. The authors question the value of reconstructive surgery for the hip itself, but epiphysiodesis should be considered to treat the coexisting leg length discrepancy.

VI. Pyomyositis

Pyomyositis represents a pyogenic intramuscular infection which is seen most commonly in tropical regions. The differential diagnosis is extensive, and includes muscle strain injury, hematoma, thrombophlebitis, osteomyelitis, septic arthritis, and neoplasia. The symptoms and clinical findings evolve over a period of days to weeks from the insidious onset of pain and swelling during early infection (the invasive stage) to abscess formation often associated with systemic toxicity (suppurative stage). Most patients present in later stages. Many sites of involvement have been reported, although most cases seem to involve the larger muscles of the thigh and pelvic region. Involvement of the psoas muscle may simulate septic arthritis of the hip. In general, skeletal muscle is quite resistant to infection, and although no clear predisposing factors have been defined, associations may include low grade trauma, chronic skin infection, and poor nutritional status. Staphylococcus Aureus is identified in approximately 80% of cases. Although plain films are often normal, soft tissue abnormalities may be seen. If available, MRI is the imaging modality of choice. In addition to identifying the size and location of abscesses, MRI may demonstrate the stage of involvement. If the diagnosis is made in the invasive stage, patients may respond to antibiotics alone. Those with abscess formation will require drainage, and a percutaneous technique may be effective depending on the site of involvement. Patients should be started on an intravenous antistaphylococcal agent, which can be modified based upon sensitivities. The optimal

duration and method of delivery of antibiotics have not been established. Based on the literature, a short course of intravenous therapy followed by an additional period of oral antibiotics may be the best approach, guided by the clinical response. The overall duration should probably be 3-6 weeks.

Bonomo RA, Graham R, Makely JT, Petersilge CA. Tuberculous pyomyositis: An unusual presentation of disseminated mycobacterium tuberculosis infection. *Clin Infect Dis* 20:1576-1577, 1995.

This case report in a 40 year old man highlights an unusual presentation of tuberculosis. Although extremely rare, TB should be kept in the differential diagnosis, especially when an intramuscular abscess does not respond to drainage and antibiotics.

Burkitt RT. Tropical pyomyositis. *J Trop Med Hyg* 50:71-75, 1947.

Fifty cases in west Africa were reviewed. Associated factors that may lead to the development of pyomyositis include localized susceptibility of muscle tissue (filariasis, ancylostomiasis, trauma), a focus of infection/bacteremia (often associated with foot lesions from chigger bites or trauma), and poor host resistance (malaria, avitaminosis, sickle cell anemia, debility). Staphylococcal species were isolated in 30/40 cultures obtained (10 were sterile). Although some cases resolved early in their course, most patients required operative drainage.

Chacha PB. Muscle abscesses in children. *Clin Orthop Rel Res* 70:174-181, 1970.

Seventy cases from Singapore are reviewed, and 8 of these had multiple sites of involvement. The thigh was the most common site (29/81), followed by the buttocks, arm, leg, and groin. Most patients presented from 4 days to 2 weeks following the onset of symptoms, and 15 patients had a history of trauma. 66/81 lesions underwent surgical drainage, and clinical resolution usually occured after one week, while wounds took an average of 44 days to heal. No bony involvement was identified. Staphylococcus aureus was cultured in 36/41 cases, and the average duration of antibiotics was 9.2 days.

Chiedozi LC. Pyomyositis: Review of 205 cases in 112 patients. *Am J Surg* 137:255-259, 1979.

This report from Nigeria found multiple lesions in 43%, and the quadriceps and gluteal muscles were most commonly involved. 40% of patients were between 2 and 5 years of age. The clinical course evolves, and during the early stages there is pain followed by edema, and a "wooden" stiffness without fluctuation. Leukocytosis and eosinophilia are also seen. Only 2% presented at this "invasive" stage of the disease. Needle aspiration is negative at this point in the disease process. After 10-20 days, symptoms worsen and signs of inflammation become more pronounced. More than 90% presented at this "suppurative" stage, which requires operative drainage. 90% of cases involved staphylococcus aureus, with 3.5% streptococcus pyogenes, 0.9% E Coli, and 0.9% streptococcus. The etiology was unclear, but may relate to enhanced susceptibility from nutritional deficiencies. The mortality rate was 0.89%, and residual deformities were uncommon. Early stages can be treated with antibiotics alone, whereas later stages require operative drainage followed by antibiotics.

Deboeck H, Noppen L, Desprechins B. Pyomyositis of the adductor muscles mimicking an infection of the hip. *J Bone Joint Surg* 76a: 747-750, 1994.

This case report illustrates how an extracapsular infection about the hip may simulate septic arthritis of the hip clinically. The diagnosis was made by MRI, and the patient responded well to surgical drainage and intravenous antibiotics, followed by 4 weeks of oral antibiotics.

Falasca GF, Reginato AJ. The spectrum of myositis and rhabdomyolysis associated with bacterial infection. *J Rheum* 21:1932-1937, 1994.

Six cases illustrate the spectrum of clinical manifestations of bacterial infection within muscle, including pyomyositis, fasciitis/myositis (muscle inflammation associated with bacterial infection of deep fascial and muscle planes), and toxic rhabdomyolysis (widespread noninflammatory muscle necrosis with systemic bacterial infection). CT scanning is unreliable in identifying intramuscular abscesses. Bedside needle aspiration was helpful in 2/4 cases, and surgery was required to drain abscesses. Organisms cultured included

Staph Aureus (2 cases of pyomyositis, 1 case of fasciitis/myositis), Enterobacter Cloacae (1 case pyomyositis), and Clostridium Perfringens (1 case fasciitis/myositis, 1 case toxic rhabdomyolysis).

Hall RL, Callaghan JJ, Maloney E, Martinez S, Harrelson JM. Pyomyositis in a temperate climate. *J Bone Joint Surg* 72a:1240-1244, 1990.

18 cases over an 18 year period in North Carolina are reviewed. The differential diagnosis is large (neoplasm, thrombophlebitis, muscle strain, synovitis), and the diagnosis is often delayed. The age range was 21 months to 66 years, and the duration of symptoms prior to presentation was from less than one month to one year. There was an insidious onset of symptoms, and the affected muscles included the quadriceps (6), gluteas maximus (2), gastrocnemius (2), triceps (2), psoas, piriformis/obturator internus, gracilis, pectoralis major, and forearm extensors. Bone scanning demonstrated an increase in activity but was not diagnostic. Computed tomography was helpful in making the diagnosis, and ring enhancement of the mass may be seen with contrast administration. Patients were treated by surgical drainage (average 1.6 procedures/patient) and intravenous antibiotics (2-54 days). Cultures grew staphylococcus aureus (11), streptococcus (2), E Coli (1), H Flu (1), and mixed (staphylococcus aureus, peptostreptococcus, and fusobacterium) in 1 patient. At followup, a single patient had exertional discomfort in the involved muscle.

Horn CV, Master S. Pyomyositis tropicalis in Uganda. *East Afr Med J* 45:463-471, 1968.

800 cases in Uganda are reviewed, and pyomyositis represented 3-4% of hospital admissions (70-280 per year). The prevalence seemed to be higher in September/October. Large muscles of the limbs and trunk were most commonly involved (30% were in the thigh). Pain and swelling progressed over 6-9 days, and prior trauma was rare. Fever was commonly observed, and the sed rate/wbc count were elevated. Aspiration was not always diagnostic, and incision/drainage was required in most patients. The authors hypothesize that muscle necrosis from a viral infection may predispose to secondary bacterial infection.

Malhotra R, Singh KD, Bhan S, Dave PK. Primary pyogenic abscess of the psoas muscle. *J Bone Joint Surg* 74a:278-284, 1992.

Of 41 cases of psoas abscess seen over a four year period, 27 were due to tuberculosis, and only 9 were due to bacterial infection. These 9 cases occured in children less than 9 years of age (youngest 8 months old). Findings at presentation may be similar to septic arthritis, with fever, pain, limp, and the hip is typically held in flexion, abduction and external rotation. Patients presented after 4-14 days of symptoms, and several had been treated by oral antibiotics prior to presentation. A high index of suspicion is required, and ultrasound may help make the diagnosis. Although difficult to differentiate clinically, abscence of posterior tenderness, and the ability to rotate the hip when it is held in a flexed position, make the diagnosis of psoas abscess more likely. Although a psoas abscess may occasionally be palpable on the inner wall of the ilium, none of the patients in this series had this finding. A plain film of the abdomen may demonstrate loss of definition or enlargement of the psoas muscle. Computed tomography may help to outline the lesion, but it is difficult to distinguish an abscess from a neoplasm, even with the injection of contrast material. As expected, the wbc count and sed rate were elevated. Patients were treated by open drainage, and all cultures grew out staphylococcus aureus. A drain was left in place for 2-4 days, and patients were treated with intravenous antibiotics for 3 weeks. All patients were asymptomatic with a normal examination at followup.

Marcus RT, Foster RD. Observations on the clinical features, aetiology, and geographical distribution of pyomyositis in East Africa. *East Afr Med J* 45:166-176, 1968.

Over 2-3 years, 2-4000 cases were registered in 27 hospitals in Uganda, Kenya, and Tanzania. Nearly all reported cases were from low altitude regions with high humidity. The etiology remains uncertain, and most cases involve staphylococcus aureus. Coexisting osteomyelitis was never observed.

Renwick SE, Ritterbusch JF. Pyomyositis in children. *J Ped Ortho* 13:769-772, 1993.

Five cases of pyomyositis are presented. Muscle aches and malaise were present for 3 days to 3 weeks prior to presentation, and all were febrile. All were suspected of having septic arthritis. Plain films and bone scan were negative, and MRI made the diagnosis. Four patients were drained surgically, and 2 required additional procedures (repeat debridement, drainage of a second site of involvement). Muscles included the psoas, tibialis anterior, adductors, infraspinatous, subscapularis, and gluteus minimus. Cultures grew staphylococcus aureus (2), streptococcus pneumoniae, and streptococcus pyogenes.
Patients were discharged on oral antibotics after receiving intravenous therapy while in the hospital.

Spiegel DA, Meyer JS, Dormans JP, Flynn JS, and Drummond DS. Pyomyositis in Children and Adolescents: Report of Twelve Cases and Review of the Literature. *J Ped Ortho* 19:143-150, 1999.

12 cases from an urban center over 5 years were reviewed. The differential diagnosis is large, and includes septic arthritis, cellulitis, osteomyelitis, thrombophlebitis, viral or parasitic myositis, hematoma, contusion, muscle strain injury, and neoplasm. The clinical findings were similar to previous reports. MRI was able to differentiate between the invasive and suppurative phases of the disease. Coexisting abnormalities in adjacent osseous or articular tissues were identified in 58% on MRI, and likely represent reactive inflammation rather than coexisting osteomyelitis. Percutaneous catheter drainage was successful in 5 cases, and may represent an alternative to surgical drainage in some locations. The optimal duration of antibiotic therapy remains unclear, however a combination of intravenous and oral antibiotics for 2-6 weeks was successful in all patients.

Tong CW, Griffith JF, Lam TP, Cheng JC. The conservative management of acute pyogenic iliopsoas abscess in children. *J Bone Joint Surg* 80b: 83-85, 1998.

Pyogenic abscess of the iliopsoas muscle is uncommon in children, and the differential diagnosis includes septic arthritis of the hip, appendicitis, or osteomyelitis. Common clinical findings include fever, limp, abdominal pain, and pain/flexion deformity of the hip. 3 cases are reviewed, two of whom were succesfully treated by CT or ultrasound guided percutaneous aspiration and antibiotics, and the third by antibiotics alone (small abscess was present). Although surgical drainage has been the traditional treatment, some cases of intramuscular abscess may respond favorably to percutaneous drainage followed by antibiotics.

VII. Osteoarticular Tuberculosis

Up to one third of the world's population is infected with mycobactrium tuberculosis, and 25% of avoidable deaths in developing countries are secondary to TB. Musculoskeletal manifestations include arthritis, osteomyelitis, and spondylitis. TB may mimic a host of diseases both clinically and radiographically. Chemotherapy is the mainstay of management, and surgery may be viewed as an adjunct to chemotherapy.

With adequate compliance, current chemotherapeutic protocols should successfully eradicate more than 90% of cases of osteoarticular tuberculosis. In general, for primary cases, 4 agents are initially recommended for a variable period of time (2-3 months), followed by 2-3 agents for an additional period (4-6 months). The protocol is based upon local susceptibilities and individual culture results. Intermittent (2-3x per week) dosing is acceptable. First line agents may be bacteriocidal (isoniazid, rifampicin, streptomycin, and pyrazinamide) or bacteriostatic (Ethambutol, Thiocetazone). Second line agents may be bacteriocidal (capreomycin, kanamycin) or bacteriostatic (ethionamide, cycloserine, para-amino salicylic acid). The emergence of drug resistant organisms has been a problem in many areas, particularly with partially treated cases. Resistence to at least one drug is seen in approximately 10% of primary cases (≈»1% multidrug resistence). Resistance occurs by chromosomal mutation, and the most common cause of relapse is inadequate treatment of the primary infection (poor compliance, inadequate supply of medications, improper regimen). Monitoring is crucial to limit the number of relapses due to noncompliance. In addition to the individual morbidity, the cost of treating relapses is extremely high. The treatment of relapses typically includes 5 agents initially, and then 3 agents in the second phase. Second line agents are usually employed in the treatment of relapses.

Articular involvement often presents as a monoarticular arthritis with an effusion (+/- pain). The initial phase involves the proliferation of synovial granulation tissue, which may gradually extend across the articular surface. Marginal erosions may be seen radiographically, and ultimately the joint is destroyed (+/- subluxation or dislocation). Autofusion often follows, and either fibrous (may be painful) or bony ankylosis may be problematic if the limb is malaligned. This process usually takes 2-4 years. The classic radiographic findings include juxtaarticular osteopenia, peripheral erosions, and joint space narrowing (Phemister's triad). Synovial biopsy may be required to make the diagnosis, and management is usually medical. Joint synovectomy/debridement may complement chemotherapy, although the indications for surgery are somewhat controversial, depending on the stage of disease. Early diagnosis and treatment is critical, as the outcome depends upon the degree of involvement at presentation.

Several classification schemes have been developed to assess the degree of involvement and provide recommendations for treatment. A clinical and radiographic classification for the hip includes stage 1 (synovitis: juxtaarticular osteopenia), stage 2 (early arthritis: osteopenia, erosions in femoral head or acetabulum), stage 3 (arthritis: erosions, loss of joint space radiographically) and stage 4 (advanced arthritis, destruction). For end stage hip involvement, options include resection arthroplasty, arthrodesis (intra or extra-articular), proximal femoral osteotomy to realign the limb, or total joint arthroplasty.

For the knee, Kerri and Martini have developed a classification as follows: 1 (osteoporosis), 2 (bony erosions), 3 (joint destruction without gross disorganization, and 4 (joint destruction with gross disorganization). In addition to chemotherapy, splinting with early range of motion exercises is important to maintain motion and prevent the development of contractures. Salvage options include arthrodesis and total joint arthroplasty. Although arthroplasty has been successful in patients with involvement of the hip or knee, the timing remains controversial, and reactivation of infection may be seen in up to 30% of cases. Some have suggested an interval of at least 10 years between control of disease and arthroplasty, and further work will be required to define the role of total joint arthroplasty in this setting.

Skeletal tuberculosis is seen with less frequency, and includes both common and uncommon forms. TB usually occurs at a single site, and radiographically presents as a lytic lesion with a sclerotic rim. Osteopenia is common, and less commonly there may be an aggressive appearance (with a periostial reaction) or a small sequestrum. Uncommon forms include *cystic* (no sclerotic rim, children, diverse sites, may be multisystic), *disseminated* (compromised host, appendicular in children, skull/axial in adults), *closed multiple tubercular diaphysitis* (very rare, children, swelling in forearms and legs with diaphyseal thickening and sclerosis), and *tubercular rheumatism* (Poncet's disease, multiple effusions). Skeletal lesions may invade neighboring joints, and readily crosses the physis. Sinuses are common, and up to 50% of these may be superinfected by bacteria. This should be kept in mind when evaluating nonresponders, as a coexisting bacterial infection may need to be treated.

Spinal involvement (Pott's disease) is seen in approximately 50% of patients with osteoarticular tuberculosis. The diagnosis can usually be made on plain radiographs, and typical findings include disc space narrowing, central disc involvement, and anterior collapse. Posterior element disease is uncommon, and multilevel involvement is less common (usually seen in children). Both extradural and intradural disease may occur, and intradural granulomas should be included in the differential diagnosis for patients presenting with a neurologic deficit and normal plain radiographs. Myelography may be required to make the diagnosis if MRI is not available. Neurologic deficits during the active disease phase are caused by mechanical pressure from abscess, granulation tissue, sequestra, and caseous material. In the late (healed) phase, neural compromise typically results from anterior cord compression from a transverse ridge of bone at the apex of the kyphus, and/or dural fibrosis.

Chemotherapy is the mainstay of treatment, and the indications for operative treatment in spinal tuberculosis remain somewhat controversial. Surgical intervention may help to establish the diagnosis, decompress the neural elements, prevent the development of significant deformities in a subset of patients at risk, and shorten the duration of symptoms. In addition, controversy remains regarding the most effective techniques

for decompression and reconstruction in different regions of the spine. The approach to a given case will also depend upon the resources and level of training of providers within each facility.

Surgery is viewed by some as an adjunct to chemotherapy. Both the indications and the techniques employed philosophy of treatment varies between routine decompression and fusion (usually anterior) and the "middle path" regime popularized by Tuli in India. The "middle path" includes a combination of chemotherapy and bedrest, and both the sed rate and radiographs are monitored regularly. Patients are mobilized in a brace after 6-9 months (for an additional 18-24 months). Surgical treatment is suggested for an increase in size of a paravertebral abscess despite adequate chemotherapy, involvement of the posterior elements, lack of clinical response after 3-6 months of chemotherapy (neurologically normal), lack of neurologic recovery or progression of neurologic deficits after several weeks of chemotherapy, recurrence of disease, mechanical instability, or an uncertain diagnosis. According to Jain et al, the indications for surgery may include *clinical factors* (neural arch involvement, recurrent paraplegia, and massive retropharyngeal abscess causing difficulties with ventilation or swallowing), treatment factors (persistent or progressive deficit while following an adequate course of conservative treatment), *imaging factors* [panvertebral involvement (scoliosis or severe kyphosis on plain films, global destruction on CT or MRI)] or extradural compression (circumferential cord compression from granulation tissue on MRI)], and *patient factors* (painful spasm or nerve root compression).

Surgical approaches advocated for decompression and stabilization include anterior, posterior, anterior and posterior, and lateral (extrapleural), with or without instrumentation. In most cases an anterior decompression and fusion is recommended, except in cases with isolated posterior element involvement (laminectomy) or panvertebral involvement (anterior and posterior spinal fusion). For patients unable to tolerate anterior surgery, a lateral extrapleural approach may be employed. Sources of structural graft for the anterior column include rib, iliac crest or fibula. Graft complications, at least with autogenous rib, become much more common when more than 2 levels are spanned. In such a case a posterior instrumented fusion may be performed at the same time, or prior to anterior decompression if the procedures are to be staged. Instrumentation is not contraindicated in mycobacterial infections.

Another issue surrounds *progression of deformity*, as 80% of patients will have some localized kyphosis, yet only 3-5% progress to > 60°°. Progression may occur during both the active phase and after healing. Risk factors for significant progression of kyphosis include age (children), thoracic involvement, multiple levels of involvement, and greater initial loss of vertebral height. Radiographic "at risk" factors have also been described. Identifying a subset of patients with a poor prognosis may help to refine the indications for prophylactic spine fusion.

Cervical spinal involvement is uncommon, and few series have dealt exclusively with this location. Patients typically present with pain, stiffness, and torticollis, and large abscesses may result in hoarseness, stridor, and dysphagia. Cervical lymphadenopathy, sinuses, and neurologic involvement are all commonly observed. Atlanto-axial involvement may result in instability at this joint. Noncontiguous involvement may be seen, and involvement of more than one vertebra is not uncommon in the mid cervical spine. The lateral radiograph usually demonstrates widening of the retropharyngeal space in the prescence of an abscess. In addition to chemotherapy, treatment recommendations have varied from the more conservative "middle path" regimen to routine decompression and fusion. Patients are most often started on chemotherapy and placed on bedrest with or without cervical traction. Options for decompression include the transoral route, or an anterior approach along the anterior border of the sternomastoid muscle. Arthrodesis maybe accomplished either anteriorly or posteriorly, although most surgeons will have a greater familiarity with posterior spinal fusion. With adequate treatment, neurologic recovery has been excellent, and most patients remain asymptomatic without evidence of recurrence at mid term followup.

VII A. General considerations

Bastian I, Colebunders R. Treatment and prevention of multidrug-resistant tuberculosis. *Drugs* 58:633-661, 1999.

Multidrug resistant tuberculosis is defined as a combined resistance to at least isoniazid and rifampicin, and has become a significant problem in recent years. The approximate prevalence is 1.4%, and cases usually arise in countries in which chemotherapy is available but TB control programs are inadequate. If recognized early and treated with an individualized regimen, cure rates of 96% may be achieved. The costs of managing these cases are enormous, and the best strategy is prevention. Estimates from Rwanda suggest that the cost of treating one patient with resistant disease is equivalent to the cost of treating nearly 50 patients with susceptible disease. There are many reasons for the increase in resistance, including increasing poverty and homelessness, immigration, urbanization, noncompliance, HIV, war, famine, natural disasters, physician mismanagement, and problems with health infrastructure. Resistance to an individual agent occurs as a result of a spontaneous unlinked chromosomal mutation, and the best way to avoid resistance is to adequately treat primary cases. Adequate support and surveillance during treatment is essential, and the DOT (directly observed therapy) protocol has been helpful, yet only 23% of the world's population has access to this program. A host of risk factors have been suggested, one of which is a poor response to the initial treatment. Patients who fail to defervesce after 2 weeks of a four drug protocol may be at risk, and those with positive sputum cultures after 5-6 months may be considered treatment failures. Susceptibility testing is extremely important, however this may not be possible in many settings. Using the most recent laboratory techniques, susceptibility data should be available within 4-5 weeks. Patient assessment should include any previous treatment, compliance during earlier treatment, the clinical and radiologic response, and any bacteriological response. Susceptibility results are crucial to the treatment of resistant disease. If a patient has a known contact with a resisant case, then they may be started on a protocol based upon the culture results of the contact. Many acceptible regimens have been devised for treating resistant disease, and typically patients are started on 3-4 agents while awaiting the results of sensitivity testing. Second line agents are commonly employed, including the aminoglycosides (kanamycin, amikacin), capreomycin, ethionamide, cycloserine, and the quinolones (ciprofloxacin, ofloxacin). Both bacteriocidal and bacteriostatic drugs should be used. A list of acceptable treatment protocols is provided. For the future, sequencing of the tuberculosis genome should enable the development of more effective agents for treatment. Alternative strategies for treating resistant disease include high dose isoniazid, rifabutin, clarithromycin, clofazimine, amoxicillin-clavulanic acid, metronidazole, immunotherapy and gene therapy.

Griffith JF, Kumta SM, Leung PC, Cheng JC, et al. Imaging of musculoskeletal tuberculosis: A new look at an old disease. *Clin Orthop Rel Res* 398:32-39, 2002.

This review article discusses imaging features which may help to distinguish TB from other pathologies. Since less than 50% of patients have a positive chest x-ray, the diagnosis is often difficult to reach, especially in nonendemic areas. Plain radiographs are usually sufficient to differentiate tuberculous spondylitis from other processes. Imaging features that support the diagnosis of TB include multilevel involvement, multicentric involvement, relative sparing of the intervertebral disc, a large paravertebral abscess, bone fragments, subligamentous spread, heterogeneous signal intensity on MRI, and a rim enhancement pattern on MRI. Features that are more consistent with TB versus neoplasia include a paravertebral abscess, bone fragments, subligamentous spread beyond 2 vertebrae, and a distribution adjacent to the end plates or corners of the vertebral bodies. When available, MRI can provide additional information, and contrast should always be administered. This modality can distinguish between abscess and fibrous tissue, can accurately evaluate intraspinal and paraspinal extension, and can better evaluate involvement of the neural elements. The sensitivity to inflammatory changes on MRI may overestimate the degree of vertebral involvement. CT can be helpful is determining the amount of bony destruction, and to guide a biopsy if indicated. Tuberculous osteomyelitis is most often seen peripherally within the bone, and there is early breach of the cortex with spread of debris creating juxtacortical abscesses. Central involvement may be variable in appearance, and difficult to differentiate

from other forms of osteomyelitis or neoplasia. Spread across the physis is common. MRI adds to plain films in demonstrating extraosseous extension. With respect to joint involvement, the classic plain film findings include juxtaarticular osteoporosis, peripheral erosions, and joint space narrowing (Phemister's triad). MRI can help differentiate from PVNS (demonstrates hemosiderin). The synovial membranes within tendon sheaths may become involved in TB, and biopsy is usually required to make the diagnosis.

Marchevsky AM, Damsker B, Green S, et al. The clinicopathologic spectrum of non-tuberculous mycobacterial osteoarticular infections. *J Bone Joint Surg* 67:925-929, 1985.

Eight patients (2-74 years old) presented with a variety of symptoms. Patterns of involvement included tenosynovitis (3), synovitis (2), and osteomyelitis (3). The histologic features were variable and included nonspecific chronic inflammatory changes, granulomas without necrosis, and caseating epithelioid granulomas. Some specimens demonstrated an abscence of inflammation. Organisms included mycobacterium avium-intracellulare, mycobacterium marinum, mycobacterium fortuitum, mycobacterium gordonae, and mycobacterium terrae. Six of 8 cases responded to surgical debridement alone, and the other 2 responded well to a combination of surgery and chemotherapy. In contrast, the literature supports the the combination of surgery and chemotherapy. At least 4 months of chemotherapy is recommended, and nonstandard agents may be required.

Messner RP. Arthritis due to mycobacteria, fungi, and parasites. In (Ed.) *Arthritis and Allied Conditions. A Textbook of Rheumatology*. (12th edition), Vol 2, Lea and Febiger, Philadlephia, London, 1993, pp.2035-2046.

This chapter summarizes forms of arthritis associated with different infectious agents (excluding bacteria) including tuberculosis, atypical tuberculosis, leprosy, fungi (cocciodioidomycosis, blatomycosis, cryptococcus, histoplasmosis, sporotrichosis, actinomycosis, and candidiasis), and parasites (filariasis, trichinosis, cisticercosis, echinococcus, schistosomiasis, and giardiasis).

Atypical tuberculosis may involve joints, tendons, and bursae. Fifty percent of patients have involvement around the hand and wrist, and 20% in the knee. Fifteen percent may have polyarticular disease, and 25% have a history of arthritis (osteoarthritis, rheumatoid arthritis, or SLE). The most common agent is the mycobacterium avium complex, which may cause septic arthritis or osteomyelitis in patients with AIDS. The diagnosis requires a positive culture.

Several forms of leprosy have been described. In lepromatous leprosy there are inflammed subcutaneous nodules, usually in association with fever and polyarthralgias (knees, ankles, small joints of the hand). Most joint problems result from neuropathy, and absorption of the distal ends of the metatarsal bones is a common finding. Repetative trauma often results in terminal amputations and deformities in the hands and feet. Charcot arthropathy may occur at the wrist and ankle. The diagnosis involves identifying the organisms on histology, a positive AFB smear, and skin biopsy (demonstrates peripheral nerve involvement). Triple drug therapy with dapsone, rifampin, and clofazimine is recommended.

Fungal infections may also be associated with musculoskeletal findings. Coccidioidomycosis results from inhalation of spores found in the soil, and arthritis may be seen in primary cases as well as in patients with disseminated disease. Bony involvement may be seen in 20% of patients with disseminated disease (40% multifocal). The diagnosis is made by histologic evaluation and culture, and Amphotericin B is the treatment of choice. Surgery may be indicated for debridement of osseous and articular lesions. Blastomycosis also arises from inhalation of spores from the soil. Lymphatic or hematogenous spread from the lungs results in extrapulmonary disease, and 50% of patients may have skeletal involvement, while 5% may present with joint pain. Most cases of articular involvement occur via hematogenous seeding of the synovium, but direct extension from an osseous focus may also occur. Spinal involvement may be observed. The organism is demonstrated on potassium hydroxide treated smears of infected material, and amphotericin B is the treatment of choice (ketoconazole may also

be used). Cryptococcal infection also begins after inhalation of the organism, and usually is observed in a compromised host. Only 10% have bony involvement, which radiographically presents as lytic lesions with scalloped margins and minimal periostial reaction. Involvement in multiple bones has been described, but joint involvement is rare. Treatment includes Amphotericin B and 5-flourocytosine. Histoplasmosis also results from inhalation of organisms present in the soil, and a polyarthritis may be observed. The diagnosis is by histology or culture. Sporotrichosis is commonly found in the soil and on plants, and the route of infection is direct innoculation. Patients are typically older, and have compromised immune function. A chronic granulomatous arthritis may be observed. The diagnosis is made by culture, and Amphotericin B is recommended for treatment. An arthritis may rarely be associated with Candidal infection, usually in the compromised host, and the knee is involved in 75% of cases.

Arthritis associated with parasitic infection or infestation can be due to direct infection of the joints or to the coexisting immunologic response. Wuchereria Bancrofti (filariasis) is seen in tropical and subtropical areas, and is transmitted through mosquitos. The organism is harbored in lymphatics, and an acute arthritis of large joints (especially the knee) may be seen with fever and inguinal adenopathy. In the Indian subcontinent and west Africa the guinae worm Dracunculus medinensis may infect the host and migrate through the subcutaneous tissues of the lower leg to emerge and create an ulcer. Septic arthritis may occur through bacterial infection of the ulcer, or if the organism migrates into a joint and releases it's larvae. The diagnosis is made by demonstrating the larvae in joint fluid. Trichinosis (trichinella spiralis) is transmitted through contaminated food and usually results in a myositis. Schistosomiasis is endemic in Africa, Asia, South America, and the Caribbean islands, and the organisms reside in the venous system. They produce eggs which release enzymes (allow for exit from the host). Granulomatous lesions are produced by the host response to the eggs, and tissue destruction is the result. Both a pauciarticular (reactive) and polyarticular (immune mediated) form of reactive arthritis has been observed.

Pablos-Mendez A, Raviglione MC, Laszlo A, et al. Global surveillance for antituberculosis-drug resistance, 1994-1997. *NEJM* 338:1641-1649, 1998.

Resistance to antituberculous medications results from spontaneous mutation, and typically results from inadequate treatment (poor compliance, irregular supply of medications, inappropriate regimens). The treatment of these difficult cases is costly, and must be individualized and closely supervised. Data from cross sectional surveys and surveillance reports from 35 countries (median 555 patients studied in each country) are presented. Resistent strains were identified in all countries, most commonly to isoniazid or streptomycin. In patients who had not received treatment previously, 9.9% (2-41%) of patients were resistent to at least one drug (isoniazid 7.3%, streptomycin 6.5%, rifampin 1.8%, ethambutol 1%). In the same group, the prevalence of multidrug resistance was 1.4% (0-14.4%). In patients who had been treated previously, 36% (5.3-100%) were resistant to at least one agent, and the multidrug resistance was 13% (0-54%). Combining these two groups of patients, the overall prevalence of single drug resistance was 12.6% (2.3-42.4%), and of multidrug resistance was 2.2% (0-22.1%). These findings may underestimate the true prevalence worldwide, as most participating countries were those with better resources/TB programs. Countries with a very high prevalence of multidrug resistance include the former Soviet Union, Argentina, and the Dominican Republic.

Shanmugasundaram TK. Bone and Joint Tuberculosis. Kothandaram and Co., Madras, India, 1983.

This textbook covers a series of lectures by the author on history, pathology, bacteriology, chemotherapy, and eradication/prevention, in addition to site specific information on osteoarticular tuberculosis. His personal experience, and a review of a large series seen at his institution, is covered in detail. One unique contribution from these lectures is a clinico-radiologic classification of tuberculosis of the hip joint, which includes 7 types (normal hip, travelling acetabulum, dislocating, perthes type, protrusio, atrophic, and mortar & pestle). The travelling acetabulum type involves a lesion in the acetabular roof, with joint space narrowing

and superior migration of the femoral head. This is seen most commonly in children, and carries a poor prognosis. The dislocating type (dislocated at presentation or developing during the course of treatment) also has a poor prognosis, and lesions may also be seen in the head and neck of the femur. The Perthes type is usually seen in children less than 5 years of age, and in the abscence of cystic lesions may be indistinguishable from Perthes disease. The end result is often fibrous ankylosis of the hip. The protrusio type involves a focus in the floor of the acetabulum, and occurs in the first and second decades of life. The prognosis is good in children, and poor in adolescents. The atrophic variety has significant joint space narrowing, and subchondral lesions may occur on both sides of the joint. It may be difficult to differentiate this from rheumatoid arthritis. The prognosis is poor, and this type is usually seen in older patients. In the mortar & pestle type, the head of the femur is irregular and deformed, and the articulation is incongruous. Patients are typically in the third and fourth decades of life, and the prognosis is usually good (reasonable range of painless motion).

Shembekar A, Babhulkar S. Chemotherapy for osteoarticular tuberculosis. *Clin Orthop Rel Res* 398:20-26, 2002.

This review article summarized current concepts in chemotherapy for osteoarticular tuberculosis. The success rate is greater than 90%, and the major cause of treatment failure is lack of patient compliance. In addition, success often depends upon the medical status of the host, and proper nutrition and good general medical health favor a positive outcome. Many patients may be treated by chemotherapy alone, particularly if the diagnosis is made early. Challenges have included resistant organisms, compliance, coexisting HIV infection, chronicity of infection, recurrence, and drug toxicity. Standard or first line chemotherapeutic agents that are bacteriocidal include isoniazid, rifampicin, streptomycin, and pyrazinamide. Those that are bacteriostatic include ethambutol and thiacetazone. Reserve or second line bacteriocidal drugs include capreomycin and kanamycin, and bacteriostatic drugs include ethionamide, cycloserine, and paraamino salicylic acid. An in depth consideration of each of these agents is provided. Isoniazid (oral, 5 mg/kg/day) prevents development of drug resistence to other agents when used in combination, and is metabolized by the liver. Resultant pyridoxine deficiency must be treated by dietary supplementation. Rifampicin (IM injection, 15 mg/kg/day) is effective against some of the atypical mycobacteria, as well as persisters. Toxicity is < 5%, and it must be given before meals since food interferes with absorption. Rifampicin gives a red color to the urine, feces, and sputum. Streptomycin (15 mg/kg/day) is administered via an intramuscular injection, and does not penetrate caseous material or CSF. Resistance is seen in 2-3%, and both renal and ototoxicity may be observed. Pyrazinamide (35 mg/kg/day) can treat organisms resistant to isoniazid and streptomycin. This agent can cause hepatitis, and jaundice ay occur in 3-4%. Ethambutol (150 mg /day) is especially helpful in treating atypical mycobacteria, and excretion is renal. Optic neuritis is a complication, and children should probably not receive this agent. Thiacetazone (150 mg/day) is usually given in combination with isoniazid, 2-3 times per week. This agent can't be given with streptomycin, and rare side effects include Stevens-Johnson syndrome, blood dyscrasia, and kidney/liver damage. Combination therapy is essential to avoid drug resistence, and 3 drugs should be the initial regimen of choice. Administration in a supervised clinic setting should limit the number of treatment failures due to noncompliance. Second line drugs are helpful with resistent organisms, or if toxicity develops from one of the first line agents. The current protocol includes may be subdivided into an initial period (2 months), in which several agents are administered. Then, fewer agents are given for an additional 4-8 months. Empiric therapy is started immediately, as final culture results may take time to become available. Three drugs are used initially in most patients, but for those with severe involvement 4 drugs should be given. Isoniazid is always included. Some patients may initially improve, but may then develop secondary resistence. Once susceptibility studies are available, the patient should be treated with at least 3 drugs for at least 12 months. In the case of failure due to noncompliance, patients should be treated with a program including other agents that he or she has not received, which may include one or more second line agents. Susceptibility studies will modify the final treatment recommendations. For those who are HIV positive, standard agents should be administered

for a longer period of time (9-12 months). For those with atypical mycobacteria, a program with standard agents in combination with amikacin, a floroquinolone, rifambutin, clarithromycin or clofazimine is indicated.

Tuli SM. General principles of osteoarticular tuberculosis. *Clin Orthop Rel Res* 398:11-19, 2002.

This is an excellent review of the pathology, pathogenesis, and treatment of osteoarticular tuberculosis. Most lesions result from hematogenous spread (visceral or lymphatic origin), except axial lesions which are seeded through Batson's plexus. Osteoarticular TB may originate in either bones or joints, and frequently invlovement in one will secondarily spread to the other. Metaphyseal lesions may invade the neighboring joint through the capsule or the physis. Articular involvement progresses slowly, beginning with an effusion and progressing to a proliferation of granulation tissue by the synovium (causes marginal erosions). Granulation tissue (pannus) may extend across, and destroy, portions of the articular surface. Infection initially stimulates the immune system, and the bacilli are phagocytosed by macrophages and mononuclear cells, which then coalesce to form epiphelioid cells. After one week, lymphocytes form a ring around the lesion, creating what is referred to as a nodule. Caseation then occurs within the nodule (coagulation necrosis). A cold abscess may then be created by the inflammatory response, which may migrate through periostium, ligaments and follow fascial planes and neurovascular bundles. A sinus may then form, which can be complicated with superinfection by bacteria. Bony changes include regional osteoporosis from hyperemia, followed by destruction and sequestration. Atypical mycobacteria rarely cause osteoarticular lesions, and may occur within synovial sheaths. Clinical symptoms seen in osteoarticular TB include low grade fever, malaise, anorexia, weight loss, anemia, night pain, night sweats, and patients usually exhibit monoarticular involvement or a single osseous focus. In endemic areas, the history and x-rays may be sufficient to make the diagnosis. A negative Mantoux test usually rules out TB. Biopsy is essential in cases in which the diagnosis is unclear. Chemotherapy can effectively treat sinuses/ulcers (usually heal within 6-12 weeks), and abscesses, and surgery should be directed towards prevention and correction of deformities, and improvement of function. Prognosis depends upon the stage of the disease at the time treatment is initiated. In the early, active stage of the disease, rest and immobilization using removable splints is indicated. In addition to chemotherapy active range of motion exercises are encouraged within the limits of the patients symptoms. Traction may also be useful. Weightbearing in an orthosis is begun after 3 months of therapy, and approximately 2 years of bracing time are recommended. Effusion may be aspirated, and can be injected with streptomycin (1000 mg) with or without isoniazid (300 mg). If aspiration is unsuccessful, then open drainage can be considered. Paravertebral abscesses do not always require drainage. Combination chemotherapy is indicated in all patients, and for nonresponders (after 4-5 months) and multidrug resistence second line drugs are indicated. Immunomodulation is being investigated as an adjunct to chemotherapy, especially in the case of resistence. A trial of chemotherapy is almost always indicated prior to considering surgical intervention, and a minimum of 1-4 weeks of chemotherapy should be employed. Osteotomy can be used to correct fixed deformities, and soft tissue release, synovectomy and debridement can help to maintain joint mobility and alignment. Intraosseous foci should be debrided if there is a risk of joint invasion. Debridement followed by splinting for 3-6 months is recommended for advanced stage arthritis. Arthrodesis should be delayed until children are >12 years of age, if this option is selected. In cultures in which most activities are performed low to the ground, such as in southeast asia, patients may prefer excisional arthroplasty (hip) rather than a fusion. Total joint replacement, when feasible, may be considered if the patient's disease has been inactive for more than 10 years, and multidrug chemotherapy should be administered for 3-5 months postoperatively.

Tuli SM. Tuberculosis of the skeletal system: bones, joints, spine and bursal sheaths. 2nd edition, Bangalore, Jaypee brothers, 1997.

This outstanding text represents the author's 30 year experience in treating tuberculosis of the musculoskeletal system.

Watts HG, Lifeso RM. Tuberculosis of bones and joints: Current Concepts Review. *J Bone Joint Surg* 78a:288-298, 1996.

An excellent review of bone and joint tuberculosis with an extensive list of references.

Treatment of Tuberculosis: Guidelines for National Programs, 2nd Edition, World Health Organization, Geneva, Switzerland, 1997.

The goal of this document is to provide national TB programs with updated guidelines for the control of tuberculosis. The identification and cure of infectious cases of TB is the most effective means for control, and recommendations are based upon whether cases involve smear positive pulmonary TB, smear negative pulmonary TB, and extrapulmonary TB. Standardized regimens of short course chemotherapy are currently recommended, and monitoring of individual patients is critical to the success of any program. Approximately one third of the world's population is infected, and TB represents 25% of all avoidable deaths in developing countries. The global burden of tuberculosis is related to poverty (and the widening gap between the wealthy and the poor), to neglect, to changing demography, and to the prevalence of HIV. Problems with the effort to control TB on a worldwide basis include deficient political support and funding, inadequate organization of services, failure to adequately followup all cases being treated, and an overreliance on the BCG vaccine. The 3 main properties of chemotherapeutic agents include bacteriocidal ability, sterilizing ability, and prevention of resistence. Bacteriocidal drugs include isoniazid (5 mg/kg/day), rifampicin (10 mg/kg/day), pyrazinamide (25 mg/kg/day), and streptomycin (15 mg/kg/day), while ethambutol (15 mg/kg/day) and thioacetazone (2.5 mg/kg/day) are bacteriostatic. All drugs except thioacetazone are effective if given intermittently, and current strategies involve intermittent administration (2-3 times per week). For new cases, an intensive protocol (4 drugs) is given for 2 months, and symptoms usually improve within 2 weeks (patients become smear negative within 2 months). Fewer drugs are then given for an additional 4-6 months. For patients who have smear negative or extrapulmonary disease at presentation, 3 drugs are usually given initially, followed by 2 drugs in the second phase of treatment. For patients who were previousely treated and have had a relapse, 5 drugs are given initially, followed by 3 drugs in the second phase. The exact regimen depends upon not only the patients treatment category, but also on factors relating to the country and health system in which the treatment is administered. Additionally, treatment protocols may be modified based upon the degree of involvement within each case, for example if the patient has miliary disease or meningeal involvement. The protocol is also modified in the setting of pregnancy, breastfeeding women, those on oral contraceptives, those with liver disease, and in those with renal failure. An effective monitoring strategy must also be followed to limit the number of recurrent cases. Those who are smear positive should be evaluated by sputum smear examination. If they remain positive after 2 months, the initial protocol is continued for an additional month. If they still remain positive after 5 months, then they are classified as a treatment failure and entered into a different protocol. If culture and sensitivity capabilities are present, then this may help direct treatment. Patients should be monitored clinically for drug toxicity, which is uncommon. Those with a minor adverse effect may be continued on the offending agent, but the protocol must be altered in the event of a major adverse reaction. Side effects of the majo drugs are as follows. Minor effects of rifampicin include anorexia, nausea, and abdominal pain, and the urine/feces may become orange/red colored. Pyrazinamide may result in joint pains, and isoniazid may cause a burning sensation in the feet (treat with pyridoxine 100 mg per day). Major complications infrequently associated with most of these agents include vomiting, confusion, and jaundice. Rifampicin may rarely induce shock, renal failure, and purpura. Streptomycin may cause deafness or dizziness, while ethambutol may result in visual impairment. Streptomycin and thioacetazone may be complicated by pruritis or rash. In the event of a major reaction, all drugs are stopped, and the agents are gradually reintroduced over several days starting with the agent least likely to have caused the reaction. Once the responsible agent is identified, it should be replaced. Recommendations have also been established for the management of drug induced hepatitis. Patient compliance is a major issue, and it is a public health priority to monitor the treatment program. "Directly observed treatment" requires that a trained health

professional observes the patient taking each dose of medication. This is difficult to institute, but remains the best approach to supervision. HIV continues to be a major concern worldwide, and TB may commonly complicate HIV infection. Recommendations for chemotherapy are generally the same whether or not the patient is HIV positive, but thioacetazone should never be used (ethambutol should be substituted). Mortality rates are higher in the setting of HIV infection, but the overall response rate with chemotherapy is not significantly different.

VII B. Skeletal Tuberculosis

Aggarwal AN, Dhammi IK, Jain AK. Multifocal skeletal tuberculosis. *Tropical Doctor* 31:219-220, 2001.

18 cases are reviewed in patients from 2 to 60 years of age, who presented most often with swelling and a sinus or ulcer. Only one patient had active pulmonary disease, and less than 25% had extraosseous involvement. Sites of involvement included the spine (3/18), flat bones of hands or feet (15/18), long bones (2/18), and joints (9/18). Most patients seems to be either young children or young adults, and poor host immunity may be important. All were treated effectively by 18 months of chemotherapy.

Babhulkar SS, Pande SK. Unusual manifestations of osteoarticular tuberculosis. *Clin Orthop Rel Res* 398:114-120, 2002.

Unusual forms of skeletal tuberculosis include closed cystic tuberculosis, closed multiple tubercular diaphysitis, disseminated skeletal tuberculosis, osteoarticular tuberculosis associated with sickle cell disease, and tubercular rheumatism. Awareness of these rare manifestations are essential for diagnosis. Cystic tuberculosis refers to a cystic lesion that occurs without surrounding sclerosis or osteopenia, and is most often seen in children and young adults. This occurs most commonly in the long bones, but also in the short bones and flat bones. Those in the hands and feet are notable for the abscence of a periostial reaction. Tuberculous dactylitis may be characterized radiographically by 4 forms: soft tissue swelling with marginal cortical erosion, small central destruction with periostial reaction, cystic expansile form, and multicystic honeycomb appearance. All patients responded to chemotherapy. Closed multiple diaphysitis is very rare, and was seen in 9 children over a 20 year period. These patients were both anemic and malnourished, and presented with swelling in both forearms and legs. Generalized thickening and sclerosis of the diaphysis was observed radiographically. Diagnosis was established by biopsy (after patients failed a course of antibiotics for presumed pyogenic osteomyelitis), and all responded to an 18 month course of chemotherapy. Chemotherapy alone achieved similar results to chemotherapy and curettage. Disseminated tuberculosis is typically seen in 5-10% of cases, and may involve multiple bones or bones and joints. The host is usually compromised, and chemotherapy is the mainstay of treatment. Biopsy may be required for diagnosis. Radiographically, sarcoidosis is in the differential diagnosis. Over 20 years, 37 patients with tubercular lesions associated with sickle cell disease were treated. Most cases occur in the spine (11/18 in the lumbar region), but also in the hip (6), SI joint (2), knee (3), foot/ankle (3), elbow (2), and wrist (1). Unique spinal radiographic changes in this population include a step off deformity with central depression of the end plates, which has been reported in patients with sickle cell disease and Gaucher's disease in the abscence of tubercular infection. Tubercular rheumatism is rare and presents as polyarthritis, and joint aspiration may be negative. Patients respond to chemotherapy, joint mobilization, and NSAID's.

Fu-sheng K, Ch'ing-Lang L, Lu-hua S, Shu H. Differential diagnosis of rheumatic fever and alergic arthritis due to tuberculosis. *Chinese Medical Journal*. 85:477-481, 1966.

52 cases of tuberculosis associated with allergic arthritis (Poncet's disease) are reviewed to differentiate this condition from rheumatic fever. Poncet's disease usually occurs in females during childhood and adolescence. Chronic recurrence is observed, in which there is an acute episode of fever, arthritis, and rash (erythema nodosum). These findings are similar to rheumatic fever, however patients tend to be in better overall health. Migratory polyarthralgias with swelling, warmth, and pain are common, in contrast to rheumatic fever (only 33% have arthralgias). Erythema nodosum was seen in 38/52 cases, and subcutaneous nodules (near joints) were observed in 7 patients. Lymph node biopsy revealed lymphoid cells,

giant cells, fibroblasts, and only 1/8 had caseous necrosis. Although less common, cardiovascular abnormalities may occur in Poncet's disease (7 had an abnormal EKG), but neither cardiac enlargement nor valvular lesions were seen. The antistreptolysin O titer may be elevated in Poncet's disease, and this test is therefore not specific for rheumatic fever. Tuberculosis of the lymph nodes was identified in 46/52, which aided in the diagnosis. Initially, 36 cases were treated for rheumatic fever. Despite an improvement in joint symptoms with salicylates and steroids, recurrence of symptoms was common. Therefore, the therapeutic response to these agents will not necessarily aid in the differential diagnosis. Overall, the prescence of endocarditis or valvular lesions is critical for the diagnosis or rheumatic fever. With respect to any rash that may be observed, erythema nodosum is more commonly associated with tuberculosis while erythema marginatum is seen in rheumatic fever. A Mantoux test should always be performed, and in patients who have recurrent symptoms while being treated for presumed rheumatic fever should be further evaluated.

Hsieh CK, Miltner LJ, Chang CP. Tuberculosis of the shaft of the large long bones of the extremities. *J Bone Joint Surg* 16a:545-563, 1934.

38 cases of long bone involvement are presented, representing 4.8% of all cases of osteoarticular tuberculosis over a period of 11 years. Radiographic manifestations include a periostial form (laminated new bone formation over an intact cortex), a solitary metaphyseal focus (+/- sclerotic rim), and an infiltrative lesion involving a either a segment of or the entire shaft of the bone. Multiple cystic lesions may be seen in both the medullary space and the cortex. The pathogenesis is felt to be embolic. Sites of involvement included the tibia, femur, radius, ulna, and the humerus. Most cases present with the insidious onset of dull, aching pain, without systemic symptoms. Many lesions decompressed via sinus tracts.

Huang CH. Extra-articular tuberculous osteomyelitis. A report of 11 cases. *International Orthopaedics (SICOT)* 20:169-171, 1996.

11 cases (4.7% of all cases of musculoskeletal TB) presented after an average of 8 months of symptoms. None of these patients gave a history of pulmonary disease. Typical radiographic findings included a lytic lesion surrounded by a thin area of sclerosis. Sites of involvement included the femur, ilium, calcaneus, proximal radius, talus, and third metacarpal. Patients underwent curettage (for diagnosis and treatment) without bone grafting, and all healed without recurrence following an appropriate course of chemotherapy.

Komins C. Multiple cystic tuberculosis: A review and revised nomenclature, *Br J Rad* 25:1-8, 1952.

Multiple cystic tuberculosis is rare, and sarcoidosis is high on the differential diagnosis. Cystic tuberculosis may have a rapid or slow onset, and usually is seen in patients from infancy to puberty, while sarcoidosis is a disease seen most commonly in the third decade, with slow onset and minimal constitutional symptoms. Tuberculosis usually often has active or healing pulmonary lesions, a positive Mantoux test, and a positive guinea pig innoculation, whereas sarcoidosis is associated with skin lesions. Radiographically, sarcoidosis is usually associated with lesions in the tubular bones of the hands and feet, while tuberulosis more often affects the long bones. Sarcoidosis has multiple lesions that present as oval or honeycombed areas of rarefaction, without sequestration, periostial reaction, expansion, or sclerosis. Tuberculosis presents with large, oval areas of rarefaction, and may have bony expansion, a periostial reaction, and sequestration.

Kumar K, Saxena MBL. Multifocal osteoarticular tuberculosis. International Orthopaedics (SICOT). 12:135-138, 1988.

48 patients were seen over 9 years (age 4-42 years). Symptoms were present for 3 months to 6 years. Distribution of involvement was as follows: multiple bony lesions (27%), multiple joint involvement (29%), and both bony and joint involvement (44%). Three patients had ≥ 3 joints involved, while 8 had > 4 bones involved. In 73% of patients, no primary focus of TB could be identified, in contrast to the literature which suggests that 50-75% will have evidence of pulmonary disease at the time of diagnosis of bone or joint involvement. Patients were treated with triple drug therapy for 18-24 months. Poor host immunity is often associated with multiple bone or joint involvement.

Martini M, Adjrad A, Bouddjemaa A. Tuberculous osteomyelitis. A review of 125 cases. *International Orthopaedics (SICOT)* 10:201-207, 1986.

125 lesions in 11 patients were studied, and 100 had involvement at a single site. 11 of the patients were children. Patients presented with a sinus (100), an abscess (14), or local tenderness/swelling (11). The average delay in diagnosis was 28 months, and only 17 had evidence of coexisting disease in the lungs or viscera. Radiographically, 63 demonstrated a lytic focus with a sclerotic rim, and 33 had a small sequestrum. Changes more consistent with pyogenic osteomyelitis were seen in 13, with an aggressive periostial reaction and sequestration of diaphyseal bone. Immobilization was not employed, and only 3 patients had surgery to decompress abscesses. 92% were treated effectively by chemotherapy, and only 3 patients were treated surgically, for a lack of response. Superinfection with pyogenic bacteria can complicate the diagnosis, and 50% of sinus cultures were also positive for bacteria. All 8 nonresponders had positive bacterial cultures.

Nicholson OR. Tuberculosis of the pubis. Report of eleven cases. *J Bone Joint Surg* 40b:6-14, 1958.

The pubis is an uncommon site for TB, and 11 cases (7-68 years old) were seen over a 17 year period. Complaints included pain in the groin or pubic region, limp, and thigh swelling, and patients presented after 2 weeks to 12 months of symptoms. Abscesses were found in 9/11, and sequestration occured in 6/11. Other sites of involvement were identified in 4/11. Erosive changes are seen in the pubis, and often begin on one side and progress across the symphysis pubis to include both sides. Treatment included curettage without grafting, and 6/11 received chemotherapy. Healing without recurrence was achieved in all patients, and those receiving chemotherapy had quicker resolution.

O'Connor BT, Steel WM, Sanders R. Disseminated bone tuberculosis. *J Bone Joint Surg* 52a:537-542, 1970.

A case report and review of the literature is presented. Disseminated involvement is rare. Children tend to have multiple, cystic, expansile lesions in the medullary region of the appendicular skeleton. A sclerotic border is rare. Adults tend to have small, oval lesions with well defined margins in the skull, axial skeleton, shoulder, and pelvis. Differences in location between children and adults may be explained by the distribution of reticuloendothelial and hematopoietic tissue in each age range.

Rasool MN, Govender S, Naidoo KS. Cystic tuberculosis of bone in children. *J Bone Joint Surg* 76b:113-117, 1994.

13 children with cystic tuberculosis of bone were treated The ages ranged from 1-12 years, and patients presented with pain and swelling in the region of the neighboring joint. The sed rate was normal in 5, and 46-95 mm/hr in the others. The Mantoux test was negative in 4. The WBC count ranged from 5.6 to 13.8. The lesions were usually metaphyseal (2 epiphyseal, 1 diaphyseal), could be expansile, and sites of involvement included the mandible, spine, humerus, ulna, femoral neck, tibia, radius, thumb metacarpal, pubis, acetabulum, and greater trochanter. Radiographically, 3 of the 10 lesions were multicystic, and the differential diagnosis includes simple or aneurysmal bone cyst, cartilagenous neoplasms, pyogenic infections, and osteoid osteoma. A periostial reaction was seen in 6 cases. The adjacent joint became involved in all patients with epiphyseal or metaphyseal involvement. Biopsy was employed for diagnosis, and cavities were curetted but not grafted. Chemotherapy (isoniazid and pyrizinamide) was administered for 12 months. Followup was at a mean of 3 years. All but two patients regained a normal range of motion, and radiographically most lesions healed and remodelled completely. There were two cases of growth disturbance.

Shannon FB, Moore M, Houkom JA, Waeker NJ. Multifocal cystic tuberculosis of bone. *J Bone Joint Surg* 72a:1089-1092, 1990.

This case report involves a four year old with involvement of both the scapula and the ilium. Radiographic findings included a large, expansile, cystic lesion of the ilium and an expansile lesion of the scapula with cortical destruction. Biopsy was required, and chemotherapy was curative. Bone scan is recommended in the workup, as the lesion in the ilium was not suspected clinically.

Southwood TR, Hancock EJ, Petty RE, Malleson PN. Tuberculous rheumatism (Poncet's disease) in a child. *Arthritis Rheum* 31:1311-1313, 1988.

A sterile polyarthritis may rarely be observed in patients with tuberculosis. A child presented with painless effusions in both knees and both ankles, with mild anemia, a sed rate of 54, and a normal WBC count. Multiple aspirates were culture negative, and needle biopsy revealed mild synovial hyperplasia without inflammation, granulomas, or organisms. He was diagnosed with a paravertebral abscess, which was drained, and cultures revealed TB. The patient responded well to chemotherapy and antiiflammatory agents. The authors postulate that a cell mediated cross-reactive immune response might be responsible for Poncet's disease.

Tanaka M, Matsui H, Tsuji H. Atypical mycobacterium osteomyelitis of the fibula. *International Orthopaedics (SICOT)* 17:48-50, 1993.

This case report describes infection of the proximal fibula with mycobacterium avium intracellulare in an 81 year old with a history of tuberculosis 57 years prior to presentation. She was treated by surgical excision of the fibular head, and underwent 12 months of chemotherapy with 3 agents. There was no recurrence. Osteomyelitis with atypical mycobacteria is extremely rare, with case reports in patients following trauma, open heart surgery, immunosupression, and following an intraarticular steroid injection. The limited available data suggests that chemotherapy alone may be unsuccessful, and the best treatment is probably surgical debridement combined with chemotherapy.

Versfeld GA, Solomon A. A diagnostic approach to tuberculosis of bones and joints. *J Bone Joint Surg* 64b:446-449, 1982.

17 cases of osteoarticular TB are reviewed. Most cases in this series presented early in their course, and patients responded well to chemotherapy. On biopsy, diagnostic material (histologic) is usually found in only a limited area within each lesion. The infected focus is usually surrounded by a zone of inflammation which contains nondiagnostic material. For lesions within bone, a sample from within the granulomatous focus (from within a cystic lesion, or from synovium adjacent to a cyst) will most likely be diagnostic. Making the diagnosis may be difficult with synovial involvement alone. Radiographically, a poorly defined cystic lesion with a thin sclerotic rim is most common, and osteopenia was a constant finding. Soft tissue swelling was common. Periostial reaction may occasionally be observed, either before or after treatment. These lesions may cross the physis, and invade neighboring joints.

Vohra R, Kang HS, Dogra S, Saggar R, et al. Tuberculous osteomyelitis. *J Bone Joint Surg* 79b: 562-566, 1997.

28 lesions in 25 patients (18 months - 47 years of age) were reviewed. Presentation was delayed from 2-39 months, and NSAID's were often administered as the initial treatment prior to evaluation by an orthopaedist. Plain films may be unremarkable early, and other modalities such as CT or MRI may be required to evaluate the symptomatic region. Associated clinical findings that help suggest the diagnosis include regional lymph node enlargement, and the prescence of a sinus or abscess. The radiographic differential diagnosis includes Brodie's abscess, chronic pyogenic osteomyelitis, granulomatous lesions, or neoplasm. Biopsy is essential for diagnosis. Sites of involvement were variable. In the lower extremities, in addition to the greater trochanter (2), all lesions were in the foot. The ischium, clavicle, scapula, and a variety of upper extremity sites were seen. Tuberculous dactylitis had a course trabecular pattern on plain radiographs. Most lesions were cystic and solitary, while 4 were expansile and were associated with bony destruction and a periostial reaction (spina ventosa). Following biopsy, curettage was felt to hasten the healing process.

Wang MNH, Chen WMC, Lee KS, Chin LS, et al. Tuberculous osteomyelitis in young children. *J Ped Ortho* 19:151-155, 1999.

23 cases in patients from 10 months to 11 years of age are reviewed (70% < 3 years old). The most common presenting complaints were swelling (70%) and pain (65%), and only one patient had a fever. A history of minor trauma was occasionally reported. The ESR averaged 20 (7-46 mm/h), and all but one had a normal CRP. A mild leukocytosis was common. There were no cases of pulmonary involvement. The average delay in diagnosis was 4.3 months. Sites of involvement included the spine,

humerus, radius, ulna, metacarpal, femur, tibia, and talus. Only 2 cases had more than one site of involvement. The most common radiographic finding was a lytic lesion with a thin sclerotic rim, and all lesions were in the metaphysis, without involvement of the neighboring joints. All lesions were biopsied/debrided, and chemotherapy was recommended for 12 months. At 71 months followup, all lesions had healed, and there was a single case of physeal arrest in a metacarpal which had not required treatment.

VII C. Hip

Babhulkar SS, Pande S. Tuberculosis of the hip. *Clin Orthop Rel Res* 398:93-99, 2002.

This review paper discusses hip involvement, which is typically seen in 15% of patients. Both a synovial form and an osseous form may be observed, with the latter being either intraarticular or extraarticular (may be on the femoral or acetabular side). Extraarticular lesions ultimately involve the joint. Early on, patients present with limp and pain, which may occur at night. Cold abscesses with or without sinuses may be seen later. Four stages have been described, and the outcome following treatment can be correlated with the degree of involvement at presentation. In stage 1 (synovitis), there is haziness and rarefaction radiographically, and the hip is flexed, adducted, and externally rotated. Stage 2 (early arthritis) has similar physical findings, and in addition to osteopenia, bony lesions in the femoral head or acetabulum may be seen. Fixed deformities may be seen at this stage. Stage 3 (arthritis) also involves joint destruction with loss of joint space radiographically. Stage 4 (advanced arthritis) involves complete joint destruction. The natural history in untreated cases evolves to fibrous ankylosis, subluxation, or dislocation. Treatment principles necessarily apply to the stage at which the disease is diagnosed. Early involvement is treated by chemotherapy, and traction is followed by gradual joint mobilization after 3-4 weeks (when pain and spasm are improved, and deformity is improved). Patients will usually require bedrest for 3-4 months. This approach is successful for most patients with stage 1 or 2 disease, and occasionally stage 3. Synovectomy and joint debridement is recommended for patients with stage 3 or 4 disease. Salvage procedures are also available for cases presenting late or those symptomatic patients who have not responded to other measures. Proximal femoral osteotomy and arthrodesis may be used to realign the limb, but are not well accepted in cultures that require squatting for activities of daily living. Most of these patients are satisfied by excisional arthroplasty. Total joint replacement may offer an alternative in societies with adequate resources. The indications and timing of this procedure remain controversial, and up to 30% of cases may be associated with reactivation.

Campbell JAB, Hoffman EB. Tuberculosis of the hip in children. *J Bone Joint Surg* 77b:319-326, 1995.

74 cases were seen over 41 years, and two treatment protocols were employed. Hips were classified radiographically according to Shanmugasundaram. Type 1 is normal, while type 2 is described as a travelling acetabulum. In type 3 the hip is dislocated, while type 4 demonstrates Perthes like changes. Type 5 has acetabular protrusio, while type 6 is atrophic and type 7 is referred to as mortar and pestle. Types 2, 5, and 7 all result from erosion of subchondral bone. Type 3 usually results from laxity rather than an elevation in intraarticular pressure. In the early phase (series B), patients were treated with streptomycin and isoniazid, +/- para-aminosalicylic acid for 18 months and immobilized for more than 2 years (spica cast or a frame). In more recent cases (series A), the protocol included rifampin, isoniazid, and pyrazinamide with active mobilization (skin traction with or without CPM). Those in series B were diagnosed clinically, and no biopsies were performed. Most hips were normal radiographically (27/46), 6 were dislocated, 6 mortar and pestle, and 1 Perthes type hip. The results were graded as 41% excellent, 19.5% good, 6.5% fair, and 33% poor. As might be expected, excellent results were seen in those hips who had normal radiographs. In series A, chest radiographs were positive in 42%, the mean sed rate was 70, and the Mantoux was positive in 26/27. Sixteen hips had a positive culture or smear, and 26 had caseating granulomas on histologic evaluation. 14 hips (50%) appeared normal radiographically, while 7 were dislocated and 4 were of the Perthes type. The results were graded as 43% excellent, 28.5% good, 3.5% fair, and 25% poor. The radiographic changes at presentation predicted the final outcome, and there seemed to

be no difference in the overall results between the two treatment protocols. Radiographically normal hips have synovial involvement, and 38/41 had good or excellent results. The Perthes type and the dislocating type also had good results. In contrast, hips that had subchondral erosions and some joint space narrowing (travelling acetabulum, protrusio, atrophic, mortar and pestle types) had poorer results. In areas with a high prevalence of TB, a Mantoux test and sed rate may be indicated in all patients suspected of having Perthes disease. To help differentiate, the Perthes type hips always had whole head involvement, and metaphyseal changes were never seen. Although the results with the newer protocol were not superior, a shorter course of chemotherapy was be associated with equivalent results. Open biopsy is usually the only surgery required, and prolonged immobilization does not appear to improve the results.

Hatcher CH, Phemister DB. The primary point of infection in tuberculosis of the hip joint. *Surg Gyn Obstet* 65:721-740, 1937.

82 cases (70 children) of tuberculosis of the hip are reviewed. The primary site of involvement may be either the acetabulum or the proximal femur (epiphysis, metaphysis or femoral neck, and trochanteric apophysis). The gluteal or iliopsoas bursae may rarely be involved initially, with hip involvement occuring through direct spread. The most common site is the juxtaphyseal region of the femoral neck, which may secondarily involve the joint by direct extension. Similarly, acetabular foci may may extend into the joint. Although a primary focus was never observed in the capital femoral epiphysis, the epiphysis may become involved by direct extension of a metaphyseal focus, or from articular involvement. Physeal damage may occur, resulting in proximal femoral deformity. In the 12 adults, 9 presumably had articular involvement initially, and the other 3 had lesions in the greater trochanter (2) and the ilium. Involvement of bone was common in later stages in adults, and typically occured in the superior portion of the femoral head and the neighboring acetabulum, suggesting direct extension from intraarticular involvement.

Gruca A. The treatment of quiescent tuberculosis of the hip joint by excision and "dynamic" osteotomy. *J Bone Joint Surg* 32b:174-182, 1950.

The combination of excision and osteotomy is presented in the treatment of later stages of tuberculous arthritis of the hip in order to achieve a painless and mobile pseudarthrosis, as an alternative to arthrodesis. The goal is to remove the painful degenerated tissues, to unload the acetabulum, and to improve the mechanics of the abductor muscles. Excision of the diseased head and neck of the femur is performed, and a step cut osteotomy (oriented in the antero-posterior plane) is made at the level of the inferior margin of the acetabulum (on preop radiographs). The upper fragment is rotated outwards, which effectively lateralizes the insertion of the gluteal muscles. The region of the lesser trochanter rotates upwards to rest underneath the acetabulum. Adequate results at short term followup were demonstrated in 90% of 224 patients.

Katayama R, Itami Y, Maruno E, Treatment of hip and knee joint tuberculosis: An attempt to retain motion. *J Bone Joint Surg* 44:897-917, 1962.

An approach to treating TB of the hip and knee, at various stages of involvement, is presented. The authors favor chemotherapy during the acute stage, and chemotherapy combined with synovectomy or debridement in the chronic stage (except in children). Early motion and weightbearing were encouraged for all patients. For those receiving chemotherapy alone, active motion exercises were started as soon as symptoms would permit. An ischial weightbearing orthosis was prescribed for 6 weeks, and with adequate control of the disease and symptoms, patients were transitioned to a brace which allowed full weight transmission (worn for > 2 years). The rehab protocol was modified in those treated surgically. For synovectomy of the knee, a long leg cast was applied, and a spica was cast was used following all hip procedures. The period of immobilization was approximately 5 weeks, and after this patients were placed in an apparatus for flexion and extension at the hip and knee, and after a few weeks to another device to facilitate passive abduction and adduction. An ischial weightbearing brace was then employed for 6-8 months, followed by a simpler brace which allowed weight transmission. Although a detailed followup assessment was not provided, this approach using early motion was felt to result in improved joint range of motion following treatment. In addition,

a new procedure is described to treat severe involvement with destruction of the head and neck. The "Katayama procedure" involves debridement of the acetabulum (lateral approach, trochanteric osteotomy), a shelf procedure using bone graft from the ilium, and coverage of the exposed stump of the femoral head and neck with an interposing membrane.

Kim YH, Han DY, Park BM. Total hip arthroplasty for tuberculous coxarthrosis. *J Bone Joint Surg* 69:718-727, 1987.

44 hips in 38 patients underwent THA from 3 months to 45 years following completion of treatment for their tuberculosis, and were followed for 45 months. Those suspected as having active disease were treated with 3 months of chemotherapy prior to the procedure. Four patients had positive cultures at the time of implantation, and 6 patients developed recurrence of infection which was effectively treated with chemotherapy with or without removal of sinus tracts. None of these 6 required removal of their prosthesis. One prosthesis did require revision for loosening. Six of fifteen with inactive disease for less than ten years developed reactivation of infection, in contrast to none of twenty-nine who had inactive disease for greater than ten years. Those who had reactivation had normal sed rates preoperatively, and had a negative histologic evaluation of specimens from the capsule, acetabulum, and femur. The authors recommend 3 months of preoperative prophylaxis prior to arthroplasty in those having inactive disease for less than 10 years, those having evidence of active infection, and those who have not been previousely treated with modern chemotherapeutic agents. If intraoperative histology is positive, treatment with chemotherapy for 18 months is recommended. In patients requiring postoperative therapy, the authors used four drugs (streptomycin, rifampicin, isoniazid and ethambutol) were used for 2 months postoperatively, followed by rifampin, isoniazid, and ethambutol for an additional 16 months. Removal of the prosthesis may not always be required in cases of reactivation. Patients achieved significant improvement in their symptoms and function.

Lynch AF. Tuberculosis of the greater trochanter. *J Bone Joint Surg* 44b:185-188, 1982.

8 patients were diagnosed over a 15 year period, and the diagnosis was delayed 3-24 months from the onset of symptoms. Symptoms include vague discomfort, and a cold abscess may be present on either the medial or lateral side of the thigh. Findings were most consistent with initial involvement in the bursa, with subsequent involvement of the trochanter itself. This site seems to be prone to recurrence, and the literature review suggested that either chemotherapy alone, or chemotherapy combined with limited drainage were less successful in eradicating the infection. Recommended treatment includes preoperative chemotherapy for one month, followed by debridement and closure over an irrigation-suction drain system (streptomycin is the irrigant). Chemotherapy is continued for at least a year.

Marmor L, Chan KP, Ho KC, Justin M. Surgical treatment of tuberculosis of the hip in children. *Clin Orthop Rel Res* 67:133-142, 1969.

109 cases of tuberculosis of the hip in children treated surgically are reviewed. Only those with positive biopsy, culture, or guinea pig innoculation were included. Cases were divided in 3 groups. Those with bony lesions (early destruction of the acetabulum or femoral neck) and an intact joint were treated by synovectomy with or without curettage, while those with a advanced destruction with or without dislocation were treated by synovectomy and curettage. The third group, in whom there was severe involvement with loss of the femoral head, were treated by arthrodesis. The Brittain extraarticular technique for arthrodesis was employed, in which an autogenous tibial graft is placed from the proximal femur to the ischium. This technique is particularly helpful when the femoral head and neck have been destroyed. All patients received chemotherapy with 3 agents (18 months), and after surgery patients were casted for 6 weeks (3 months for arthrodesis). Fourteen of twenty-two patients in the first group had an excellent response, and seven had a poor result because of stiffness. In the second group, results were poor in nearly all cases, and 31 of 45 ultimately required arthrodesis. In the third group, nonunion occured in 17/38 cases treated by primary arthrodesis, but only in 6 of 31 cases in which an initial synovectomy and debridement were performed as a first stage. Repeat arthrodesis was successful in 11/12 cases.

Fusion took at least 8 months to occur. Control of disease was achieved in these patients. The authors recommend early surgical intervention in an effort to prevent joint destruction.

Milch H. Surgical treatment of the stiff, painful hip- The resection-angulation operation. *Clin Orthop Rel Res* 31:48-57, 1963.

The author describes a salvage procedure to treat patients with end stage arthritic changes in the hip from various causes, including tuberculosis. The goal is to relieve pain, improve mobility, and retain some element of stability. The femoral head is resected at the intertrochanteric line, and an abduction osteotomy is performed. The details of preoperative planning (determining the "postosteotomy angle") are included. Fixation is with a plate and screws, and at the time an angulated blade plate was developed for the procedure.

Tuli SM, Mukherjee SK. Excision arthroplasty for tuberculosis and pyogenic arthritis of the hip. *J Bone Joint Surg* 63b:29-32, 1981.

A Girdlestone arthroplasty was performed in 30 patients with chronic, symptomatic pyogenic or tuberculous infection of the hip (20 had active infection at the time of surgery). The age at surgery ranged from 10-30 years (6 patients < 12 years old), and the followup was 2-7 years. The femoral head and neck were resected at the intertrochanteric line, and the acetabulum was debrided. No soft tissue interposition was employed, and concurrent upper femoral osteotomy was not felt to be necessary. After surgery, patients were maintained in skeletal traction (40-50 degrees abduction) for 4-8 weeks, and then skin traction for a total of 3 months in traction. They were then allowed to ambulate in a weight relieving caliper, which was discontinued at 1 year following surgery. 83% had satisfactory results (pain relief in 29, control of infection in 27, and the ability to squat and sit cross legged in 27). The average shortening was 3.8 centimeters. Sixteen patients could stand without support on the involved side. Of the 5 poor results, 3 had persistent infection, and 3 were unable to sit or squat. In the eastern hemisphere, patients require a mobile joint for sociocultural reasons, and excisional arthroplasty often represents the best option for salvage.

Wilkinson MC. Tuberculosis of the hip and knee treated by chemotherapy, synovectomy and debridement: A follow-up study. *J Bone Joint Surg* 51:1343-1359, 1969.

138 patients (children and adults) with TB of the hip and knee were treated by a protocol including chemotherapy and synovectomy/debridement. 49/70 patients with hip involvement were children, while only 16/68 patients with knee involvement were < 14 years of age. Two to three months of preoperative chemotherapy was followed by 6 months of postoperative chemotherapy (isoniazid and streptomycin). Secondary procedures included proximal femoral osteotomy and arthrodesis. Range of motion exercises were begun as soon as tolerated. The results were better in younger patients with lesser degrees of involvement. A spectrum of intraoperative findings were observed. Overall, the amount of cartilage damage was variable. Milder cases tended to have only peripheral involvement on inspection of the joint. In the knee, the synovium was thickened and produced marginal erosions around the joint. In more advanced cases, pannus extended across the articular surface resulting in more widespread ulcerations in the joint surface. Most often the pannus was mature and fibrotic, however in some children this was "soft" and could be stripped off easily. Changes in articular cartilage may also be observed adjacent to subchondral bony foci (cysts).

VII D. Knee

Chow SP, Yau A. Tuberculosis of the knee – A long term followup. *International Orthopaedics (SICOT)* 4:87-92, 1980.

Thirty cases are reviewed at 15 years followup, and 75% were less than 18 years of age at presentation. Fifteen patients were treated by chemotherapy alone (2 years), with casting or splinting (12), bedrest (2), or traction (1). Sixteen patients were treated surgically, in addition to receiving the same chemotherapeutic protocol. Following synovectomy/debridement, casting was employed for 1-2 months, and patients were then fitted with a brace. Early mobilization was encouraged in all patients. Although one third of

patients in the conservative group had mild pain at followup, those treated surgically had greater stiffness. Radiographically, more than 50% had chronic changes, most often irregularity of the joint space termed "congrous incongruity", which was felt to relate to bony collapse rather than articular destruction. Other radiographic changes included osteophytes, chondrocalcinosis, osteoporosis, loose bodies, abnormal patellae, and a decrease in size of the epiphysis. Those who did not have a sinus at presentation were asymptomatic following either treatment, and the authors suggest that a discharging sinus may be predispose to late pain, perhaps due to low grade secondary bacterial infection. Overall, those diagnosed at an earlier age, who were treated within 6 months of the onset on symptoms, and who were mobilized early had, a better outcome.

Eskola A, Santavirta S, Konttinen YT, Tallroth K, et al. Arthroplasty for old tuberculosis of the knee. *J Bone Joint Surg* 70b:767-769, 1988.

6 patients were treated an average of 35 years after their infection, and followed for 6.3 years. Three had no antitubercular chemotherapy, and three had chemotherapy for 2-3 weeks before and three weeks after the procedure. One patient had infection (presumably reactivation, although there was no previous diagnosis of TB) at 18 months postoperatively, and was salvaged with 12 months of chemotherapy. The authors recommend a long interval in between primary treatment and arthroplasty, and both preoperative chemotherapy (2 drugs for 2-3 weeks) and postoperative chemotherapy (2 drugs for 6-9 months).

Hoffman EB, Allin J, Campbell JAB, Leisegang FM. Tuberculosis of the knee. *Clin Orthop Rel Res* 398:100-106, 2002.

52 cases (mean age 5.3 years) were reviewed at a mean followup of 5 years. At the time of initial evaluation, the sed rate averaged 55, and 53% demonstrated positive findings on chest radiographs. The Mantoux test was positive in 91%. Patients presented at 1 week to 3 years following the onset of symptoms, and although all had swelling, only two thirds complained of pain. Fifteen percent of cases presented with findings suggestive of septic arthritis. 49 patients underwent open biopsy, and triple drug therapy (rifampicin, isoniazid, and pyrazinamide) was continued for 9 months. The degree of involvement was classified according to Kerri and Martini. Those with early involvement were initially immobilized for 3 months, but later in the study were mobilized as soon as symptoms allowed. Those with later stages of involvement were splinted in extension to prevent flexion contracture. Histologic evaluation was positive in 85%, while cultures were positive in 75% (all patients had either one or both of these). Patients presenting with stage 1 or 2 disease (osteopenia, periarticular erosions, normal joint space) (92%) had excellent results, and immobilization did not affect the outcome. Those with stage 3 or 4 disease (narrowed joint space, arthritic changes) (8%) had poor results secondary to loss of motion or pain. The radiographic stage of involvement did not correlate with the timing of presentation. Given the excellent response of early (stage 1 or 2) lesions to chemotherapy alone, the authors do not recommend surgical synovectomy. For those with a negative histologic analysis and culture, pauciarticular juvenile rheumatoid arthritis should be highest on the differential diagnosis.

Kerri O, Martini M. Tuberculosis of the knee. *Int Orthop* 9:153-157, 1985.

98 cases are reviewed (13 children), and only 30% presented at the early stage in which only synovitis was present (average delay in presentation was 40 months). All patients received chemotherapy, and most were splinted to prevent or correct deformity. Outcome corelated with the stage of disease at presentation. Most patients presented with pain and swelling, and 26 patients had a sinus at the time of presentation. The authors present a radiographic classification as follows: stage 1 involves localized osteoporosis without bony lesions, stage 2 has one or more erosions within bone, stage 3 involves joint destruction without gross anatomical disorganization, and stage 4 has gross destruction of the joint. Most patients responded well to chemotherapy, and there were 5 relapses. Patients with ankylosis were pain free. Flexion contracture was treated by serial casting, and progressive posterior subluxation of the tibia may occur. Surgical procedures included arthrodesis (16), partial synovectomy (6), and a single patient underwent supracondylar osteotomy for flexion contracture. For early lesions, rehabilitation should be started once symptoms allow, and the goal is to improve flexion. In advanced cases, the

authors attempt to regain full extension initially, and if possible to promote mobility. Ankylosis in extension is generally well tolerated, and those with pain may be treated by arthrodesis. The importance of prompt diagnosis and institution of therapy cannot be overemphasized.

Kim YH. Total knee arthroplasty for tuberculous arthritis. *J Bone Joint Surg* 70:1322-1330, 1988.

22 knees in 19 adults (mean age 53 years) were treated by one or two stage total knee arthroplasty 3 months to 5 years after resolution of their symptoms. Eight patients had prior surgery, and the duration of active infection prior and during treatment was 70 months (3 months to 35 years). Followup was 24-49 months. Only 4 knees were cemented. Three patients had recurrence of infection, all of whom had an interval of only 3-4 months between resolution of symptoms and arthroplasty. None had preoperative chemotherapy. Two were treated effectively with debridement and chemotherapy, and the third required arthrodesis two years later because of recurrent infection. There was no recurrence in those who waited 1-5 years between resolution and implantation. Symptoms and motion were improved considerably. The author feels that a shorter interval in between disease control and prosthetic implantation may be appropriate, perhaps between one and five years. The literature suggests waiting 10-20 years. It also remains unclear what the indications for preoperative or postoperative chemotherapy are in this population. The followup is short, but the results are somewhat encouraging.

Lee AS, Campbell JAB, Hoffman EB. Tuberculosis of the knee in children. *J Bone Joint Surg* 77b:313-318, 1995.

33 children with monoarticular knee involvement (mean age 4.7 years) were reviewed. Swelling was the most common complaint, and all patients had a decreased range of motion. 19/33 had pain. Only 5 knees presented with symptoms consistent with septic arthritis of the knee. The sed rate ranged from 25-110, and the Mantoux was positive in 96%. 59% had evidence of disease on chest radiographs. The time of presentation ranged from 1 month to 3 years following the onset of symptoms. Diagnosis was made by open biopsy in 30 and aspiration in 3 (definitive diagnosis by culture only made in 76%). Radiographically, 22 presented only with osteopenia and soft tissue swelling (stage 1), while 8 presented with stage 2 involvement (epiphyseal or metaphyseal cysts with a normal joint space. A single patient had a narrowed joint space (stage 3), and 2 had gross destruction of the joint (stage 4). Triple drug chemotherapy was used (rifampicin, isoniazid, pyrazinamide), and most patients were splinted for at least 3 months. At 4 years followup, all those with stage 1 and 2 involvement had excellent results. The patient with stage 3 required a posterior release for fixed flexion deformity, while the 2 with stage 4 involvement were immobilized in extension (for autofusion) after range of motion could not be restored. Seven of the patients had been treated by early, active mobilization, and all had an excellent result. The radiographic changes at presentation predict the outcome, and those with stage 1 or 2 disease (synovial involvement) did very well. The authors do not feel that synovectomy is necessary in these patients, based on the outcome with chemotherapy and either splinting or active motion. Patients typically take more than one month to demonstrate a response. Early mobilization is recommended, and splinting is used to prevent flexion contracture and to achieve autofusion in extension in those with stage 3 or 4 disease.

VII E. Foot/Ankle

Dhillon MS, Nagi ON. Tuberculosis of the foot and ankle. *Clin Orthop Rel Res* 398:107-113, 2002.

75 feet in 74 patients were treated over an eleven year period. The mean age was 23 years (6 months to 78 years), and symptoms were present for 2 months to 1.9 years before a diagnosis was made. Only 9 patients had evidence of visceral disease. Only 7 patients had significant constitutional symptoms, and the sed rate was elevated in all cases (25-100). Fine needle aspiration biopsy was attempted in all, and some required open biopsy for diagnosis. Seventeen patients had a sinus at the time of presentation, and eight of these were secondarily infected. Some patients were diagnosed

on clinical and radiographic findings even if cultures were negative. Osseous lesions were identified in the calcaneus (11), metatarsals (4), cuboid (4), talus (1), and cuneiform (1). Articular involvement was observed in the ankle (13), midtarsal (14), lisfranc (13), 1st TMT (4), IP (2), and subtalar joints (7). Typically, articular involvement appears as a later stage in cases in which there is a delay in diagnosis of a primary osseous focus. Radiographically, marked osteopenia is observed during the active phase, especially surrounding the tubercular focus. Sequestra were uncommon, and were typically observed in the larger bones (6 cases in the calcaneus, 1 in the cuboid). MRI demonstrates nonspecific marrow edema (high on T2, low on T1), and CT scans will show the extent of the lesion, as well as any sequestra or fractures within the cortex. The appearances on imaging studies may lag behind the clinical response. The mainstay of treatment is chemotherapy, and surgery may be required for biopsy, debridement, or for salvage. Open biopsy is indicated if needle aspiration fails to obtain sufficient material. Debridement may be helpful in cases that do not respond clinically after sufficient chemotherapy, to rule out other diagnoses and to treat the bony lesion. This may also be indicated if a focus of involvement is at risk to penetrate into a joint. For painful joints with destruction, arthrodesis may be performed after debridement. Immobilization may be required for 3-6 months to achieve fusion. The best results are achieved with early diagnosis and prompt treatment.

Mital R, Gupta V, Rastogi S. Tuberculosis of the foot. *J Bone Joint Surg* 81b:997-1000, 1999.

44 patients were reviewed, with ages ranging from 4-63 years. Seven patients had involvement of soft tissue only (biopsy required for diagnosis), while 37 had bony involvement (treated based upon clinical and radiologic findings). Patients presented with pain, stiffness, and swelling. Sites of involvement included the calcaneus (17), metatarsals (18), phalanges (15), and the tarsal bones (12). More than two bones were involved in 14 cases. Patients were treated with four agents (rifampicin, isoniazid, ethambutol, and pyrizinamide) for 2 months, followed by rifampicin and isoniazid for 16 months. All patients healed, and no surgical intervention was required. A radiographic classification is also presented. *Cystic* lesions (n=15) had a well defined, central lucent area with no sequestrum. *Rheumatoid* lesions occur in the midfoot (n=10), and demonstrated osteoporosis and loss of articular cartilage throughout the region. The appearance is similar to that of the wrist and carpal bones in rheumatoid arthritis. *Subperiostial* scalloping of bone was seen in seven cases, including the lateral cuboid, the base of the 5th metatarsal, and the head of the talus. *Kissing* lesions involved scalloping of both sides of an involved joint. *Spina ventosa* refers to a spindle shaped expansion with multiple layers of periostial bone formation, which occurs in the short tubular bones (n=1).

VII F. Vertebral

1.) Imaging

Buchelt M, Lack W, Kutschera HP, et al. Comparison of tuberculous and pyogenic spondylitis. An analysis of 122 cases. *Clin Orthop Rel Res* 296:192-199, 1993.

This retrospective study compared tberculous spondylitis with pyogenic spondylitis in 122 patients, based upon radiographic, pathologic, and clinical features. The mean time interval from the onset of symptoms to diagnosis was 8.7 months for tuberculous spondylitis, and 3.5 months for pyogenic spondylitis. Those with bacterial infection often had a history of trauma, abscess, or other infection prior to the development of spinal disease. Of those with tuberculosis, 43% had extraspinal involvement. Patients with tuberculosis had more than 2 segments involved in 23%, versus 9% of those with pyogenic disease. A histologic diagnosis was made in 58% on biopsy, and 68% of surgical specimens. A clear distinction could be made on histologic analysis in only 63% of cases. The sed rate was elevated in all patients and tended to be higher in those with bacterial disease, although the degree of overlap in values makes distinction based upon this variable alone impossible. Neurologic symptoms were present in 18% of those with tuberculosis and 23% of those with pyogenic spondylitis. There were no significant differences in spinal alignment. Sclerosis of the involved vertebrae was more common in

patients with tuberculosis. At followup, 28% of those with tuberculosis experienced pain, in contrast to 51% of patients with bacterial disease. Fusion was observed in 49% (tuberculosis) and 64% (pyogenic) of cases, and only 39% of those who fused had pain, in contrast to 55% of those who did not achieve fusion. The authors conclude that biopsy is essential in diffeentiating between these two forms of spinal infection.

Hoffman EB, Crosier JH, Cremin BJ. Imaging in children with spinal tuberculosis. A comparison of radiography, computed tomography, and magnetic resonance imaging. *J Bone Joint Surg* 75b:233-239, 1993.

25 children with spinal involvement were studied by plain radiographs, computed tomography, and MRI. At least 2 vertebrae were involved in all patients, and both CT and MRI demonstrated the true extent of involvement versus plain films. CT reveals cystic areas of bony destruction within the vertebral body, and in advanced cases the degree of destruction. Soft tissue masses are well delineated by both CT and MRI. All 25 had extradural compression from 20-100%. Of the 11 with neurologic complaints or findings, 10 involved the thoracic spine and had > 60% compression. All but 1 patient (neurologic symptoms for one year prior to presentation) recovered with chemotherapy alone. The authors conclude that plain radiographs are usually sufficient to make the diagnosis, and the typical findings include disc space narrowing, central involvement of the disc, and collapse which begins anteriorly. Tomography may be helpful in the thoracic spine, as the ribs may obscure the visualization of the vertebral bodies. CT is best for showing the degree of bony destruction, and was helpful in evaluating the posterior elements. If bilateral pedicular involvement (or other findings suggestive of posterior element involvement) is seen on plain radiographs, CT may help define the scope of involvement and help plan the surgical approach in some patients who require decompression and fusion. MRI is excellent in demonstrating the vertebral anatomy and best for evaluating the neural elements. MRI can differentiate between abscess and fibrous tissue, and is best for evaluating the extent of disease, which the authors feel may be of benefit in preoperative planning if an anterior decompresion and fusion are required.

Mehta JS, Bhojraj SY. Tuberculosis of the thoracic spine. A classification based on the selection of surgical strategies. *J Bone Joint Surg* 83b:859-863, 2001.

MRI was used to evaluate the extent of disease in 47 patients with thoracic involvement, and a classification scheme was derived to help select the appropriate surgical approach. Posterior column involvement is not uncommon in these patients, and a knowledge of the pathologic anatomy helps to plan the surgical strategy. In addition, patient related factors are considered in this algorithm.

Group A = anterior column disease without deformity (paradiscal or central body involvement)
Transthoracic decompression/ strut grafting

Group B = Anterior and posterior column disease, unstable spine
Two stage procedure: PSF with Luque rectangle/ sublaminar wires (3 above,3 below) followed by anterior decompression and strut grafting.

Group C = A or B in a compromised host with high anaesthetic risk
Transpedicular decompression followed by Luque rectangle/sublaminar wires

Group D = Posterior involvement with no instability or deformity
Limited posterior decompression without instrumentation or fusion

2.) Craniovertebral Region/Cervical Spine

Fang D, Leong JCY, Fang HSY. Tuberculosis of the upper cervical spine. *J Bone Joint Surg* 65b: 47-50, 1983.

Six cases 3-51 years old) were treated for atlanto-axial tuberculosis. Presenting complaints

include pain, stiffness, torticollis, hoarseness, and dysphagia. Four patients had neurologic dysfunction, and al had cervical lymphadenopathy. Two had a draining sinus. The lateral radiograph demonstrated retropharyngeal soft tissue swelling (> 7 millimeters at the lower margin of the axis), and osteolytic erosions were seen in all patients. Chemotherapy was started, and 2 patients were initially treated in halo traction. All patients were treated surgically, and 5/6 underwent anterior debridement via a transoral approach. At the time of anterior debridement, 4 patients had an anterior fusion performed with autogeous iliac crest or rib inserted into oblique troughs in the lateral facet joints. Two patients were treated by posterior spinal fusion (atlanto-axial in 1, C1-C3 in 1). Several patients had dislodgement of anterior grafts, one of whom lost reduction. Overall, fusion was achieved in all cases, and neurological status was normal in 3 of 4, and improved in the fourth. The authors feel that chemotherapy alone is not sufficient to treat patients with upper cervical involvement, and that the transoral route is safe and effective for debridement and anterior grafting. They recommend fusion for all patients, and prefer anterior fusion. Alternatively, a posterior fusion can be performed as a second stage.

Hsu LCS, Leong JCY. Tuberculosis of the lower cervical spine (C2 to C7). A report on 40 cases. J Bone Joint Surg 66b:1-5, 1984.

40 patients with involvement from C2 to C7 are described, and the pattern of involvement was related to age. In patients less than 10 years old, diffuse involvement was usually associated with abscess formation. In patients older than 10 years, involvement was typically more focal, and abscesses were observed less often, however the incidence of neurologic involvement was higher (42% overall, 3/16 adult patients). The average number of vertebral bodies involved was 2.6. Neck pain, stiffness, and occasionally torticollis, were the presenting symptoms. Dysphagia and stridor were also observed from the mass effect of abscesses. In addition to chemotherapy, patients underwent anterior surgery for debridement (children) or anterior decompression with strut grafting (Hong Kong procedure). Patients were symptomatically improved, and neurologic function normalized in all those with signs of cord compression. All patients fused, and their disease was eradicated. Neither progressive deformities nor complications related to strut grafts were reported. Noncontiguous vertebral involvement did occur in 5 patients.

Jain AK, Kumar S, Tuli SM. Tuberculosis of spine (C1-D4). *Spinal Cord* 37:362-369, 1999.

33 lesions in 31 patients are reviewed [C1-C2 (11), C3-C6 (13), C7-T4 (9)]. Patients were 6-50 years of age, and neurologic involvement was seen in 55% (C1-C2), 61% (C3-C6), and 78% (C7-T4) of patients within each group. Involvement of more than one vertebra occured in 12/13 mid cervical lesions. For atlanto-axial lesions, an increase in the prevertebral soft tissue shadow on the lateral radiograph identified patients in the presubluxation stage. Widening of the mediastinum and an increase in the prevertebral soft tissue shadow with anterior convexity of the tracheal shadow on lateral films of the upper thoracic spine indicated involvement of the lower cevical/upper thoracic vertebrae. Patients were managed according to the “middle path” regime (Tuli). Most patients were managed as outpatients with chemotherapy, an orthosis, and rest. Surgical decompression was reserved for those who had an inadequate response following 3-4 weeks of rest and chemotherapy. A standard course of 12-18 months of multidrug therapy was employed. The indications for admission (20 patients) included neural complications, subluxation or dislocation, difficulty with swallowing or respiration, or severe pain and spasm. All were initially placed in traction with skull tongs and started on chemotherapy.

Of the 11 atlanto-axial lesions, one required late posterior spinal fusion for instability, and none required decompression. The authors recommend surgical intervention for drainage of retropharyngeal abscesses causing dysphagia or dyspnea, for stabilization of unstable lesions (on flexion-extension radiographs) after 3-6 months of treatment, and to obtain tissue for a diagnosis in uncertain cases. Although persistent degrees of subluxation remained in some patients, adequate neural recovery was observed, and mechanical instability was not oberved following healing. Using this protocol, surgical decompression was required in 3/13 lesions in the mid-cervical spine, and 4/9 in the cervicodorsal spine. Overall, only 7/21 patients presenting with neurologic involvement required surgical decompression (5/7 have excellent recovery). Nineteen of twenty-one patients

presenting with neurologic dysfunction had excellent recovery.

Lifeso R. Atlanto-axial tuberculosis in adults. *J Bone Joint Surg* 69b:183-187, 1987.

Twelve cases are reviewed, and an approach to classification and management is outlined. The average age was 34 years (14-65 years), and patients typically had symptoms for more than 10 months prior to presentation. Pain was the major presenting complaint, and torticollis was commonly observed. Other symptoms included hoarseness, dysphagia, paralysis of cranial nerves 6 or 12, and stridor. Spinal cord dysfunction was identified in 5 patients, one of whom died before treatment could be instituted. Radiographically, 10/12 had a retropharyngeal abscess and bony abnormalities. All patients underwent transoral biopsy/decompression, and treatment was based upon the authors radiographic classification. Standard chemotherapy (4 agents) was recommended for 12 months. Those with stage I disease (minimal ligamentous and bony destruction without subluxation) were treated by transoral biopsy/decompression and an orthosis for 3 months. Those with stage II involvement (ligamentous destruction, minimal bony destruction, and anterior displacement of C1 on C2) are treated by transoral biopsy/decompression, reduction by halo traction, and then a posterior atlanto-axial fusion. Patients with stage III involvement (significant ligamentous and bony destruction with greater degrees of subluxation or dislocation) were treated by transoral biopsy/decompression, followed by halo traction, and subsequently a posterior fusion from the occiput to C2 or C3. All patients were mobilized as soon as possible, and all were discharged within 17 days of admission. Halo traction was effective in reducing the subluxation or dislocation within 7 days in all patients. All those in stage I were stable at followup, and all of those treated by posterior spinal fusion achieved union by 16 weeks. Neurologic recovery was complete in all patients.

Tuli SM. Tuberculosis of the craniovertebral region. *Clin Orthop Rel Res* 104:209-212, 1974.

25 patients were treated by the "middle path" regime. Symptoms were present from several months to several years prior to presentation, and included pain, torticollis, dysphagia, and difficulty withy speech or respiration. Clinical kyphotic deformity was present in 3 cases. On x-rays, atlantoaxial subluxation or dislocation was seen in 14 patients, and involvement of the occipital bone (7) and C3 (7) were also observed. Widening of the prevertebral shadow greater than 7 mm was common. Patients were treated by chemotherapy (3 drugs), bedrest with or without traction, and occasionally an orthosis. Fourteen were hospitalized for neurologic symptoms, large symptomatic abscesses, or atlantoaxial subluxation or dislocation. The remainder were treated as outpatients. Four patients required operative drainage of symptomatic abscesses, which was performed through an anterior approach along the anterior margin of the sternomastoid muscle. Traction with skull tongs was employed for 4-6 weeks in the fourteen with atlantoaxial instability, and then a brace was worn for one year. In this group, an improvement in alignment was seen in all, and 12/14 were stable by clinical exam and flexion/extension radiographs at followup. Posterior fusion was recommended in the 2 patients with residual instability. The persistence of mild atlantoaxial subluxation in patients with an incomplete reduction did not appear to influence neurologic recovery, and did not result in chronic symptoms. Seven of eight patients with neurologic involvement recovered completely, and one partially.

3.) Thoracic/Thoracolumbar Spine

Boachie-Adjei O, Squillante RG. Tuberculosis of the spine. *Orthop Clin North Am* 27:95-103, 1996.

This outstanding review article summarizes the existing literature on tuberculosis of the spine". Alternatively, in the interest of space and flow, this could be left without a description, or could be deleted.

Garst RJ. Tuberculosis of the spine. A review of 236 operated cases in an underdeveloped region from 1954-1964. *J Spin Dis* 5(3):286-300, 1992.

The author presents his personal experience with 236 surgical cases over a ten year period. 55% of patients had active pulmonary disease, and 50% had involvement of greater than 3 vertebrae. All patients with sinuses were superinfected with bacteria, and their approach was to perform curettage and administer the appropriate intavenous antibiotics until the sinuses had healed, and spine surgery was only undertaken a minimum of 3 months after

healing of sinuses. Patients were treated with 3 drugs for 18 months. A lateral extrapleural approach enabled both debridement and strut grafting (autogenous rib or allograft), and a noninsrumented posterior fusion was performed through the same approach. 8.6% of patients required reoperation to achieve fusion, all of which were successful. This approach was found to be safe, did not require the expertise of a thoracic surgeon, and allowed for adequate visualization of the spinal cord and decompression of the offending pathology. 58% required < 6 weeks hospitalization.

Guven O, Kumano K, Yalcin S, et al. A single stage posterior approach and rigid fixation for preventing kyphosis in the treatment of spinal tuberculosis. *Spine* 19(9):1039-1043, 1994.

39 adults and 5 children with involvement of the lower thoracic or upper lumbar vertebrae were treated by a one or two-stage procedure. Triple drug chemotherapy was employed for 18 months. The first stage involved posterior stabilization (Harrington rods, or TSRH in adults, Rush rods or Steinmann pins with sublaminar wires in children) from 2-3 levels above and below the focus of disease. Anterior debridement and strut grafting were performed after posterior stabilization, either the same day or staged. Followup averaged 3.6 years. All patients achieved fusion and adequate correction of deformity. Loss of correction was only 3°°. The average time to fusion for a single level of involvement was 4 months in adults and 3.5 months in children, and for two levels of involvement was 6 months. There was no graft resorption or fracture in adults. Graft resorption occurred in one child, due to loss of stability from migration of a Steinmann pin. Another child has graft slippage, but this ultimately healed without further problems. The posterior stabilization seems to provide a better mechanical environment for healing of anterior grafts.

Hodgson AR, Skinsnes OK, Leong CY. The pathogenesis of Pott's paraplegia. J Bone Joint Surg 49a:1147-1156, 1967.

The authors describe intrinsic and extrinsic causes for neurologic dysfunction. Extrinsic factors may be important in the active phase of disease (abscess, granulation tissue, sequestered bone/disc, vertebral dislocation or instability), and in the chronic phase after healing (dural fibrosis, anterior ridge of bone at apex). Intrinsic causes involve the penetration of granulation tissue or inflammation into or through the dura, with involvement of the meninges and spinal cord. 8/9 biopsies of the dura demonstrated granulomatous inflammation, and the pattern suggested direct spread of inflammation across the dura.

Hodgson AR, Stock FE. Anterior spinal fusion. A preliminary communication on the radical treatment of Pott's disease and Pott's paraplegia. *Br J Surg* 44:266-275, 1956.

Early results of anterior debridement and strut grafting are described in 48 patients. This approach offers excellent visualization and enables a thorough debridement and complete decompression of the spinal cord. Autogenous strut grafting is performed in order to prevent deformity.

Hodgson AR, Stock FE. Anterior spine fusion for the treatment of tuberculosis of the spine. The operative findings and results of treatment in the first 100 cases. *J Bone Joint Surg* 42a:295-310, 1960.

Operative findings are reviewed in 100 patients, and included necrosis of the intervertebral disc in 45%, sequestration in 65%, and paravertebral abscesses in 91%. In patients with thoracic involvement, extension of abscesses to include the pleura and/or lung (adhesions or intraparenchymal abscesses) occurred in 75%. A layer of granulation/fibrous tissue may be adherent to the dura, and may also result in compression. This layer should be peeled off the dura. In chronic cases, a ridge of bone may result in cord compression at the apex of the kyphus. Normal dural pulsations should be seen following adequate decompression. Iliac crest graft was felt to be preferrable to rib graft. Patients were kept supine until union occurred, usually for 3 months, but often longer. Only 1 recurrence was observed.

Hodgson AR, Stock FE, Fang HSY, Ong GB. Anterior spinal fusion. The operative approach and pathological findings in 412 patients with Pott's disease of the spine. *Br J Surg* 48:172-178, 1960.

The surgical technique, operative findings, and results for patients undergoing anterior spinal fusion (Hong Kong method) are reviewed in 412 patients.

Jain AK. Treatment of tuberculosis of the spine with neurologic complications. *Clin Orthop Rel Res* 398:75-84, 2002.

The literature on tuberculosis of the spine with neurologic deficit is summarized in this review article. Neurologic deficits may occur in both the active and healed phases of the disease, and the prognosis is much improved in the former. Deficits in the active phase are caused by mechanical pressure from abscess, granulation tissue, sequestra, and caseous material, while in the late phase neural compromise typically results from a transverse ridge of bone anterior to the spinal cord and dural fibrosis. The author presents an algorithm to help approach such patients. Although surgical indications in patients with neurologic involvement have varied in the literature, the "middle path" regime may be most practical. A significant subset of patients may experience neurologic recovery with a 3-4 week trial of chemotherapy, bedrest, and adequate nutritional support. The indications for surgery may include clinical factors (neural arch involvement, recurrent paraplegia, and massive retropharyngeal abscess causing difficulties with ventilation or swallowing), treatment factors (persistent or progressive deficit while following an adequate course of conservative treatment), imaging factors [panvertebral involvement (scoliosis or severe kyphosis on plain films, global destruction on CT or MRI) or extradural compression (circumferential cord compression from granulation tissue on MRI)], and patient factors (painful spasm or nerve root compression). Myelography is recommended to assess the adequacy of surgical decompression in questionable cases. In considering the extent of debridement in cases requiring surgery, the author recommends removing only pus and sequestra to decompress the spinal cord. Radical debridement (entire zone of involvement) may result in an excessive gap anteriorly, and graft complications are increased in this setting. In the thoracic spine, especially in patients with compromised pulmonary function, the lateral extrapleural approach may be safest, and offers the best exposure in patients with a severe kyphotic deformity. For those with paraplegia from healed disease, removal of the anterior ridge of bone is performed for decompression, although a complete recovery is rare and results are inferior to decompression during the active phase of the disease. Neural recovery may be improved in younger patients with better nutritional status, patients with active disease, less severe kyphosis, slower onset of neurologic symptoms, and anterior rather than panvertebral disease. Myelomalacia seen on MRI carries a poor prognosis, especially if associated with thinning of the cord and prescence of a syrinx. Craniovertebral disease is also reviewed, and usually begins in the retropharygeal region. Atlantaxial subluxation/dislocation in seen in 56-76%, and other problems include basilar invagination, cranial nerve abnormalities, neck pain and deformity. The diagnosis can be made by needle aspiration or transoral biopsy, and traction may help achieve reduction. Immobilization (halo, cervicothoracic orthosis), bedrest, and chemotherapy are employed initially. Decompression is required for large retropharyngeal abscesses or in those who do not respond to conservative treatment. In the cervical spine, traction and chemotherapy are employed initially, and given an adequate response patients may be mobilized in a cervicothoracic orthosis at 6 weeks. Those not responding are treated by decompression.

Jenkins DHR, Hodgson AR, Yau AMC, Dwyer AP, et al. Stabilization of the spine in the surgical treatment of severe spinal tuberculosis in children. *Clin Orthop Rel Res* 110:69-80, 1975.

160 children with involvement of two or more vertebrae (mean 3 vertebrae) were treated by four surgical techniques (ASF, PSF, ASF/PSF, PSF/ASF) and reviewed at 10 years followup. Combined procedures were performed 3 months apart. Rib grafts were used most commonly, followed by iliac crest. Patients were kept on bedrest until healing was evident (3-7 months). The tuberculous focus healed in all cases. The group treated by ASF alone (40) demonstrated the greatest loss of alignment postoperatively, and complications associated with the strut grafts included fracture (4), resorption (6), and protrusion (1). The strength of these long strut grafts is felt to be inadequate. The authors conclude that a posterior spinal fusion alone may be

helpful in less severe cases in which an abscess is not present. When an abscess is present, PSF alone was associated with the worst results. A combined approach offers the best overall results and allows drainage of the abscess, removal of sequestra and debris, faster union, and better preservation of alignment.

Kemp HBS, Jeremiah JD, Cook J. Anterior fusion of the spine for infective lesions in adults. *J Bone Joint Surg* 55b:715-733, 1973.

131 adults (age 37 years) were treated with anterior decompression and grafting. Rib grafts were found to be unsuitable, as 32% fractured at an average of 13 months (kyphosis increases 13°°). Banked bone was suboptimal due to a lack of incorporation. Full thickness iliac crest graft provided the best results. Posterior fusion is recommended if >2 vertebral bodies are involved. Methods that may be successful for grafting in children are less beneficial in adults.

Lifeso RM, Weaver P, Harder EH. Tuberculous spondylitis in adults. *J Bone Joint Surg* 67a:1405-1413, 1985.

107 adults (mean age 41 years) were treated for spinal TB. Bone scans were negative in 35%, gallium scans were negative in 70%, and skin tests were negative in 14%. Fifty-three patients were treated surgically for neurologic impairment, instability, or failure of medical management (3 agents). Anterior decompression and fusion resulted in complete neurologic recovery in more than 90%, versus 79% after nonsurgical treatment. Surgical management resulted in a quicker resolution of symptoms. Patients with mild neurologic symptoms and no significant kyphosis may be best treated medically (2/23 worsened with medical therapy). Five patients had neurologic symptoms with normal plain films, and were subsequently found to have intradural or extradural involvement from tuberculomas or arachnoiditis. Those with inflammatory damage to the dura or the neural elements had a poor prognosis for neurologic recovery. Kyphosis did not worsen in those treated by either approach.

Louw JA. Spinal tuberculosis with neurologic deficit. Treatment with anterior vascularized rib grafts, posterior osteotomies and fusion. *J Bone Joint Surg* 72b:686-693, 1990.

19 patients (mean 25 yo) with thoracic or thoracolumbar deformity underwent the Kalafong procedure, which involves anterior decompression and vascularized rib strut graft, followed by posterior osteotomies, instrumentation and fusion. This can be performed in one stage (both wounds open simultaneously), or the procedures may be seperated by two weeks. The rib of the first univolved vertebrae (superiorly or inferiorly) should be selected. The posterior osteotomies shorten the posterior column, while strut grafting lengthens the anterior column. Harrington compression instrumentation (Luque rectangle with mersilene tape in children) was employed. Kyphosis was corrected from 56°° (avg. 3 vertebrae involved) to 27°° (30°° at followup), and radiographic healing was in 3.3 months. Neurological recovery averaged 2.6 Frankel grades, and 95% had complete function at 14 months postoperatively. Two patients had minor complications.

Moon MS, Woo YK, Lee KS, et al. Posterior instrumentation and anterior interbody fusion for tuberculous kyphosis of dorsal and lumbar spines. *Spine* 20(17):1910-1914, 1995.

Forty-four patients (39 adults) from 5-52 years of age with tuberculosis from the lower thoracic spine to L3 were treated by 18 months of chemotherapy in addition to spinal decompression and fusion. Those with draining sinuses were excluded. Most of the procedures were staged, and an instrumented posterior spinal fusion (3 levels above, 3 levels below the level of involvement) was performed first. An anterior decompression and grafting was performed 2-4 weeks later, and in the later period of the study both procedures were performed simultaneously. Patients were mobilized after 3-4 weeks without external support. The followup was a mean of 3.6 years. For adults, the kyphosis was corrected from a mean of 37° preoperatively to a mean of 18° at followup. In 4 children, the kyphosis was corrected from 55° preoperatively to 31° at followup. A single child had loss of correction due to migration of Steinmann pins associated with loosening of segmental wire fixation, and this was the only case associated with resorption of the anterior grafts. The authors feel that an isolated anterior procedure cannot be expected to prevent loss of correction and graft complications,

and that the posterior atbilization provides a more stable environment for the grafts to heal. There was no loss of correction at followup, and an additional benefit of this combined approach is that patients may be mobilized earlier.

Moon MS, Ha KY, Sun DH, et al. Pott's paraplegia. 67 Cases. *Clin Orthop Rel Res* 323: 122-128, 1996.

67 patients (9 children) were treated with three drugs, and 54 underwent decompressive surgery (all adults). In 14 patients, an instrumented posterior fusion was performed before anterior decompressive surgery, and these patients could be mobilized faster. Neurologic recovery occured in 47/54 patients. Paraplegia associated with healed disease (fibrosis, deformity) did not respond favorably to surgery, and was typically associated with spinal cord compresssion by a ridge of bone at the apex of the deformity. Recovery was faster (< 2 months) in those treated surgically versus those treated by chemotherapy alone (2-6 months). Either MRI or CT myelography is recommended preoperatively to assess the status of the spinal cord, especially in those cases of healed disease with deformity. Patients with an "atrophic" cord do not respond well to decompression.

Parthasarathy R, Sriram K, Santha T, Prabhakar R, et al. Short-course chemotherapy for tuberculosis of the spine. A comparison between ambulant treatment and radical surgery-ten year report, *J Bone Joint Surg* 81b:464-471, 2001.

This randomized, prospective study placed patients (thoracic and thoracolumbar disease without neurologic involvement) into three treatment groups (radical anterior surgery/grafting with 6 months of isoniazid and rifampicin, ambulant chemotherapy with isoniazid with rifampicin for 6 months, and ambulant chemotherapy with the same agents for 9 months). At 10 year followup, an adequate response was seen in 90% of the first group, 94% of the second, and 99% of the third. The angle of kyphosis increased in all three groups (15°° for the surgical group, 17°° for the 6 month chemotherapy group, 13°° for the 9 month chemotherapy group). The final angle of kyphosis could not be predicted based upon the initial vertebral loss. All patients should be followed closely, and those with the greatest progression in kyphosis were less than 15 years of age with an initial deformity of greater than 30°°. The authors suggest that this subset of patients are candidates for surgical intervention at the time of presentation. Treatment recommendations for neurologically normal patients with TB of the thoracic and thoracolumbar spine include 2 months of chemotherapy with 4 agents (isoniazid, rifampicin, pyrazinamide, and ethambutol), followed by four months of isoniazid and rifampicin. Surgery is indicated for those less than 15 years of age with more than 30°° of kyphosis, those with progressive kyphosis during treatment, those < 10 years old who do not autofuse by adolescence, and those with spinal cord compression despite chemotherapy. For the patients requiring surgery, an anterior debridement and strut grafting is recommended unless three or more disc spaces need to be spanned by the graft, or there is posterior element involvement. In these cases, a supplementary posterior spinal fusion with instrumentation is recommended.

Pattisson PRM. Pott's paraplegia: An account of the treatment in 89 consecutive patients. *Paraplegia* 24:77-91, 1986.

Of 724 patients with spinal tuberculosis seen over a 6 year period, 89 (12%) either presented with paraplegia or developed this problem during the course of treatment in Masan, Korea. All but four of these patients were treated conservatively, and the others underwent costotransversectomy for decompression. Within this group, 89% were felt to have paraplegia associated with active disease, while 11% had symptoms within the setting of healed disease. All patients were admitted to the hospital and treated with two oral agents (isoniazid and either rifampicin, ethambyutol, or para-aminosalicylic acid). Patients were mobilized as tolerated without any untoward effects on their neurologic status. Followup varied between one and six years, with 25% having more than 5 years. At latest followup, 72% were neurologically normal, and 84% achieved the ability to ambulate without assistive devides. Two patients died, and 5 others were unable to ambulate. Eight percent required crutches for

ambulation. During the early stages of treatment, 46% of patients demonstrated some deterioration in their neurological examination and level of function. Approximately 50% recovered within 3 months, and 78% had recovered following 6 months of therapy.

Tuli SM. Result of treatment of spinal tuberculosis by the "middle path" regime. *J Bone Joint Surg* 56b:13-23, 1975.

The author describes the "middle path" regime. Many patients may be adequately treated by chemotherapy and bedrest, and both the sed rate and radiographs are monitored regularly. Patients are mobilized in a brace after 6-9 months, for an additional 18-24 months. Abscesses are aspirated, and streptomycin solution is injected. Surgical treatment is indicated for an increase in size of a paravertebral abscesse despite adequate chemotherapy, involvement of the posterior elements, lack of clinical response after 3-6 months of chemotherapy (neurologically normal), lack of neurologic recovery or progression of neurologic deficits after several weeks of chemotherapy, recurrence of disease, mechanical instability, or an uncertain diagnosis. Anterior debridement/ fusion is employed most often, although posterior decompression is indicated for disease invlving the posterior elements (or extradural disease), and posterior spinal fusion is indicated for instability (pain, radiographic) after healing. The results in 900 cases are reviewed. Back pain was relieved in 96%, and all sinuses healed in 1-7 months. Surgical excision of a sinus tract was recommended if there was no resolution after 3-4 months of chemotherapy, and this was required in few cases. The tracts can extend for great distances, and complete excision is rarely possible. 85% of cold abscesses were treated effectively with repeated aspirations, and 68% of deep paravertebral abscesses resoled radiographically after 6-12 months (16% regressed butdid not disappear, and 14% calcified). Only 2% of these abscesses required drainage for an increase in size radiographically. 200 patients had neurologic involvement at presentation, and 38% resolved with chemotherapy alone. Of those decompressed surgically, 69% recovered completely, 11% had partial recovery (could ambulate with an assistive device), 8% had no change, and 12% died. Two percent of patients had recurrence of neurologic symptoms (1 extradural granuloma, 1 progressive kyphosis). In those receiving chemotherapy alone, 31% achieved osseous union across the disc space, while 52% had both fibrous and osseous replacement of the disc space, and 15% had fibrous tissue alone. After surgery, 89% had osseous healing and 11% had fibrous and osseous healing. Regeneration in vertebral height was observed in a significant number of patients treated by chemotherapy alone. In those receiving chemotherapy alone, an increase in kyphosis was seen in 67% of thoracolumbar lesions, 55% of thoracic lesions, and 33% of lumbar lesions, but only 20% in the series had > 10°° increase in kyphosis. Kyphosis progressed > 30°° in only 6/104 with more than 1 year followup, and this was mainly in children with more than 3 vertebral bodies involved in the thoracic spine. In those treated surgically, 19% had an increase in kyphosis > 10°°. 96% of lesions were healed at 12 months, and the others were salvaged by debridement. Only 2 cases recurred. Using the "middle path" regime, only 6% of neurologically normal patients, and 60% of those who presented with neurologic findings, ultimately required surgical intervention.

Yilmaz C, Selek H, Gurkan I, Erdemli B, et al. Anterior instrumentation for the treatment of spinal tuberculosis. *J Bone Joint Surg* 81a:1261-1267, 1999.

38 patients (mean 38 years) with kyphosis were treated by decompression, structural grafting, and anterior instrumentation. 22 of these had localized kyphosis at one level, and were internally fixed with a plating system, while an additional 16 had multilevel involvement and were stabilized with an anterior rod based system. Strut grafts included autogenous rib (24) or iliac crest (4), fibular allograft (8), or rib/fibular allograft (2). Patients were mobilized immediately. Deformity correction averaged 64% (1-2 levels of involvement) to 81% (more than 2 levels). Alignment was maintained postoperatively, and there was no recurrence or complications relating to the grafts or implants. This approach should not be employed when the posterior column is involved. Anterior instrumentation represents an alternative to posterior instrumentation for isolated anterior column disease, especially with multilevel involvement where progression of deformity tends to be greater.

Medical Research Council Studies on Tuberculosis of the Spine

The Medical Research Council Working Party on Tuberculosis of the Spine designed a series of collaborative studies in Korea (Masan and Pusan), Rhodesia (Bulawayo), South Africa (Johannesburg, Pretoria), and in Hong Kong in order to evaluate the efficacy of different protocols for the treatment of spinal tuberculosis. The experimental designs were controlled, and patients were randomized. In addition to a standardized course of chemotherapy (isoniazid and para-aminosalicylic acid +/- streptomycin for the first 3 months), treatment was based upon the local resources within each region. The following methods were investigated: inpatient chemotherapy, outpatient chemotherapy, either of these with or without immobilization (plaster body jackets), anterior debridement, and radical anterior debridement with bone grafting (Hong Kong procedure). In addition, there were uniform exclusion criteria, including lesions involving only the cervical spine, patients with paraparesis who were unable to ambulate across a room, those with a history of previous chemotherapy (> 12 months), the prescence of significant extra-spinal disease that might require an alteration in the protocol, and in Hong Kong those with destruction of 3 or more vertebral bodies. In measuring outcome, the criteria for a favorable result were as follows: capable of full activities, radiographically silent disease, no abscess or sinus, normal neurologic examination, and no change in their treatment program was required during the study period. The overall results of these studies documented that uncomplicated spinal tuberculosis can be adequately managed by outpatient chemotherapy. These excellent results were not improved by inpatient treatment, immobilization, or by surgical debridement alone. However, in settings with adequate resources and skilled spinal surgeons, the Hong Kong procedure results in faster healing and improved cosmesis (less kyphosis at followup).

Medical Research Council. A controlled trial of ambulant out-patient treatment and in-patient rest in bed in the management of tuberculosis of the spine in young Korean patients on standard chemotherapy. A study in Masan, Korea. *J Bone Joint Surg* 55b:678-697, 1973.

This was the first report from the council, and involved 200 patients treated by chemotherapy with bed rest (6 months as an inpatient) or outpatient treatment. Additionally, some patients received streptomycin for the first 3 months. Seventy-eight per cent of patients were less than 10 years of age, and the followup was 3 years. Most of the lesions were thoracic and thoracolumbar, and more than two-thirds of patients had more than 3 vertebrae involved (25% of patients had 5 or more vertebrae involved). An abscess was identified in 76% of inpatients and 72% of outpatients at presentation, and only 11% of inpatients and 5% of outpatients had a residual abscess or sinus at followup. Four patients required additional chemotherapy for persistent abscesses. The mean total vertebral loss at presentation was 1.8 for the inpatients and 1.3 for the outpatients, and at 3 years followup this had increased by 0.2 and 0.3, respectively. The mean kyphosis at presentation was 37° for the inpatients and 25° for the outpatients, and kyphosis increased 8° and 18°, respectively, at the time of most recent review. Only 10 patients had paraparesis at presentation, and all were neurologically normal at followup. Two outpatients developed paraparesis during treatment, and in both cases the deficit resolved. A favorable response was achieved in 84% of inpatients and 88% of outpatients. Favorable results were seen in 90% of those treated by 2 agents, and in 82% of those receiving streptomycin in addition to the other two drugs. Multiple regression analysis did not identify any prognostic factors.

Medical Research Council. A controlled trial of plaster-of-paris jackets in the management of ambulant outpatient treatment of tuberculosis of the spine in children on standard chemotherapy: A study in Pusan, Korea. *Tubercle* 54:261-282, 1973.

One hundred and fifty patients were treated by outpatient chemotherapy with or without immobilization in a plaster-of-paris jacket, and 141 of these were included in the final review at three years followup. A subset received streptomycin for the first 3 months of their treatment. An abscess or simus was identified in 21% clinically, and 45% had abscesses identified on radiographs. Fifty per cent of patients had involvement of 2 vertebral bodies, while 50% of lesions involved the thoracic

or thoracolumbar spine. The mean pretreatment kyphosis was 26°. A favorable result was seen in 82% of those receiving chemotherapy alone, and in 86% of those who were also treated by immobilization. The degree of kyphosis increased a mean of 10° for the outpatient chemotherapy group and 12° in those also treated by immobilization. Neither immobilization nor the addition of streptomycin appeared to improve the results of outpatient chemotherapy.

Medical Research Council. A controlled trial of debridement and ambulatory treatment in the management of tuberculosis of the spine in patients on standard chemotherapy. A study in Bulawayo, Rhodesia. *J Trop Med Hyg* 61:853-866, 1974.

One hundred and thirty patients were treated by either ambulatory chemotherapy or surgical debridement and chemotherapy. A subset of patients also received streptomycin for the first 3 months. At presentation, 52% of patients were older than 35 years of age, and half had involvement of the thoracic or thoracolumbar spine. Two vertebrae were involved in 72%, while 26% had more than 3 vertebrae involved. Abscesses (clinical or radiographic) were identified in 72% of the debridement group and 76% of the ambulatory chemotherapy group. The pre-treatment kyphosis was 27° for the debridement group and 24° for the chemotherapy group. After exclusions, 98 patients were evaluated at 3 years followup. Favorable results were seen in 85% of the debridement and 86% of the chemotherapy group. If those patients requiring a modification of their chemotherapeutic protocol are included in the analysis, then favorable results were observed in 89% and 90%, respectively. The addition of streptomycin did not improve the results. The degree of kyphosis increased a mean of 13° in the debridement group and 8° in the chemotherapy group, but this did not reach statistical significance. Six patients in each group were paraparetic at the start of treatment, and the symptoms resolved in 5 treated by debridement and 4 treated by chemotherapy. Overall, the results were similar, thus there was no advantage to adding anterior debridement. When reviewing the 43 cases presenting with neurologic dysfunction from Zimbabwe (Bulawayo) and Korea (Masan and Pusan), 23 were treated by chemotherapy alone, and all but one had recovered by 36 months. Fifteen of these patients were treated by surgery (4 had paraplegia), and the conclusion was that surgical intervention did not appear to expedite recovery of neurologic function at these particular sites.

Medical Research Council. A controlled trial of anterior spinal fusion and debridement in the surgical management of tuberculosis of the spine in patients on standard chemotherapy: A study in Hong Kong. *Br J Surg* 61:853-866, 1974.

One hundred and fifty patients were entered into this study to compare radical debridement and strut grafting (Hong Kong procedure) with debridement alone. All patients received the standard regimen of chemotherapy, and 130 patients were included in the three year followup. Prior to treatment, 40% of patients were less than 10 years of age, and only one patient had neurologic involvement. Abscesses were identified clinically or radiographically in 62%, and 52% had involvement of the lumbar or lumbosacral spine. The mean vertebral destruction was 0.7, and 97% had less than 2 vertebrae involved in the disease process. The mean preoperative kyphosis was 23° for the radical resection group and 16.4° for the debridement group. All of those treated by radical resection and bone grafting were kept on bedrest for a mean of 73 days. At 3 years followup, the mean kyphosis decreased 0.9° decrease in the radical group and increased 4.5° in those treated by debridement. In considering vertebral loss, the radical group gained 0.2 vertebral bodies, while the debridement group lost 0.2 vertebral bodies. The fusion rate was 93% for the radical group and 69% for the debridement group. Favorable results were seen in 87% of the radical group and 86% of the debridement group. If patients who required a change in chemotherapy or other modification of the standard protocol are included, then favorable results were seen in 97% and 95%, respectively. If resources are available, advantages to the Hong Kong procedure include a higher fusion rate and less deformity.

Medical Research Council. A five-year assessment of controlled trials of in-patient and out-patient treatment and of plaster-of-paris jackets for tuberculosis of the spine in children on standard chemotherapy. Studies in Masan and Pusan, Korea. *J Bone Joint Surg* 58b:399-411, 1976.

This represents the five year followup data for the 2 studies cited above (masan and Pusan, Korea) in which a total of three hundred and fifty patients were treated by chemotherapy (inpatient, outpatient, +/- immobilization). Twenty-three patients ultimately required surgery or a change in their chemotherapeutic protocol. A sinus or abscess was initially present in 41%, and at 5 years ten of these patients had a persistent lesion (8 sinuses). Thirty-two had evidence of paraparesis at admission, and 20 of these resolved with chemotherapy alone, and in 8 after surgery and/or a change in chemotherapeutic agents. Arthrodesis was achieved in 49% of inpatients, 46% of those treated as outpatients, and 49% of those treated with a cast. Eighty-nine per cent of patients had a favorable status at 5 years (91% inpatient, 89% outpatient, 90% cast, 84% without cast). The mean angle of kyphosis at presentation was 30°, and all groups demonstrated an increase in deformity at 5 years followup. The mean increase in kyphosis was 9° for the inpatients, 14° for the outpatients, and 9° for those treated with or without a cast. The loss of vertebral height was observed during the first 18 months. Approximately 5% developed a significant increase in kyphosis, and all lesions were in the thoracic or thoracolumbar spine. Overall, the results of standard chemotherapy were not improved by inpatient treatment with bedrest, immobilization, or by the addition of streptomycin to the chemotherapeutic protocol.

Medical Research Council. Five-year assessments of controlled trials of ambulatory treatment, debridement and anterior spinal fusion in the management of tuberculosis of the spine. Studies in Bulawayo (Rhodesia) and in Hong Kong. *J Bone Joint Surg* 60b:163-177, 1978.

This is the five year followup on the patients treated by debridement in Bulawayo and by radical debridement and strut grafting in Hong Kong. At the time of latest followup, arthrodesis was obtained in 92% of those treated by radical resection and in 84% of those undergoing debridement in Hong Kong, 82% of those treated by debridement in Bulawayo, and 85% treated by ambulatory chemotherapy. There was minimal reconstitution in vertebral height in the radical group, whereas the other groups all experienced some loss of vertebral height. Similarly, the angle of kyphosis improved a mean of 1° in the radical group, but increased 4° for the Hong Kong debridement group, 11° for the Bulawayo debridement group, and 6° for the ambulatory chemotherapy group. Here was no clear relationship between the initial angle of kyphosis and the degree of progression, and generally no progression was identified after 18 months following the start of treatment. The percentage of favorable results were as follows: radical debridement (89%), Hong Kong debridement (88%), Bulawayo debridement (84%), and ambulatory chemotherapy (82%). There were no statistically significant differences between these groups. In addition, there was no disease reactivation between three and five years after treatment. Adding streptomycin for the first 3 months did not affect the results in Bulawayo. The results suggest that debridement alone is of no aditional benefit. If resources are available, the Hong Kong procedure results in faster union and less deformity.

Medical Research Council. A 10-year assessment of a controlled trial comparing debridement and anterior spinal fusion in the management of tuberculosis of the spine in patients on standard chemotherapy in Hong Kong. *J Bone Joint Surg* 64b:393-398, 1982.

This is the ten year followup on the patients in Hong Kong treated by either debridement or radical resection and bone grafting. This review included 119 patients, none of whom had a change in their regimen since the 5 year followup study. Overall, the results were quite similar to those observed at 5 years followup. The radical debridement and grafting group achieved arthrodesis earlier than the debridement group, but the overall percentages at 10 years were staticstically similar (rad = 97%, Deb = 90%). The mean increase in vertebral loss was 0.05 for the Rad group and 0.23 for the debridement group, and there were no significant changes observed after 18 months postoperatively. In the Rad group, kyphosis inproved a mean of 1.4° (thoracic and thoracolumbar) and 0.5° (lumbar). In the debridement group, kyphosis increased a mean of 9.8° (thoracic and thoracolumbar) and 7.6° (lumbar). Overall, patient status was favorable in

100% of the Rad group and 98% of the debridement group.

Medical Research Council. A 10-year assessment of controlled trials of inpatient and outpatient treatment and of plaster-of paris jackets for tuberculosis of the spine in children on standard chemotherapy. Studies in Masan and Pusan, Korea. *J Bone Joint Surg* 67b:103-110, 1985.

This 10 year followup included 283 patients (350 were originally entered into the series), and did not demonstrate any significant changes from the results reported at 5 years. Favorable results were achieved in 88%, and in 96% if those who had a modification of the original protocol were included in the analysis (additional chemotherapy, surgery). There was no change in vertebral loss or in the degree of kyphosis between 5 and 10 years. Thirty five patients had paraparesis at some point during the ten years, and 26 of these had complete resolution (6 required additional chemotherapy or surgery). At followup, 2 patients had paraplegia while a single patient had residual paraparesis.

ICMR/BMRC. A controlled trial of short-course regimens of chemotherapy in patients receiving ambulatory treatment or undergoing radical surgery for tuberculosis of the spine. *Indian J Tub* 36s:1-21, 1989.

Three hundred and four patients were entered into this study in Madras, and patients were treated by either 6 or 9 months of ambulatory chemotherapy with rifampicin and isoniazid, or radical debridement and 6 months of ambulatory chemotherapy. Two hundred and sixty of these patients were evaluated at 3 years followup. One third of these patients were less than 15 years of age, 75-80% had a sinus or abscess, and 7% had neurologic involvement. Nineteen patients had myelopathy with functional impairement either at presentation or within the first 2 months, and one of these developed complete paraplegia following anterior spinal surgery. Myelopathy resolved completely in 13/19 without additional chemotherapy or surgery. Only 2 patients developed myelopathy after 2 months, one following anterior debridement, and the other patient was in the ambulatory chemotherapy group. The patient on chemotherapy was neurologically normal at followup, while the patient in the surgical group had a persistent deficit at followup. Fusion was achieved in 63% of the surgical group, 63% of the 6 month chemotherapy group, and 59% of the 9 month chemotherapy group. The mean angle of kyphosis increased in all groups, and was 12.5° for the radical surgery group, 12° for the 6 month chemotherapy group, and 10.5° for the 9 month chemotherapy group. Early resolution of sinuses and abscesses was more frequent in those treated surgically, and new abscesses or sinuses were seen more frequently in those treated by chemotherapy alone (19%) versus radical surgery (7%). At the time of latest followup, a favorable result was seen in 80% of the radical surgery group, 87% of the 6 month chemotherapy group, and 96% of the 9 month chemotherapy group. Those treated by 9 months of chemotherapy had a statistically better outcome than the radical surgery group.

Medical Research Council. Controlled trial of short-course regimens of chemotherapy in the ambulant treatment of spinal tuberculosis. *J Bone Joint Surg* 75b:240-248, 1993.

Two hundred and sixty-five patients were randomized into four protocols to evaluate short term outpatient chemotherapy in the management of tuberculosis of the spine. The study groups included the following: isoniazid + rifampicin for 6 months or 9 months, and isoniazid + paraaminosalicylic acid or ethambutol for 9 months or 18 months. Fifty-five percent of patients were children. No orthoses were used, and none of the patients had surgery. Clinically evident abscesses or sinuses were present in 33%, and 40% of the remaining patients had an abscess identified on a radiograph of the chest. Favorable results were achieved in 77%, and in 92% if the radiographic evaluation was excluded. The percentage of unfavorable results was highest in those treated by isoniazid + ethambutol for 9 months (19%). Overall, isoniazid + rifampicin for 6 or 9 months was as efficacious as an 18 month protocol, and the only inferior regimen was isoniazid + para-aminosalicylic acid or ethambutol for 9 months.

Medical Research Council. A 15-year assessment of controlled trials of the management of tuberculosis of the spine in Korea and Hong Kong. *J Bone Joint Surg* 80b:456-462, 1998.

The final results of the trials in Korea and Hong Kong are reported with 15 year followup. In Korea,

350 patients were originally entered. Seventy-five were excluded, leaving 271 for review, 87% of whom achieved a favorable status. Of those with an unfavorable status, 24 patients required additional chemotherapy with/without surgery, 3 had persistent myelopathy, and 6 died of their spinal disease. The radiographic findings were similar to those seen at 10 year followup, and overall 72% had achieved complete fusion, while an additional 13% had a partial fusion. In Hong Kong, 88% of the 150 patients entered into the study were available for followup. The disease was less extensive than in the patients from Korea, and 53% had lumbar or lumbosacral involvement. Only 30% had kyphosis greater than 21°, and 62% had a vertebral loss of less than one vertebral body. At final review, 87% of those having either debridement or the Hong Kong procedure had a favorable status. The debridement group had as mean increase in kyphosis of 10°, while there was no change in the angle of kyphosis in those treated by radical debridement and bone grafting. The rate of fusion in both groups was 94%.

4.) Lumbosacral Spine

Moon MS, Moon YW, Moon JL, Kim SS, et al. Conservative treatment of tuberculosis of the lumbar and lumbosacral spine. *Clin Orthop Rel Res* 398:40-49, 2002.

56 adults with involvement of the lumbar (42) and lumbosacral spine (14) were treated with 12-18 months of chemotherapy (3 agents). NSAID's were administered to decrease inflammation and pain during the first 4-6 weeks. All patients were treated effectively, and no cases of neurologic involvement were identified. Significant kyphosis was seen in 2/8 who presented with greater involvement, and most patients had a mild nonprogressive kyphosis at followup. A "telescoping" pattern of vertebral collapse along the longitudinal axis of the vertebral bodies was observed in 48 patients initially, but in only 6 following treatment. Autofusion was identified in 87.5% at 3 year followup.

Pun WK, Chow SP, Luk KDK, et al. Tuberculosis of the lumbosacral junction. *J Bone Joint Surg* 72b:675-678, 1990.

26 patients with lumbosacral involvement were reviewed at 20 years followup. Patients under 10 years of age usually presented with a draining sinus and a kyphotic deformity, and a single patient had paraparesis. Those over 10 years of age presented with back pain. Levels of involvement included L4 S1 (10), L5 S1 (5), L3 S1 (5), L2, S1 (1), and L2-L4, S2 (1 each). All were treated by chemotherapy, and 18 underwent surgery (7 anterior debridement/strut graft, 4 posterior spinal fusion, 1 anterior/posterior spinal fusion). Radiographic fusion was obtained in all, but 14 had from 10-88°° of kyphosis. Compensatory lordosis of the upper lumbar and thoracic spine was observed. Range of motion was adequate, and degenerative changes were observed in 57.7% (80% of these had osteophytes at the disc above the fusion mass). 53.8% had back pain, usually in the setting of a kyphotic or hypolordotic lumbosacral junction. All those treated by chemotherapy alone developed kyphosis, in comparison with 6/16 treated surgically. Anterior debridement and strut grafting seemed to be associated with the best sagittal alignment at followup. Unfortunately, the initial degree of deformity for all of these patients was not known.

5.) Progression of Deformity

Rajasekaran S. The problem of deformity in spinal tuberculosis. *Clin Orthop Rel Res* 398:85-92, 2002.

Although medical management is the mainstay of treatment, approximately 80% of patients will have some kyphosis at presentation, and 3-5% will ultimately develop a deformity of > 60°°. Prevention is essential, as severe kyphosis can lead to late onset paraplegia, and the treatment of large deformities is fraught with difficulties. Progression may be observed during the first 18 months (active phase) as well as after healing, and children are more susceptible than adults. Thoracic lesions tend to progress more than lumbar lesions. The severity of involvement, as measured by the degree of loss of vertebral body height, is also important. Those with severe disease, especially with multiple levels of involvement in the thoracic spine, are likely to progress. In this setting, the authors favor an instrumented posterior fusion followed by a second stage anterior debridement and strut grafting. Surgical treatment of severe deformity

after healing is technically difficult and fraught with complications. A three stage procedure is recommended, beginning with an anterior osteotomy and decompression, followed by a period in halo-pelvic traction. The second stage is an instrumented posterior spinal fusion, and the third stage is an anterior spinal fusion. The procedure is indicated in cases with a high risk of paraplegia or death.

Rajasekaran S. The natural history of post-tubercular kyphosis in children: Radiological signs which predict late increase in deformity. *J Bone Joint Surg* 83b:954-962, 2001.

This review of 61 children treated by chemotherapy documents the progression of kyphosis over a fifteen year period following treatment, defines signs of instability which are integrated into an instability score (predicts progression), and classifies 3 patterns of progression seen in these patients. At the start of treatment, the mean angle of deformity was 35°°, and this progressed to 41°° at the time of latest followup. Type I progression (39%) involves a gradual progression of deformity until the end of growth (during both the active phase of the disease and during the healed or growth phase). Type Ia curves progressed continuousely (15°° during the active phase, 9°° during the healing phase), while Ib curves progressed after a lag period of 3-6 years following treatment and healing (11°° during the active phase, 47°° during the healing phase). Type II curves (44%) actually improved during the healing phase. Type IIa deformities increased 8°° during the healing phase, but improved 26°° during the healing phase (improved 18°° overall). Type IIb deformities progressed 9°° during the healing phase, and improved 15°° during the healing phase (improved 6°° overall). Type III deformities (17%) remained stable throughout the active and healing phases. They had minimal disease at the start of treatment. A spinal instability score may be calculated from 4 radiographic findings, each being given a score of 1. These include dislocation of the facets, retropulsion of diseased fragments, lateral translation of a vertebra on the PA view, and toppling of the superior vertebra (tilt) on the PA radiograph. Of those with an instability score < 2, only 8% had an increase in deformity (<10°°). For those with an instability score ≥ 3, 50% had an increase of less than 30°° and 27% progressed more than 30°°. The ultimate angle of deformity could be correlated with the instability score, the pretreatment angle, and the level of involvement. Significant predictors of progression in a separate analysis included the instability score, the pretreatment angle, the level of the lesion, and the vertebral loss at presentation. Children should be followed through the end of growth, and those with an instability score greater than 2 may be candidates for prophylactic surgical stabilization.

Rajasekram S, Shanmugasundaram TK. Prediction of the angle of gibbus deformity in tuberculosis of the spine. *J Bone Joint Surg* 69a: 503-509, 1987.

90 patients were followed for 6 years, and the kyphotic angles were compared between those having anterior decompression and those treated without surgery. A formula is presented to predict the final kyphotic angle with 90% certainty (y = ax + b) [y = final kyphotic angle, a = 5.5, b = 30.5, and x = initial loss of vertebral height]. The intial loss of vertebral height is the most important factor, and a 100% loss resulted in 30-35 degrees of kyphosis at followup. The ability to predict the magnitude of deformity may help to better select patients for decompression and fusion. Overall, 10% of patients treated by surgery demonstrated a severe increase in kyphosis, versus 32% of the nonoperative group. A mild or moderate increase in kyphosis was seen in 76% of the surgical group and 56% of those in the nonsurgical groups.

Rajasekram S, Soundarapandian S. Progression of kyphosis in tuberculosis of the spine treated by anterior arthrodesis. *J Bone Joint Surg* 71a:1314-1323, 1989.

81 patients treated by anterior debridement and strut grafting were followed for 8 years to determine the fate of bone grafts and evaluate for progression of kyphosis. Graft materials included autogenous rib (67), iliac crest (11), tibia (2), and one graft came from a family member. In those receiving rib grafts, 1-2 grafts were inserted into slots within the vertebral bodies. Patients were hospitalized for at least 3 months, and some were placed in a cast depending on stability of the graft. Maintenance of alignment, without progression of kyphosis, was observed in 59%, while 20% had an increase in kyphosis of less than 20°°. 22% had

an increase of greater than 20°°. In 22 children (< 10 years old), a gradual decrease in kyphosis was observed, presumably due to continued growth of the anterior column. Graft failure was observed in 59% from fracture, resorption (20%), subsidence, or slippage (24%). The most important factor was the length of graft required. The success rate was 85% for involvement of a single disc space, 60% if 2 disc spaces were involved, 35% for 3 disc spaces, and 0% for 4 disc spaces. When more than 2 disc spaces are involved, the authors recommend either a supplementary posterior fusion or prolonged bedrest or external immobilization.

Schulitz KP, Kothe R, Leong JCY, Wehling P. Growth changes of a solidly fused kyphotic block after surgery for tuberculosis. Comparison of four procedures. *Spine* 22(10):1150-1155, 1997.

A review of lateral radiographs in 117 children (2-6 years old) treated by four procedures (anterior debridement without fusion, anterior fusion, posterior fusion, and anterior and posterior fusion) was performed at 10 years followup to compare the angle of kyphosis. Anterior fusion was associated with an increase in kyphosis of 12°°, while those treated with posterior fusion had no progression. Those undergoing debridement or an anterior and posterior fusion demonstrated a 4-7°° improvement in the angle of kyphosis. All groups demonstrated better results in the lumbar spine. Results also differed based upon the number of vertebrae involved. For those with involvement of a single vertebra, both the posterior spinal fusion and the anterior and posterior spinal fusion groups showed an improvement of 10°° at followup. With 3 levels involved, only the anterior debridement group and the anterior/posterior fusion groups showed an improvement (7°°). Finally, with > 4 vertebrae, only those undergoing anterior and posterior fusion did not develop progression.

Upadhyay SS, Saji MJ, Sell P, Yau ACMC. The effect of age on the change in deformity after radical resection and anterior arthrodesis for tuberculosis of the spine. *J Bone Joint Surg* 76a: 701-798, 1994.

The authors compared the degree of kyphosis in 33 children (mean 5 years old) with 71 adults (> 18 years old) following anterior debridement and strut grafting at a followup of 15 years to determine if children were prone to progressive deformity from continued posterior growth of the spine. They excluded patients with involvement of more than 3 vertebral bodies. Either rib or iliac crest grafts were used, and patients were maintained on bedrest for 4-10 weeks, without external immobilization. Chemotherapy with 3 agents was continued for 18 months. Posterior overgrowth was not observed, and the authors conclude that a prophylactic posterior fusion is not indicated in children.

Upadhyay SS, Sell P, Saji MJ, et al. 17 year prospective study of surgical management of spinal tuberculosis in children. Hong Kong operation compared with debridement surgery for short and long term outcome of deformity. *Spine* 18:1704-1711, 1993.

A prospective study of debridement versus the Hong Kong procedure in 80 children (mean age 7.6 years) with involvement of less than 3 vertebra (T1-S1) was performed. Followup was 17 years. There were no differences observed in relief of pain or in neurologic outcome. Progression of kyphosis was not observed, suggesting that posterior overgrowth does not result in progressive deformity in children. A deterioration in sagittal alignment was seen in 69% following debridement alone in both the thoracic and lumbar spine. In the lumbar spine, 60% of patients had a mean kyphosis of 24°°. The Hong Kong procedure resulted in 5°° or more improvement in alignment in 56% of patients.

Upadhyay SS, Sell P, Saji MJ, et al. Surgical management of spinal tuberculosis in adults. Hong Kong operation compared with debridement surgery for short and long term outcome of deformity. *Clin Orthop Rel Res* 302: 173-182, 1994.

71 adults (mean 35 years) treated by the Hong Kong procedure were compared with 34 undergoing debridement alone, with a followup of 15 years. There were no differences with respect to symptoms or neurologic recovery at followup, and there were no cases of reactivation in either group. Those treated by debridement alone had deterioration in sagittal alignment, whereas those treated by radical debridement and grafting demonstrated maintenance or improvement (40%) in alignment. In the lumbar

spine, only 63% had preservation of lordosis following debridement, in contrast to the Hong Kong group which demonstrated preservation of lordosis. The findings at 6 months postoperatively were not significantly different than those at 15 year followup.

6.) Miscellaneous

Arthornthurasook A, Chongpieboonpatana A. Spinal tuberculosis with posterior element involvement. Spine 15(3):191-194, 1990.

6 cases of spinal TB with posterior element involvement (pedicle, laminae, spinous process transverse process, rib) are described, and the pathology is well visualized on computed tomography, but may be difficult to identify on plain films. Although uncommon, the posterior elements may be involved.

Babhulkar SS, Tayade WB, Babhulkar SK. Atypical spinal tuberculosis. *J Bone Joint Surg* 66b:239-242, 1984.

Involvement of the neural arch (10%) or in an extradural location (5%) may occur infrequently, and patients present with neurologic symptoms in the abscence of the typical radiographic changes seen in spinal tuberculosis. Fot those with involvement of the posterior elements, the diagnosis was made on coned down views of the spine, and laminectomy relieved the compression. Myelography was used to make the diagnosis of extradural disease, and at surgery granulomatous material was found in the spinal canal, usually in the posterior epidural space. Significant recovery following decompression was seen in all but one patient.

Bradford DS. Anterior vascular pedicle bone grafting for the treatment of kyphosis. *Spine* 5: 318-323, 1980.

The technique for vascularized rib grafting is described.

Govender S, Parbhoo AH. Support of the anterior column with allografts in tuberculosis of the spine. *J Bone Joint Surg* 81b:106-109, 1999.

Fresh frozen humeral allografts, supplemented by autogenous rib, were used for strut grafting following anterior decompression in 47 children (mean 4.2 years old) with kyphosis and paraplegia. The concern is that autogenous rib may not be of sufficient caliber and strength to support the anterior column in children. There were no graft related complications and recurrence was not observed. All grafts healed by 6 months and demonstrated evidence of remodelling at 30 months (mean followup 39 months). The kyphotic angle was improved from 53°°to 15°°, and complete neurologic recovery was seen in 45/47 children.

Jain AK, Aggarwal A, Mehrotra. Correlation of canal encroachment with neurologic deficit in tuberculosis of the spine. *Int Orthop (SICOT)* 23: 85-86, 1999.

15 patients (15-65 years) with tuberculosis of the spine and no deformity were evaluated by computed tomography to determine the maximal percentage of spinal encroachment. All patients responded favorably to chemotherapy and bracing. Ten of these had thoracic involvement. 7 of these had more than 65% canal encroachment (maximum 76%), despite normal clinical findings. Given the gradual progression in these cases, the neural elements can accommodate significantly greater extradural compression in comparison with either trauma or a pyogenic infection.

Janeway T, Mosberg WH, Jr. Tuberculous paraplegia with lateral vertebral dislocation. A case report. J Bone Joint Surg 59a:554-555, 1977.

This case report of a ten year old child with paraparesis documents the rare finding of lateral translation (of T11on T12) with instability from tuberculous infection. The patient recovered useful function following debridement via costotransversectomy.

Oga M, Arizono T, Takasita M, Sugioka Y. Evaluation of the risk of instrumentation as a foreign body in spinal tuberculosis. Clinical and biologic study. *Spine* 18(13):1890-1894, 1993.

11 patients underwent anterior debridement and strut grafting, followed by posterior spinal fusion with instrumentation. There were no persistent or recurrent infections. The adherence properties of mycobacterium tuberculosis were also studied in an experimental model, and the authors found that the tubercle bacilli were less adherent than staphylococcus epidermidis, and that “only a few biofilm-covered microorganisms were observed”. It is well known that bacteria may colonize

inert surfaces such as stainless steel through an extrapolysaccharide biofilm, and that this can lead to persistent infection. They conclude, based on both the clinical observations and the experimental study, that posterior instrumentation is safe within the setting of tuberculous infection.

Pande KC, Babhulkar SS. Atypical spinal tuberculosis. *Clin Orthop Rel Res* 398:67-74, 2002.

This review article discusses atypical radiographic and clinical features reported in patients with tuberculosis of the spine. Atypical radiographic findings include disease confined to a single vertebra, and multiple vertebral involvement (contiguous vs. noncontiguous). Atypical clinical findings include presentation as a disc herniation or failed back syndrome, as a cold abscess without an obvious bony lesion, and as tubercular granulomas (spinal tumor syndrome, extradural granuloma, subdural granuloma, and intramedullary granuloma). Single vertebral involvement may present as vertebra plana, without deformity or cold abscess, and TB should be added to the usual differential diagnosis of eosinophilic granuloma, metastatic disease, etc. Secondary bacterial infection may give the radiographic appearance of an "ivory" vertebra due to both lytic and blastic changes. The posterior arch is infrequently involved in TB, and panvertebral involvement (anterior and posterior columns) is extremely rare. Multiple vertebral lesions are seen less frequently, involving up to four vertebrae, and "skip" lesions may also occur infrequently. Failed back syndrome following lumbar disc surgery may in rare cases be due to tuberculosis involving the disc space. Tubercular granulomas (extradural, intradural, intramedullary) may result in neurologic deficits in the abscence of abnormalities on plain radiographs.

Rahman NU. Atypical forms of spinal tuberculosis. *J Bone Joint Surg* 62b: 162-165, 1980.

Thirteen patients (7-45 years old) presented with spinal cord compression, and plain radiographs did not demonstrate the typical findings associated with tuberculosis. Atypical forms included isolated posterior element involvement associated with an intraspinal abscess, and disease confined to a single vertebra simulating metatstatic disease. Those with posterior involvement had laminectomy after a myelogram demonstrated a complete block, and most had extradural compression from tuberculous granulation tissue (1 had intradural extension).

Shipley JA, Craig JB. Spinal tuberculosis with translational instability. *Spine* 18(3):397-401, 1993.

The authors present 4 cases in which involvement of both the anterior and posterior columns resulted in spinal instability. Radiographic findings suggestive of instability include anterior or lateral translation of the vertebrae. Children seem to be at greater risk, and neurologic involvement in two cases was related to cord impingement from translation of the involved segments. Posterior instrumentation is recommended for patients without neurologic involvement to prevent deformity and avoid neurologic symptoms from instability. This is also recommended as a first stage, prior to anterior decompression and grafting, in those with spinal cord compression.

Travlos J, Du Toit G. Spinal tuberculosis: Beware the posterior elements. *J Bone joint Surg* 72b:722-723, 1990.

This case report documents intraoperative loss of alignment and spinal cord compression during an anterior decompression in a patient with involvement of the posterior column. Progressive posterior and lateral displacement of the caudal segment was observed. Posterior column involvement is rare, but should be always be kept in mind. Posterior decompression and fusion (instrumented) is recommended for posterior element involvement, and an anterior decompression can be added as a second stage if necessary.

VIII. Poliomyelitis

Despite a decrease in the number of new cases of polio due to the success of worldwide vaccination programs, residual deformities are still seen with frequency in developing countries. Although the literature on the orthopaedic management of polio is extensive, the principles and techniques have been well outlined by Huckstep, Watts and Gillies, Krul, and in the comprehensive chapters in the second and

third editions of Tachdjian's pediatric orthopaedic textbook. Goals of management outlined in the International Society of Prosthetics and Orthotics concensus conference on poliomyelitis (Hammamet, Tunisia, 1997) include the following: overcoming the effects of paralysis, correcting deformities, restoring joint mobility, relieving pain, and restoring limb length inequality. After the acute phase of poliomyelitis, most muscles will recover function at a similar rate, and motor strength will plateau by 12 months in most patients.

A comprehensive treatment plan should be established for each patient, and priorities include (Watts and Gillies) 1.) *ambulation*, 2.) the *prevention of deformities during growth*, 3.) *decreasing the requirements for bracing*, 4.) *addressing the upper extremity*, and finally, 5.*) treating spinal deformity*. Early deformities result from postural changes associated with the pain and muscle spasm that occur during the acute phase of the disease. Late deformities are secondary to muscle imbalance, the effects of body weight and gravity, and the effects of positioning (sitting, crawling). Surgery is indicated to correct deformities that interfere with activities of daily living, to stabilize unstable joints, and to improve motor function by tendon transfer. Patient selection is perhaps most important.

General criteria for intervention (Krul) include: weakness or contractures within a single lower extremity that impair ambulation, weakness or contracture in both lower extremities in a patient who has adequate muscle strength in the trunk and upper extremities, young patients with few or moderate deformities, patients with lack of elbow flexion which impairs activities of daily living (hand must be functional), and patients with bilateral lower extremity involvement, a weak trunk, but adequate strength in the upper extremities (relative indication). Contraindications to surgery include involvement of both the trunk and the lower extremities in patients with weak upper extremities, and adults with extensive involvement of the limbs. When resources are scarce younger patients and those with lesser degrees of deformity should receive priority. Treatment principles are also based on the age of the patient.

Problems at the hip include muscle contractures and subluxation/dislocation. The most common contracture is abduction with or without flexion, and the tensor fascia lata/iliotibial band are primarily responsible. Soft tissue releases are indicated for flexion deformity > 30°°, adduction > 5°°, and abduction > 15°°. Lesser degrees of contracture may respond to stetching or serial casting, and post operative traction may improve the results following surgical release. For milder degrees of abduction contracture, the Soutter procedure may suffice. Overcorrection should be avoided, and the hip should be left in approximately 5°° of abduction. For deformities greater than 60°°, the combination of a proximal and distal release (Ober and Yount procedures) is usually most effective. If greater extension, and/or varus or valgus is required, then a subtrochanteric osteotomy may be the best choice. Femoral rotational abnormalities generally do not require surgical treatment. Hip subluxation or dislocation should be treated, as unilateral involvement may contribute to pelvic obliquity, which in turn may be associated with scoliosis. A femoral osteotomy combined with an iliopsoas transfer to the greater trochanter (Mustard and variants) may be indicated in patients less than 7 years of age, and an acetabular procedure should be added in those greater than 7 years of age.

At the knee, the most common problem is flexion contracture with or without valgus deformity, due to contracture of the iliotibial band. In general, flexion contractures < 30°° may respond to stretching and/or serial casting, whereas those > 30°° will require at least a soft tissue release. Serial casting or skeletal traction may be employed following soft tissue release to improve the degree of correction. An extension osteotomy of the distal femur may be required in those who do not repond to this program, or when a large deformity is present initially. Shortening may help decrease the likelihood of neurovascular compromise. Varus or valgus deformities may usually be managed with an orthosis, however those > 25°° may require an osteotomy for realignment. In patients with quadriceps weakness, functional improvements may be seen with hamstring tendon transfer in appropriately selected patients. Although a strong gluteus maximus and gastrocsoleus are certainly desirable, several studies have suggested that these are not necessarily a prerequisite. Transfer of the biceps femoris alone has been associated with patellar subluxation at longer term followup, and the best results have been reported with transfer of both the biceps and the semitendinosus, or the triple

transfer described by Perry et al. Knee instability is best treated by orthotic support. Recurvatum is also seen with frequency. An orthosis is commonly employed, and a flexion osteotomy and/or bone block procedure have been successful. Total joint arthroplasty is an excellent option for painful degenerative changes, and technical considerations are especially important in this population with global instability and/or recurvatum deformity. A more constrained system may be beneficial, and those with weak quadriceps may benefit from alignment in mild hyperextension. A brace may be required postoperatively in patients with residual laxity. Pain relief has been adequate, however the functional results may deteriorate with time (probably related to the disease process).

Foot and ankle problems include equinus, equinovarus, equinovalgus, and footdrop from weakness of the anterior compartment muscles. Equinus deformities are treated by lengthening of the tendoachilles, and care should be taken to avoid overlengthening. In patients wih quadriceps weakness, it is desirable to leave 5-10°° of residual equinus. Calcaneus deformities may be treated by transfer of one half of the tendoachilles to the fibula (Westin procedure). Although soft tissue release and/or osteotomies may be used to realign the hindfoot, triple arthrodesis is most commonly recommended in the mature foot. Muscle balancing should also be performed. For an isolated paralysis of the tibialis anterior, transfer of the extensor hallucis longus to the first metatarsal neck may suffice. Anterior transfer of the tibialis posterior or the peroneals (if the subtalar joint is stabilized) may be helpful.

Upper extremity deficits commonly include shoulder abduction, elbow and wrist flexion, forearm supination, and opposition. The goal of any intervention is to facilitate hand function, and to improve the ability to ambulate with assistive devices. Shoulder fusion may be helpful, although the timing is an area of controversy. Early stabilization may promote function during childhood, although there is a greater risk of growth disturbance. The maximum shortening may be up to 6 centimeters, however shortening is rarely a functional or cosmetic problem. A prerequisite is adequate strength of the periscapular muscles (especially serratus anterior). Options for enhancing elbow flexion include transferring the flexor origin (Steindler), the triceps, the pectoralis major, or the sternocleidomastoid. The triceps should not be employed if the patient uses crutches or a wheelchair. Supination contracture may be addressed by release of the interossous membrane and rerouting of the biceps tendon (Zancolli). Wrist fusion in 20-40°° dorsiflexion may improve function, especially in those who use crutches and/or a wheelchair. Opponensplasty may improve opposition, but the transfer may stretch out in those who rely upon crutches and/or a wheelchair.

Scoliosis may be observed in 2-25% of patients. Progressive curvatures may interfere with both sitting balance and ambulation, and the upper extremities may be required to achieve stable sitting posture. Severe deformities may be associated with pain and a decline in pulmonary function. In addition, many curves will be associated with pelvic obliquity and infrapelvic contractures, and hip instability may also need to be addressed. Occasionally, correcting the infrapelvic obliquity will result in a significant improvement in the scoliosis. Curvatures in this population tend to remain flexible until the teenage years, even in the face of significant progression, and it is probably best to delay surgical intervention until after 12 years of age. Athough bracing probably does not alter the natural history, progression may be delayed, and an orthosis may help improve sitting balance until definitive stabilization. For progressive curves greater than 40-60°, a posterior spinal fusion with segmental spinal instrumentation is recommended. An anterior release, with or without anterior instrumentation, may be appropriate in larger, stiffer deformities. Extension of the instrumentation and fusion to the pelvis is essential is significant pelvic obliquity is present. Preserving lumbar lordosis is important, as the center of gravity must be maintained behind the hips.

VIIA. General Considerations

Huckstep RL, Poliomyelitis. A Guide for Developing Countries. Edinburgh: Churchill Livingstone, 1975.

This well illustrated and comprehensive textbook covers a spectrum of issues involved in the care of patients with polio. The scope of the problem is described, and the importance of treating coexisting malnutrition, infectious diseases (schistosomiasis,

malaria, helminths), and chronic anemia. Other topics include history, virology, epidemiology, pathology, immunization, nursing, respiratory care, physical therapy, and the development of adequate facilities to provide the range of services needed by this population. The construction and appropriate use of wheelchairs and other assistive devices is described in detail. Causes of deformity and radiographic changes are also described. Osteopenia is a common finding in both children and adults. A host of findings may be observed in the skeletally immature. Epiphyseal shape may be altered by muscle imbalance and contracture, and flattening is commonly observed. Varus or valgus of the femoral neck may be seen, as well as flattening of the posterior femoral condyle associated with lateral or posterior subluxation at the knee. The differential diagnosis for acute poliomyelitis includes meningitis or encephalitis (usually don't produce a flaccid paralysis, may need lumbar puncture), acute infective polyneuritis (symmetric changes observed in all four limbs, abnormal sensory findings), viral infections (Coxsackie, ECHO), pseudoparalysis (trauma, infection, nerve palsy), or miscellaneous causes including vitamin deficiencies, peripheral neuropathy, and heavy metal poisoning. Surgical indications are based upon the prognosis for ambulation, and whether ambulation will benefit overall function. The indications for calipers in children and adults are described. For children with quadriceps strength less than 3 (antigravity), a long leg caliper should be used. Modifications are made for valgus and recurvatum. For those with greater than grade 3 strength and a flail foot, a short leg caliper is recommended, and a back stop can be added to compensate for residual equinus deformity. Contraindications to the use of a caliper include significant contractures, and severe leg weakness in the setting of weakness of the trunk and at least one upper extremity. Contraindications to surgery in adults include involvement of one or both upper extremities, and severe involvement of both lower extremities, especially at the knees. Mild flexion contractures (< 30°°) at the hip and knee may be managed with serial manipulation and splinting under anaesthesia in children with strong upper extremities. Surgical release is indicated for greater degrees of deformity, and percutaneous methods are presented. The iliotibial band is released using a four incision technique, but the biceps tendon should be released via an open technique to avoid injury to the peroneal nerve. Knee flexion contracture may also be managed by percutaneous release, and for those with < 40°° an incomplete osteotomy followed later by osteoclasis and casting may be sufficient. For greater deformities, an extension osteotomy with shortening may be required. In some adults, a compression arthrodesis may be preferred (stable ankle, minimal shortening). A percutaneous heelcord release may benefit those with equinus, as long as the patient does not require a mild equinus deformity to stabilize the knee, or those in whom the equinus compensates for a leg length inequality. Varus deformity may require medial release or triple arthrodesis. In the upper extremity, shoulder arthrodesis may help with a paralyzed deltoid in the patient with a normal hand. Wrist drop may be treated by a splint or wrist fusion.

Krul J (Ed.). Rehabilitation surgery for deformities due to poliomyelitis. Techniques for the district hospital. World Health Organization, Geneva, 1993.

This concise and well illustrated text is designed for physicians (not necessarily orthopaedic surgeons) who will be responsible for managing the sequelae of polio at the district level. "Rehabilitation" surgery promotes function, and should only be performed if patients have access to physical therapy and orthoses. The introduction covers basic information on the etiology and stages of polimyelitis. Early deformities result from postural changes in response to the pain and muscle spasm during the acute phase of the disease. Late deformities are secondary to muscle imbalance, the effects of body weight and gravity, and the effects of positioning (sitting, crawling). The clinical evaluation of patients is then reviewed, followed by the goals of surgical intervention. Surgery is indicated to *correct deformities that interfere with activities of daily living, to stabilize unstable joints, and to improve motor function by tendon transfer*.

Suggested criteria for patient selection include the following:

1.) Weakness or contractures within a single lower extremity that impair ambulation
2.) Weakness or contracture in both lower

extremities in a patient who has adequate muscle strength in the trunk and upper extremities

3.) Young patients with few or moderate deformities
4.) Patients with lack of elbow flexion which impairs activities of daily living (hand must be functional)
5.) Patients with bilateral lower extremity involvement, a weak trunk, but adequate strength in the upper extremities (relative indication)

Contraindications for surgery include involvement of both the trunk and the lower extremities in patients with weak upper extremities, and adults with extensive involvement of the limbs.

Techniques for traction and casting are presented. Surgical techniques are reviewed for a limited number of procedures that can be performed within the district hospital setting. These include muscle releases about the hip (for flexion/abduction/external rotation contracture and adduction contracture), the knee (posterior release, tibial osteotomy), and the foot and ankle (gastrocsoleus lengthening, triple arthrodesis, anterior transfer of the tibialis posterior).

Sharrard WJW. Muscle recovery in poliomyelitis. *J Bone Joint Surg* 37b:63-79, 1955.

Over a single year, 185 patients were admitted with acute poliomyelitis, and their course was followed for 3 years to evaluate recovery of motor function. At followup, data was available on 142 of these cases. Daily passive and active range of motion exercises were employed throughout the course of treatment. Sequential manual muscle testing was used to follow recovery. Of 3033 muscles with varying degrees of paralysis, 962 (32%) demonstrated no recovery by 3 years. In general, an improvement of one grade in strength was seen at one month in about 50% of patients (all muscle groups), and by the fourth month 25% of these had gained an additional grade of strength. Most of the recovery was observed during the first 12 months, and only rarely was any improvement identified after 2 years. The results in 1905 upper extremity muscles were similar, although the rate of recovery per month was about 5% higher than in the lower extremities. All of the muscles in both the upper and lower extremities demonstrated similar rates of recovery. Interestingly, in patients less than 2 years of age, none of whom could comply with a structured program of rehabilitation, the pattern of recovery did not differ in comparison with older patients. The rapidity of recovery could be correlated with age, and those from 2-4 years of age recovered faster than those 10-20 years of age. Patients older than 20 years of age recovered the slowest. In the lower extremities, most muscles recovered 1-3 grades, and a small proportion recovered 4 grades or did not demonstrate any recovery. Upper extremity muscles seemed to recover to a greater degree, and in general the ultimate recovery could be estimated by adding 2.5 grades to the grade at 1 month, and 1 grade to the grade at 6 months. Some degree of recovery is nearly always observed in muscles with partial paralysis, however more than 90% of muscles that remained completely paralyzed after 6 months failed to regain any useful motor strength. Since muscles recover at about the same rate, imbalance will persist even in the face of significant recovery, and the weaker muscles do not "catch up" with the stronger muscles.

Tachdjian M. Pediatric Orthopaedics 2nd Edition, W.B. Saunders, Philadelphia, 1990 pp. 1910-1971.

Herring JA (Ed.) Tachdjian's Pediatric Orthopaedics, 3rd Edition, Vol. 2, W.B. Saunders, Philadelphia, 2002, pp. 1321-1443.

These oustanding chapters provide a detailed description all of the deformities associated with polio and options for their management. The list of references is exhaustive.

Watts HG, Gillies H. A practical guide to the orthopaedic management of children with the residua of poliomyelitis. Reprints available form the HVO office.

The authors present a thoughtful, well organized approach to the child with residual deformities from polio. Priorities for treatment are established based upon a comprehensive physical assessment (a patient evaluation form is included). The ability to ambulate is the first priority, and the prevention or correction of hip and knee deformities are important. Stretching may suffice early on, and older patients may require appropriate releases (+/- traction) to facilitate bracing and mobilization. Standard techniques are outlined. The second priority is to prevent deformities during growth,

which may ultimately interfere with function. Bracing, stretching, tendon transfers, and arthrodesis alone or in combination may be indicated. All of the common deformities are addressed, and suggestions for management made. The third priority is to decrease bracing, and procedures are recommended to achieve this goal. For example, hindfoot stabilization and/or tendon transfer may obviate the need for a long leg brace in patients with weakness of the quadriceps. The fourth priority is the upper extremity. Stabilization of the shoulder may facilitate function, and transfers about the elbow may help with use of the hand. Forearm pronation or supination contractures may require treatment, while lack of opposition may need to be addressed. The fifth priority involves treatment of scoliosis. Infrapelvic obliquity from contractures about the hip should be addressed first, as the spinal deformity may improve spontaneously. These paralytic curves tend to stay quite flexible until skeletal maturity, and the indications for stabilization should relate to the flexibility, and not the absolute magnitude, of the deformity. Bracing may help delay the need for intervention. Both an anterior and posterior spinal instrumentation and fusion are required for these curves.

VIIB. Upper Extremity

Barr JS, Freiberg JA, Colonna PC, et al. A survey of end results on stabilization of the paralytic shoulder. Report of the research committee of the American Orthopaedic Association. *J Bone Joint Surg* 14a:699-707, 1942.

One hundred and one patients treated by arthrodesis of the shoulder were examined. Arthrodesis was beneficial from a functional standpoint, and the best position for arthrodesis will depend upon the age, sex, and remaining muscle power about the shoulder. With adequate strength in the serratus anterior and trapezius, the fusion should be performed in 45-55°° abduction, 15-25°° flexion, and 15-25°° internal rotation. With good muscle power and fusion in 45°° abduction, the arm will abduct to 90°°. Further abduction improves motion at the expense of cosmesis. When function of the serratus is absent, the arthrodesis should be in only 30°° of abduction, as a greater amount will allow gravity to rotate and depress the scapula, which stretches and weakens the trapezius. Excessive flexion will result in scapular winging when the arm is by the side, which then stretches the serratus. With the arm in 15°° of internal rotation, the hand can reach up to the head with abduction of less than 40°°. Excessive external rotation is worse than excessive internal rotation, and a greater degree of internal rotation (up to 45°°) may be beneficial if there is significant weakness in the elbow or hand. Patients with a flail extremity may benefit from enhanced positioning of the extremity. In this setting a flexion contrature at the elbow was found to be helpful. In patients with a flail elbow, only slight abduction is preferable to keep the arm close to the side, and 40-45°° of internal rotation was beneficial. The mean age at arthrodesis was 12 years (6-30 years old), and range of motion was improved if the procedure was performed in children less than 12 years of age. Only a single case of growth disturbance was identified. Patients were treated in a shoulder spica cast, and a minimum of 3 months was felt to be desirable. Those who have not fused by this point may be immobilized for an additional 1-2 months. A mild loss of abduction in plaster was commonly observed, which suggests the need for some form of internal fixation.

Bunnell S. Restoring flexion to the paralytic elbow. *J Bone Joint Surg* 33a:566-571, 1951.

The author reviews the methods available to restore elbow flexion, including the Steindler flexorplasty, a modified Steindler procedure, or transfer of the triceps, pectoralis, or sternocleidomastoid muscles. In addition to flexion, the modified Steindler procedure enables the patient to gain strength in supination. The technique involves transfer of the forearm flexors to the lateral border of the distal humerus (2 inches up) using a fascia lata graft. The triceps transfer is supplemented by a fascial graft to achieve greater length, and is attached through drill holes to the bicipital tuberosity of the radius with a pull-out wire. The pectoralis major transfer (Clark) involves a two and one-half inch wide strip of the inferior portion of the muscle. This strip is sutured down to the muculotendinous junction of the paralyzed biceps muscle. Similarly, the sternocleidomastoid transfer is lengthened by attaching a free fascial graft, and is brought subcuataneously down to the bicipital tuberosity and secured with a pull-out wire. All of

these muscles may be successful, and the choice depends upon the pattern of paralysis or weakness in a each patient.

Carroll RE, Hill NA. Triceps transfer to restore elbow flexion. A study of fifteen patients with paralytic lesions and arthrogryposis. *J Bone Joint Surg* 52a:239-244, 1970.

Fifteen cases of triceps transfer to enhance flexion at the elbow were performed in patients with post-traumatic/paralytic paralysis (7) and in arthrogryposis (8). A single patient had polio. None of these were candidates for Steindler flexorplasty. Bilateral transfers should not be performed since one functional triceps is required for toileting and raising up from a chair. The criteria for success was the ability to raise the hand to the mouth. All but one patient with arthrogryposis was treated surgically prior to triceps transfer, and procedures included excision of the radial head or modified elbow arthroplasty. Five of these had a shoulder arthrodesis. Through a midline incision, the ulnar nerve is isolated and protected, and the triceps is detached distally with a long strip of periostium off the ulna. The muscle is mobilized, and the end is rolled into a tube to facilitate transfer. The biceps tendon and it's insertion on the radial tuberosity are exposed, and the interval in between the brachioradialis and the pronator teres is developed. The triceps tendon is then passed from posterior to anterior through a subcutaneous tunnel and sutured to the biceps tendon (or through drill holes into the radial tubersosity) with the elbow in 90°° flexion and the forearm supinated. The elbow is immobilized in a posterior splint at 90°° flexion for 4 weeks, after which active range of motion exercises are started. In the post traumatic and paralytic group, there were 5 successful results, one limited success, and one failure. The average arc of motion was 116°°, and the residual flexion contracture averaged 24°°. In the arthrogrypotic group there were 5 successes, one limited success, and 2 failures. Overall, the results were less predictable in the arthrogrypotic group, as the average arc of flexion was 43°°, with a residual flexion contracture of 59°°.

Clark JMP. Reconstruction of biceps brachii by pectoral muscle transplantation. Br J Surg 34: 12-13, 19

This case report illustrates the technique of pectoral muscle transplantation in patient with a traumatic loss of biceps function. The incision extends from the apex of the axilla to the seventh rib, along the axillary border of the pectoralis muscle. The lateral border and lower costal attachments of the muscle are then defined. The origin of the muscle on the 6th rib is detached, and a portion (2 ½ inches wide) is mobilized to serve as the transfer. A second incision is made anteriorly over the distal humerus, and the biceps tendon is exposed. The transfer is passed through a subcutaneous tunnel, looped through the biceps tendon, and sutured to itself (elbow flexed to 90°°). A sling was used for 3 weeks, and then active motion waas started in the sling. At followup the patient lacked 5°° of extension and 15°° of flexion. Strength was estimated at 40% of normal.

Makin M. Early arthrodesis for a flail shoulder in young children. *J Bone Joint Surg* 59a:317-321, 1977.

Seven children between 5 and 9 years of age with flail shoulders from polio were treated by arthrodesis of the shoulder. The philosophy is that the functional gains of an arthrodesis should not be delayed due to the concern of growth retardation and shortening of the humerus at skeletal maturity. All patients had functional scapular rotators, a prerequisite for the procedure. The author highlights the important structural differences between the humeral head in children and adults. The child's epiphysis is covered by articular cartilage on the superomedial side, and by the cartilage of the tuberosities on the superolateral side. The physis is found distally. The procedure involves removal of the cartilage in both of these regions, and fixation is achieved with smooth Steinmann pins drilled across the humeral head and into the acromion. The articular cartilage is removed from the glenoid prior to securing the alignment. The position of fixation includes nearly 90°° of abduction, with 25°° of flexion and 25°° of external rotation. In this position, a gap remains between the lower glenoid and the medial border of the epiphyseal plate, which should protect against bony bridging and premature

physeal closure. A spica is applied, and the pins are removed 4-6 weeks later. All fusions healed within 12 weeks, and there were no complications. No clinically significant humeral shortening was identified at skeletal maturity. With growth, the humeral head became less round, resulting in prominance of the acromion which was of some cosmetic significance. No functional problems were identified. Although the author expected some loss of abduction through bending during growth, this was not observed. At the completion of growth, the humerus remained in 20-30°° of abduction while the arm was at the side. No patients were symptomatic as a result of this. However, arthrodesis at 20-30°° less abduction initially could potentially result in medial bony bridging and growth disturbance.

Steindler A. A muscle plasty for the relief of flail elbow in infantile paralysis. ***Interstate medical Journal*** **235-241**

The Steindler flexorplasty is introduced as a means to improve elbow flexion in patients with a flail elbow (+/- flail shoulder), and a prerequisite is preservation of function in the wrist and forearm. The technique involves proximal transfer of the flexor origin (pronator teres, FCR, PL, FCU, periostium) from the medial epicondyle, through the intermuscular septum, to the medial aspect of the distal humerus (2-3 inches proximally). Postoperatively the arm is held in flexion for 6-8 weeks. After 3 weeks, active flexion exercises are started. Four of seven cases did well, and the major reason for failure was if the forearm muscles were not full strength.

Zancolli EA. Paralytic supination contracture of the forearm. ***J Bone Joint Surg*** **49a:1275-1284, 1967.**

The mechanism of supination contracture in polio is the unopposed action of the biceps in the setting of pronator paralysis, and activities of daily living such as dressing, eating, and writing may be impaired. The deformity increases with growth, and will become fixed over time. Initially, the interosseous membrane becomes contracted, and progressive angulation of the radius may occur with growth. Instability at both the proximal and distal radioulnar joints may follow. The author describes a procedure involving release of the interosseous membrane and rerouting of the biceps tendon around the neck of the radius to augment pronation. A longitudinal dorsal incision is used for release of the interosseous membrane, and the range of motion is then determined. A capsuloplasty of the distal radioulnar joint and/or release of the supinator muscle may be required. If a full passive range of motion is present preoperatively, then transfer of the biceps using a second incision may suffice. If the radial head is reducible, a capsuloplasty is performed. If irreducible, a resection of the radial head is performed. Fourteen patients were followed up at more than 5 years, and active pronation from 20 to 80 degrees was observed in 8. All patients maintained their correction, and 2 were overcorrected, presumably because the biceps transfer was placed under too much tension.

VIIC. Hip

Eberle CF. Pelvic obliquity and the unstable hip after poliomyelitis. ***J Bone Joint Surg*** **64b:300-304, 1982.**

This prospective study evaluated the treatment of hip instability associated with pelvic obliquity from abduction contracture on the contralateral side. Of 400 patients seen for deformities associated with polio over a 2 year period, 32 had abduction contactures, with or without flexion deformity, in which the contralateral “high” hip was unstable (subluxated, dislocatable, or dislocated). Most hips were flail, and only one patient had an unstable hip without coexisting pelvic obliquity. Muscle imbalance could not be correlated with hip deformity. The surgical goal was correction of infrapelvic obliquity, and in many cases hip stability was achieved with this alone. The surgical procedure was a proximal soft tissue release. The skin incision was longitudinal if a significant flexion deformity was present, or transverse in the case of a pure abduction deformity. All tight fascial structures were divided until the hip could be brought to neutral position, including the anterolateral fascia, tensor fascia lata, fascia over the gluteus medius, and occasionally the superior hip capsule required release. The sartorius, rectus femoris, and iliopsoas were released if significant flexion deformity was present. An iliopsoas transfer (Mustard or Sharrard) was considered if the muscle had suitable strength. Bilateral long leg casts were

applied, and the abducted hip was held in neutral or slight adduction. The casts were left in place for 4 weeks, and prone positioning was maintained for at least 4 hours per day. Braces were then applied as the children were mobilized. For hips that were dislocated and flail, closed reduction was often successful, and acetabular dysplasia was corrected by pelvic osteotomy. In cases with flexion deformity, absent abduction and active iliopsoas function (muscle imbalance), open reduction was often required and the iliopsoas was transferred to the greater trochanter. Thirty patients were available for followup at more than four years, and all hips remained stable. All but two patients ambulated independently. Scoliosis was reevaluated after corrrection of pelvic obliquity, and in many cases the curvature improved or resolved spontaneously.

Lau JHK, Parker JC, Hsu LCS, et al. Paralytic hip instability in poliomyelitis. *J Bone Joint Surg* 68b:528-533, 1986.

A retrospective review was performed on 39 patients treated surgically for hip subluxation or dislocation secondary to poliomyelitis. The average age at surgery was 13.4 years, and the average followup was 9.3 years (2-22 years). Procedures performed included muscle transfers, femoral osteotomies, and pelvic osteotomies. Fifty-four percent had more than one of these procedures. The results were good (stable, pain free, > 75% coverage) in 46%, satisfactory (stable, pain free, coverage < 75%) in 24%, and unsatisfactory (unstable and painful) in 30%. Muscle imbalance was identified in 17.5% of those with a good outcome, bersus 45.5% of those with a poor outcome. In patients with flaccidity, the hip could often be reduced with traction and abduction. The etiology of hip instability was either muscle imbalance (flexors/adductors stronger than extensors/abductors) or pelvic obliquity (suprapelvic or infrapelvic). In patients with muscle imbalance, the Mustard procedure decreased the deforming force (flexion) and improved abduction strength by one grade, however an abductor lurch often persisted. This transfer may potentially prevent bony changes if performed early, and should be performed in concert with procedures to restore normal bony anatomy. Femoral osteotomies should address both the abnormal neck-shaft angle and femoral anterversion. If present, acetabular deficiency is usually posterior. There was a poor correlation between the type of pelvic osteotomy and the final results, probably because many of these improved anterior and lateral coverage when the deficiency was posterior. The authors did perform a "posterior acetabuloplasty" similar to a Pemberton osteotomy in a single patient. Hip arthrodesis should be reserved for salvage.

Lee DY, Choi IH, Chung CY, et al. Fixed pelvic obliquity after poliomyelitis. Classification and management. *J Bone Joint Surg* 79b:190-196, 1997.

Fifty-five patients with pelvic obliquity secondary to polio were classified into two major types based upon the relationship between pelvic obliquity and the shorter extremity. Each major type is then divided into 4 subtypes. In Type I deformities, the pelvis is lower on the side of the short leg, while in Type II deformities the pelvis is lower on the side of the long leg. Subtype A was associated with a straight spine, and lumbar compensation mainly at the L4-L5 level. Subtype B deformities had a mild, long scoliotic curve with the convexity towards the side of the short leg. In subtype C, there is a mild scoliotic curve with the convexity towards the long leg, while in subtype D there is a severe scoliosis associated with pelvic obliquity (convexity towards the short leg in Type I and towards the long leg in Type II). Subtypes A through C are caused by infrapelvic contractures, while subtype D is caused by suprapelvic contracture (scoliosis). Overall, 84% had Type I deformities. The authors also present treatment guidelines based upon this classification scheme. The first goal was to correct the lower extremity deformities (A,B,C), and the scoliosis improved spontaneously. In patients presenting with larger, uncompensated spinal deformities (D), treatment of the spinal deformity and associated pelvic obliquity was accomplished first. Procedures included lumbodorsal fasciotomy, abductor fasciotomy, and triple innominate osteotomy (+/- transiliac lengthening could also be accomplished). In type ID and II D, posterior spinal fusion was usually necessary. In these cases the lumbodorsal fasciotomy on the convexity improved curve correction, however abductor fasciotomy was not required. The lumbodorsal fasciotomy involved transverse sectioning of the lumbodorsal fascia from the spinous process of L5 to the iliac crest, and

release of the interspinous ligaments (L4-L5, L5-S1), the short rotator muscles from the transverse processes of L5 and S1, and the iliolumbar ligament. Skeletal traction was then employed for 3 weeks, followed by stretching exercises.

Lee DY, Choi IH, Chung CY, et al. Triple innominate osteotomy for hip stabilization and transiliac lengthening after poliomyelitis. *J Bone Joint Surg* 75b:858-864, 1993.

62 unstable hips in patients 12-35 years of age underwent a triple innominate osteotomy and were followed for an average of 4 years. Soft tissue procedures were performed prior to bony hip reconstruction, and included release of the lumbodorsal fascia and of hip abduction or adduction contractures. Iliopsoas transfer (Mustard) was performed in 6 cases to enhance abductor function, either at the same time or later. Iliopsoas tenotomy was performed in dislocated hips to facilitate reduction, and in those with significant flexion contracture. The osteotomy was modified if leg lengthening was needed, as up to 3 centimeters in length could be gained by transiliac lengthening. The osteotomy was distracted anteriorly and posteriorly, and a trapezoidal bone graft was inserted. Femoral lengthening occasionally required later. Overall, 95.2% had a significant improvement in hip stability, based upon a classification scheme developed by the authors. In patients treated for coexisting shortening, the mean gain in length was 1.7 centimeters (0.6-3.0 cm.), and 33% did not require any additional lengthening. Abductor strength was improved in 30%. Complications included femoral nerve palsies (recovered within 15 months) in 3 patients having concomitant iliopsoas transfer. Additionally, there was 1 soft tissue infection and 1 case of progressive arthritis.

Legg AT. Transplantation of tensor fasciae femoris in cases of weakened gluteus medius. *JAMA* 80:242-244, 1923.

The author describes transfer of the tensor fascia lata to the lateral aspect of the femur to treat abductor insufficiency. The fascia is incised from the anterior superior iliac spine down to a point 3 inches below the greater trochanter, and then extended posteriorly. At this point the tensor muscle has blended in with the fascia lata. A periostial flap is elevated 2.5 inches below the greater trochanter, and the free end of the elevated muscle is sutured into a trough in the bone. The periostial flap is then sutured over the transfer.

Mustard WT. Iliopsoas transfer for weakness of the hip abductors. *J Bone Joint Surg* 34a:647-650, 1952.

The author describes transfer of the iliopsoas for treatment of abductor insufficiency, which is commonly associated with an external rotation deformity of the involved extremity. Prerequisites include normal function of the gluteus maximus and sartorius, and a functional rectus femoris isalso desirable. The iliopsoas is removed with a fragment of the lesser trochanter, and transferred through a notch in the pelvis between the anterior superior and the anterior inferior iliac spines. The muscle is then attached to the lateral shaft of the femur below the greater trochanter. With adequate patient selection and proper technique, improvement was seen in abductor insufficiency.

Mustard WT. A follow-up study of iliopsoas transfer for hip instability. *J Bone Joint Surg* 41b: 289-298, 1959.

Fifty patients with polio and weakness of the hip abductors underwent iliopsoas transfer. The ideal patient has isolated weakness of the abductors, and has normal function in the abdominal muscles, sartorius, psoas, quadriceps, and glutus maximus. Through an anterior approach, the interval in between the sartorius and tensor fascia lata is exposed. The anterior superior iliac spine is osteotomized, and the sartorius reflected. The iliac crest is subperiostially exposed, and the iliopsoas muscle is mobilized after identification and protection of the femoral nerve. The lesser trochanter is released with an osteotome. After a trough is cut in the ilium, the muscle is passed through the trough and then a split in the abductors. The transfer is placed into a trough in the lateral femur, with the hip in abduction to provide adequate tension. The patient is immobilized in a hip spica. The hip is maintained in maximal abduction, mild hip flexion, and medial rotation. The cast is removed after 6 weeks, and active exercises are begun. When adequate strnegth in abduction is achieved, weightbearing is begun. Patients typically use crutches for 6 months. At followup most

patients experienced less fatigue, and an increase in walking distance. The abductor lurch was also improved in a significant number of patients. Two patients developed quadriceps weakness, most likely from traction on the femoral nerve.

Parsons DW, Seddon HJ. The results of operations for disorders of the hip caused by poliomyelitis. *J Bone Joint Surg* 50b:273, 1968.

The results following treatment of 111 hips (85 patients) are reviewed. For contractures, the authors found no obvious correlation between muscle balance and deformity, suggesting the importance of postural mechanisms of deformity. For flexion and abduction deformities, the Soutter procedure worked well as long as an anterior capsulotomy was performed if needed. No postoperative instability was identified in those undergoing capsulotomy. The authors recommend femoral osteotomy for severe deformities (especially if shortening is advantageous to relax the neurovascular structures), or as a supplement to soft tissue release. For hip subluxation, both femoral varus osteotomies and pelvic osteotomies were unsuccessful. The authors suggest that an acetabular procedure combined with an iliopsoas transfer should be considered. Iliopsoas transfer was successful in treating abductor insufficiency.

Soutter R. A new operation for hip contractures in poliomyelitis. *Boston Med Surg J* 170:380-381, 1914.

The author describes a technique for managing flexion and abduction contractures at the hip. A longitudinal incision is made 2 inches posterior to the anterior superior iliac spine, and the fascia is released from the anterior spine back towards the greater trochanter. Then, subperiostial release of all structures off the region of the anterior spine is performed. The patient is placed in a spica cast with the hips in extension.

Thomas LI, Thompson TC, Straub LR. Transplantation of the external oblique muscle for abductor paralysis. *J Bone Joint Surg* 32a: 207-225, 1950.

The external oblique muscle often hypertrophies in the prescence of weakness of the hip abductors. Transfer of the distal aponeurosis of this muscle was developed to improve abductor strength, global balance, and walking endurance. A long oblique incision is made parallel to the iliac crest, and two parallel incisions are made in the aponeurosis of the external oblique muscle. These are joined about one centimeter from the pubis, and the muscle belly is mobilized back to it's origin on the ribs. A lateral incision is made over the greater trochanter, and the external oblique is passed through a subcutaneous tunnel. The transfer is then passed through drill holes in the greater trochanter and sutured back to itself with the hip in maximum abduction. A spica cast is worn for 4 weeks, and then abduction exercises are begun. Weightbearing is permitted 8 weeks after the procedure. The transfer may be augmented by the tensor fascia femoris, or by rotating the superior portion of the gluteus maximus forward, if these muscles are strong. If the gluteus maximus is also weak, then the sacrospinalis and tensor fascia lata may be transferred to augment abduction. Twenty-seven cases were reviewed, and all but 2 were unilateral. All patients demonstrated an improvement in strength, although the abductor lurch was improved but not eliminated. Nineteen cases were graded, and 3 were excellent. Eight patients had a good result (abduction against gravity), while 6 had a fair result. Patients reported an improvement in gait, and had a greater sense of security while ambulating.

VIID. Knee/Leg

Asirvatham R, Rooney RJ, Watts HG. Proximal tibial medial rotation osteotomy to correct knee flexion contracture and lateral rotation deformity of tibia after polio. *J Pediatr Ortho* 11:646-651, 1991.

Lateral rotation deformity of the tibia may accompany flexion deformity at the knee in polio. The authors review the results of proximal tibial osteotomy (extension and medial rotation) in seventeen extremities. The mean age was 12.6 years, and the mean flexion contracture was 17.7°°. Most of these patients required additional procedures such as extraarticular subtalar arthrodesis, tendoachilles tenodesis to the fibula, tendon transfers/lengthenings, and Yount fasciotomies. Both biplane and step-cut osteotomies were performed (staple fixation), and the goal was to achieve 5-10°° hyperextension. Clinically, 10/16 patients improved their ambulatory status, and 4/8 who wore a brace

were able to discontinue racing. Four patients were relieved of a hand-thrust gait. However, complications were frequent. Five patients developed recurrence of flexion deformity (20-30°°), and four of these were less than 10 years of age at the time of the initial procedure. Nonprogressive genu recurvatum (> 20°°) was observed in 5 patients. Although most patients benefitted from the procedure, the authors recommend abandoning this technique given the prevalence of complications.

Caldwell GD. Transplantation of the biceps femoris to the patella by the medial route in poliomyelitic quadriceps paralysis. *J Bone Joint Surg* 37a:347-360, 1955.

52 patients were treated for quadriceps paralysis by medial transfer of the biceps femoris (33), lateral transplantation of the biceps femoris (13), or transfer of both the biceps femoris and the semitendinosus (6). Followup for the medial transfers was 7 years, for the lateral tansfers was 8 years 6 months, and for the combined transfers was 4 years 6 months. A good result was achieved if the knee was stable under normal activity, and fair if the knee gave way occasionally. Overall, 60-70% had a good result with each of these techniques, however 61% of those treated by lateral transfer alone had patellar subluxation at followup, versus 33% of the combined transfers, and none of the medial transfers. Recurvatum developed in 5% of medial, 17% of lateral, and none of the combined procedures. A strong gasctocsoleus and gluteus maximus is advantageous but not a prerequisite. Ofthe medial transfers, poor results were observed in 15% because of infection, rupture of one repair during therapy, recurvatum in the setting of a strong gastrocsoleus, and in a single case in which the preoperative quadriceps strength was trace. The technique of medial transfer is described, and involves first detaching the insertion of the biceps femoris, and mobilizing the muscle proximally. The linea aspera must be rellease for a sufficient distance to enable transfer of the muscle behind the femur. The tendon is passed posteriorly and medially around the femur, and is brought out between the rectus femoris and the vastus medialis. It is then sewn into a longitudinal tunnel in the patella with the knee in full extension, and also secured into a split in the quadriceps tendon. A long leg cast is applied for 4 weeks, and then active range of motion exercises are begun. A posterior splint is employed for an additional 4 weeks, and then patients are allowed to extend the knee against gravity and to begin weight bearing.

Celebi G, Kurt R, Lok V, et al. Prevention of neurovascular complications in extension osteotomy of the tibia in poliomyelitis. *International Orthopaedics (SICOT)*15:29-30, 1991.

Nine patients undergoing an extension osteotomy of the proximal tibia for flexion contracture had blood flow monitored by Doppler sonography before, during, and after the procedure. Measurements were obtained at progressive degrees of knee extension, and a correlation was established between the degree of extension and a decrease in blood flow. Given the risk of decreased perfusion with acute correction, the authors recommend gradual correction using a hinged plaster cast postoperatively.

Connor AN. The treatment of flexion contractures of the knee in poliomyelitis. *J Bone Joint Surg* 52b:138-144, 1970.

Nineteen patients with flexion contractures from 30-90°° were treated by serial casting, with or without release of the hamstrings and iliotibial band. Cast wedging or longitudinal traction may result in subluxation, and a technique for manipulation is suggested to avoid this complication. One hand pulls the tibial plateau anteriorly and distally, while the other exerts proximal and posterior pressure on the anterior distal femur. This effectively translates the plateau anteriorly during the correction, and avoids subluxation or dislocation. In patients less than 15 years of age, 10/11 achieved correction with maintenance of articular congruity. Supracondylar osteotomy or arthrodesis was recommended in patients greater than 15 years of age.

Crego CH, Fischer FJ. Transplantation of the biceps femoris for the relief of quadriceps femoris paralysis in residual poliomyelitis. *J Bone Joint Surg* 12a:515-529, 1931.

Sixty-three cases of biceps femoris transfer to the quadriceps mechanism are reviewed. The procedure is indicated in patients with strong hip and calf muscles, and coexisting deformities

should be corrected prior to muscle transfer. A strong gasctroc-soleus complex should maintain posterior knee stability after loss of the stabilizing force of the biceps. Patellar subluxation may occur postoperatively in the setting of genu valgum. The operative technique is described in 3 stages. A longitudinal incision is made over the patella, and the fibrous membrane overlying the patella is incised and reflected. A bony trough is prepared in the anterior surface of the patella. The biceps femoris and popliteal nerve are exposed through a lateral incision, and the insertion of the tendon is released along with a segment of the head of the fibula. The tendon is mobilized proximally and then transferred through a subcutaneous tunnel. The iliotibial band, fascia over the vastus lateralis, and the intermuscular septum are all released. The transfer is secured into the trough in the patella with both the hip and the knee in full extension, and the fibrous membrane is then sutured over the tendon to prevent adherence to the overlying skin. The patient is placed in a long leg cast, which is converted to a drop-out cast after 2 weeks to facilitate early rehabilitation. Physical therapy is crucial, and the patient must be trained to use this out of phase transfer. The most common complication was genu recurvatum (5 cases), which may be secondary to either a tight tendoachilles or insufficient posterior support for the knee (weak gastrocsoleus). A brace is required for treatment. Patellar subluxation (2 cases), was treated by medial transfer of the tibial tubercle. Excellent or good results were seen in 52/61 cases, and only one failure was observed.

El Maadawy, A. Correction of old standing fixed flexion deformity of the knee in poliomyelitis by soft tissue operation followed by gradual plaster wedging. *Central Afr J Med* 40:18-20, 1994.

Thirty knee flexion contractures (mean 100°°) in patients 10-24 years of age were managed by a posterior release followed by gradual correction by cast wedging. The posterior release included the iliotibial band, intermuscular septum, and the posterior capsule, while Z-plasty was performed to lengthen the biceps, gastrocnemius, semitendinosus, semimembranosus, and gracilis. Patients were placed in a long leg cast in 50% of the desired correction. Three weeks later the cast is replaced in about 10°° more extension, and the remainder of the correction is achieved by wedging the cast at intervals. Good results were observed in 93%, and complications included one case of stiffness, one case of genu recurvatum, and 10% had partail breakdown of the L-shaped skin incision. All patients were ambulatory with or without a caliper at followup.

Irwin CE. Genu recurvatum following poliomyelitis. A controlled method of operative correction. *JAMA* 120:277-280, 1942.

Two types of genu recurvatum deformity may be observed in patients with poliomyelitis. Hyperextension deformity with structural changes in the tibial condyles is assocated with quadriceps weakness. The hamstrings are of normal strength and are not attenuated, while the gastrocsoleus complex is strong and a tendoachilles contracture is often present. The plantarflexion/knee extension couple results in a posteriorly directed force at the knee. The condyles become elongated posteriorly, and a recurvatum deformity of the proximal tibia ensues. Subluxation of the knee may be observed. The second type is due to weakness of the hamstring and gastrocsoleus muscles, and a calcaneus or calcaneovalgus foot deformity is often seen as well. The posterior structures become elongated gradually, and no bony deformity is observed. The goal of surgery is to restore normal sagittal alignment, and to prevent recurrence by correcting the underlying problem. The prognosis is good for those deformities associated with osseous changes. The surgical approach includes proximal tibial osteotomy for deformity correction, and hamstring transfer to prevent recurrence. The prognosis is poor for the second type, and a caliper or KAFO is usually required. Correction of the deformity is usually followed by recurrence since there are no available muscles to transfer. A technique for proximal tibial osteotomy is described.

Irwin CE. The iliotibial band. Its role in producing deformity in poliomyelitis. *J Bone Joint Surg* 31:141-146, 1949.

The fascia lata has a wide origin, extending from the sacrum and coccyx posteriorly, along the iliac crest, to the ligament of Poupart and the superior ramus of the pubis anteriorly. This structure has 2 layers which invest the gluteus maximus and the tensor fascia lata. Fibers from both of these muscles originate from the fascia lata. The iliotibial

band represents the lateral, thickened portion of the fascia lata. The iliotibial band has attachments to the intermuscular septum, and distally gives origin to the short head of the biceps. The distal insertion fans out, attaching to various structures at the lateral aspect of the knee, including the fibular head. Deformities associated with contracture of the iliotibial band include flexion/abduction contracture at the hip, flexion contracture at the knee, external rotation contracture of the thigh, genu valgum, and external tibial torsion. Associated deformities include pelvic obliquity, scoliosis, and lumbar hyperlordosis. Varus deformity of the foot may result from bracing within the setting of external tibial torsion. The author recommends a Yount fasciotomy, which is performed about 10 centimeters proximal to the knee joint. Two to three centimeters of the iliotibial band is excised, the intermuscular septum is divided down to the femur, and the fascia lata is released over the vastus lateralis. A spica cast may be applied, and additional correction may be achieved by wedging the cast.

Leong JCY, Alade CO, Fang D. Supracondylar femoral osteotomy for knee flexion contracture resulting from poliomyelitis. *J Bone Joint Surg* 64b:198-201, 1982.

Eighty-nine knees in 82 patients (8-25 years of age) with flexion contractures from 15-95 degrees were treated by supracondylar osteotomy of the femur. Indications for surgery included deformities that prevented ambulation or interefered with fitting of a caliper. A prerequisite was normal motor function (at least the triceps) in the upper limbs. The mean followup was 7 years and 2 months. The technique involved a distal release of the iliotibial band (Yount procedure), and an anteriorly based closing wedge osteotomy of the distal femur (2.5 centimeters proximal to the physis). The posterior cortex is left intact, which helps to control rotation, and obviates the need for internal fixation. The limb was immobilized in a long leg cast. Mild hyperextension is desirable. Seven patients who could not walk preoperatively were able to do so postoperatively, while 34/53 were able to discontinue the use of a caliper. All but one of those who ambulated with a hand-knee gait no longer needed to use this maneuver to walk. Complications included 6 infections, 2 peroneal palsies, and 2 cases of tibial subluxation. Those with subluxation had deformities of 60 and 90 degrees, and had a prior soft tissue release including posterior capsulotomy. Six cases had recurrence of deformity >5°°, and recurvatum >5°° in 10 patients. Care should be taken to avoid recurvatum > 5°°.

Mehta SN, Mukherjee AK. Flexion osteotomy of the femur for genu recurvatum after poliomyelitis. *J Bone Joint Surg* 73b:200-202, 1991.

Flexion osteotomy of the distal femur was performed in 33 limbs with a mean recurvatum of 31°°. Twelve limbs were flail while 7 had a quadriceps strength less than grade 3/5. Although ligamentous laxity was common, especially in cases with greater than 30°° recurvatum, all cases had femoral flattening. A vertical quadriceps splitting incision was used in the limb was flail, however if the quadriceps had function then a lateral approach was utilized. The femur was osteotomized with care to leave the posterior cortex, and then the deformity was corrected by osteoclasis after ten days (goal of 5°° recurvatum). All but one patient had an excellent result, and there were no complications. Three of twelve with flail limbs were able to walk brace free, while 5/7 with a weak quadriceps and normal hamstrings were able to ambulate without external support. Remodelling of the articular surfaces was observed in a significant number of cases.

Men HX, Bian CH, Yang CD, et al. Surgical treatment of the flail knee after poliomyelitis. *J Bone Joint Surg* 73b:195-199, 1991.

This review concerns 281 flail knees in 228 patients managed by soft tissue release, distal femoral extension osteotomy, and a patellar bone block, either alone or in combination. Nearly all patients were less than 25 years old, and none had a quadriceps strength greater than grade 2. Patients were evaluated with a functional index based upon walking ability, with a followup of greater than 8 years. Three specific scenarios are outlined, along with the approach to treatment and the outcome. Type I patients (228) had a fixed flexion deformity at the knee. Those less than 25°° were treated by extension osteotomy, while patients with 25-60°° loss of extension underwent soft tissue release followed by extension osteotomy. If the deformity was greater than 60°°, a soft tissue release was followed by serial casting, and when the deformity

was corrected to 25°° an extension osteotomy was performed. The osteotomy was used to obtain partial correction initially, and then the cast was wedged 2 weeks later to complete the correction. The recommended soft tissue release includes a release of the iliotibial band, z-lengthening of the biceps, and both the semimembranosus and semitendinosus. Two incisions were utilized. A dome osteotomy was performed 5 centimeters proximal to the supracondylar flare. The goal is to obtain 5-10°° of recurvatum. Type II deformities include knees with hyperextension that are painful and/or unstable. In this situation, patellectomy is performed, and both the articular cartilage and anterior cortex are removed from the upper half of the patella. The front of the intercondylar region is cleared (between the menisci), and a transverse slot is fashioned in the proximal tibia. The upper portion of the patella is impacted into this space, such that 5°° of hyperextension of the knee is permitted when the knee is extended. The patella is fixed with 2 screws. In Type III deformities there is a mild degree of hyperextension at the knee, and pain was commonly observed. In this case, a combination of an extension osteotomy and a patellar bone block are employed. Overall, 80% of patients had an excellent result, indicated by an improvement of 2 grades, or a grade 4 (can walk with one hand on the thigh) or grade 5 (can walk independently with or without a mild limp). Less than 5% had an increase in hyperextension due to stretching of the posterior structures or changes in the bone block.

Patterson BM, Insall JN. Surgical management of gonarthrosis in patients with poliomyelitis. *J Arthroplasty* 7:419-426, 1992.

Nine patients with knee arthritis associated with polio were treated by a cemented total knee arthroplasty and followed for 6.8 years. Unique features in this population include lower extremity weakness, genu recurvatum, and varus/valgus instability. The average knee score (HSS scale) was 70. Three patients required revision (1 infection, 2 painful loosening), and a more constrained implant was utilized. Although pain was reliably improved, the functional status of several of the patients continued to decline, the etiology of which was unclear. Technical difficulties in these patients surround soft tissue balancing, and consideration should be given to a more constrained system at the primary procedure. Although the risk of excessive stress transmission and subsequent loosening remain a concern, this population tends to have a low-demand lifestyle. Recurvatum deformity creates a technical challenge, and the authors recommend a distal femoral resection that results in an extension gap that is 2-3 millimeters less than the flexion gap. A constrained condylar femoral component with an intramedullary stem is recommended. For the tibial component, either a posteriorly stabilized insert or a more constrained condylar knee design may be used. Weightbearing radiographs help to determine whether augmentation will be required. In addition, patients with weak quadriceps preoperatively may develop buckling of the knee postoperatively secondary to the mild flexion contracture that is common after total knee arthroplasty. A brace may be required in such cases.

Perry J, O'Brien JP, Hodgson AR. Triple tenodesis of the knee. A soft-tissue operation for the correction of paralytic genu recurvatum. *J Bone Joint Surg* 58a:978-985, 1976.

The triple tenodesis procedure may be used in cases of paralytic genu recurvatum with primary posterior soft tissue laxity and secondary bony changes. The mechanism may involve walking with the ankle in fixed equinus in the prescence of quadriceps paralysis, and the natural history involves progression with the development of knee pain. If the deformity is less than 30°°, bracing with the knee in flexion may prevent progression. The authors describe a three-layered reconstruction of the posterior structures of the knee joint. The concept is similar to the Westin procedure (tenodesis of the achilles tendon to the fibula). The posterior soft tissues must be able to withstand weightbearing forces, and protection with a brace for one year is recommended to enable the tissues to mature. In order to prevent recurrence, any equinus contracture of the ankle should be corrected, and weakness or paralysis of the gastrocsoleus complex must be corrected by tendon transfer, tenodesis, or arthrodesis. The technique is reported in 14 patients with an average age of 10 years and 4 months, and the average deformity was 42°°. Followup

averaged 51 months. In addition to soft tissue laxity, flattening of the anterior portions of both the femoral and tibial epiphyses was observed. Additional procedures were required in 11 limbs. The procedure involves three parts, and is performed in the prone position with the knee flexed 20°° (sandbag under the lower leg). First, through a s-shaped incision, the neurovascular bundle is protected and the medial head of the gastrocnemius is reflected. A large flap involving 80% of the width of the posterior capsule is elevated. The tendons of the gracilis and semitendinosus are released at the musculotendinous junction. And their proximal ends are sutured to the tendon of the sartorius. Two drill holes are then made. The first is in the tibia, from the midline posteriorly to the region of the pes anserine anteriorly. The femoral drill hole goes from the midline posteriorly to the lateral aspect of the distal femur. The physes are avoided. The gracilis and semitendinosus are passed through the tibial drill holes across the posterior kne and into the femoral drill holes. They are then sutured to the periostium on the lateral aspect of the distal femur. The posterior capsule is then advanced and sutured to the periostium. The last protion of the procedure involves the lateral structure. The biceps femoris is detached distally, as is the anterior portion of the iliotibial band. The biceps is sutured to the femoral origin of the gastrocnemius, while the iliotibial band is secured to the semimembranosis insertion on the tibia. If any of the tendons are associated with an active muscle, then they are split with one half left to the normal site of insertion. A long leg cast is applied in 30°° flexion at the knee, and after 6 weeks the extremity is placed into a long leg brace with the knee locked at 15°° flexion. The limb is splinted at night as well. All patients develop a knee flexion contracture using this protocol, which is desirable to protect the reconstruction. Patients are readmitted 12 months following the initial procedure, and extension is restored through serial casting, with a goal of several degrees of hyperextension. At followup, the average recurvatum was 6°°, and all but one patient was able to ambulate without a brace.

Schwartzmann JR, Crego CH, Jr. Hamstring-tendon transplantation for the relief of quadriceps femoris paralysis in residual poliomyelitis. A follow-up study of 134 cases. *J Bone Joint Surg* 30a:541-559, 1948.

This is a followup study to Crego et al (JBJS 1931) concerning the outcome of biceps transfer for weakness or paralysis of the quadriceps. As the length of followup increased, the authors experienced patellar subluxation/dislocation with greater frequency (29%). These complications were managed by medial transfer of the tibial tubercle and transfer of the semitendinosus forward. Based on these observations, the original procedure was modified to include routine transfer of both the biceps and the semitendinosus at the index procedure. Satisfactory results were seen in 87% when both tendons were transferred, in contrast to 56% for the biceps alone (followup 1-22 years). An additional posteromedial incision is required to mobilize the semitendinosus, after distal release of the tendon (extension of the anterior longitudinal incision). Additionally, the authors conclude that "fair or better" strength in the hip extensors and gastrocsoleus complex is not an absolute requirement for success, although greater strength is desirable. Fixed deformities should be corrected prior to transfer, and compliance with the rehabilitation protocol is essential. Recurvatum was observed in 23%, however only 4% resulted in treatment failure. No cases of patellar subluxation were observed. Recurvatum was correlated with preoperative weakness in the gastrocsoleus, and bracing was used for salvage. For prevention, the authors recommend fair or better strength of the gastrocsoleus preoperatively, avoiding hyperextension in the postoperative cast, correcting any equinus deformity at the ankle preoperatively, avoiding postoperative braces which promote hyperextension, and adequate physical therapy postoperatively. Lateral instability of the knee was observed in 5% of isolated biceps transfers and 3% of combined transfers, and care should be taken not to damage the lateral collateral ligament when harvesting the biceps tendon.

Shahcheraghi GH, Javid M, Zeighami B. Hamstring tendon transfer for quadriceps femoris paralysis. *J Ped Orthop* 16:765-768, 1996.

Fifteen cases of quadriceps paralysis were treated by hamstring transfer, and reviewed at a mean followup of 4 years. In 13 cases, both the biceps femoris and the semitendinosus were transferred (attached to medial and lateral troughs in the patella). Patients were immobilized in a long leg

cast with the knee in 5-10°° flexion for 6 weeks, and partial weightbearing was allowed. Using a detailed clinical assessment, results were excellent in 13.5%, good in 73%, and fair in 13.5%. Thirteen of fifteen patients were satisfied. All patients were brace free, and none had a hand-knee gait pattern. Gait velocity and endurance improved in 73%, and 60% had an improvement in their ability to climb stairs. Preoperative findings associated with good or excellent results included a strong gluteus maximus and gastrocsoleus, or either one of these and a strong psoas. Problems included weakness in knee flexion postoperatively, and only 7 patients had full active flexion despite full passive flexion. This created difficulties with sitting on the floor, as these patients had to manually reposition the extremity for this activity.

Yount CC. The role of the tensor fascia femoris in certain deformities of the lower extremities. *J Bone Joint Surg* 171-193,

The most common hip deformity in polio is flexion and abduction, which often results from habitual positioning in patients with extensive paralysis who are maintained in a recumbent or sitting position, especially in the setting of weak adductors. The tensor fascia femoris muscle is usually spared in polio, which contributes to the deformity. On physical examination, the hips can usually be extended fully if maintained in an abducted position. With adduction, the limb is pulled into flexion at the hip. If a knee flexion deformity is also present, then the sartorius may also be involved. The iliopsoas is infrequently involved. Associated deformities include genu valgum, knee flexion contracture, and external tibial torsion. The biceps femoris may also be important in cases with external tibial torsion in association with a knee flexion contracture. Distal release of the iliotibial band is recommended, and division of the intermuscular septum down to the shaft of the femur is an important component of this procedure. For patients with mild contracture, fasciotomy alone may be successful, while those greater than 6 years of age with all three deformities present should be treated by the more extensive release involving the iliotibial band, intermuscular septum, and fascia over the vastus lateralis. Lengthening of the biceps femoris may also be performed. The site of release is one centimeter proximal to the superior pole of the patella. For more resistent deformities, one or more percutaneous releases of the iliotibial band may be performed more proximally in the thigh, and this may shorten the period of postoperative stretching required.

V. Leg Length Discrepancy

Barry K, McManus F, O'Brien T. Leg lengthening by the transiliac method. *J Bone Joint Surg* 74b:275-278,1992.

Transiliac lengthening can gain up to 3 centimeters in length and is presented as an alternative to other techniques of limb lengthening. The limiting factors are cartilage necrosis, avascular necrosis, sacroiliac subluxation, and meurapraxia. 23 patients (mean age 14 years) with various diagnoses were treated, and the mean followup was 30 months. The technique is a modification of the Salter innominate osteotomy. For pure lengthening, a rectangular graft is inserted after distraction is accomplished with a lamina spreader. To achieve both length and redirection of the acetabulum for coexisting dysplasia, a trapeziodal graft may be inserted. An iliopsoas tenotomy is routinely performed as well. Younger patients are immobilized in a spica cast for 6 weeks, while older patients may be mobilized with crutches (nonweightbearing) and begin a early range of motion program. An average of 2.8 centimeters of lengthening was achieved (2.0-3.5 cm.), and the lengthening was sufficient in all but 6 cases. The only permanent complication was a femoral nerve palsy in a patient with coexisting congenital scoliosis. Other minor complications included 2 superficial wound infections and a transient femoral nerve palsy. Distal and lateral transfer of the greater trochanter was also performed in severl patients.

Lee DY, Choi IH, Chung CY, et al. A modified Wagner technique for femoral lengthening in skeletally mature patients with poliomyelitis. *International Orthopaedics (SICOT)* 17:154-157, 1993.

62 skeletally mature patients were treated by femoral lengthening for a mean discrepancy of 4.4 centimeters with a modification of the Wagner technique. Coexisting limb deformities were corrected prior to lengthening, and procedures included soft tissue releases, tendon transfers,

femoral osteotomies, triple arthrodesis, and triple osteotomy of the pelvis. The rationale for the Wagner approach was that there would be less time in the fixator, which might result in a decrease in muscle weakness, osteopenia, joint stiffness, and pin tract infections. The mean age was 26 years, and followup was at least one year. An Orthofix device with 2 pins above and 2 pins below was employed, and lengthening was started after 5-7 days at a rate of 1.5 mm/day. Range of motion exercises were started after 1 week. The second stage involved placement of an iliac crest graft (corticocancellous) and plating. After 2 weeks patients are placed in a long legbrace with a thigh corset. Lengthening from 2.4 to 7.0 centimeters was achieved (mean 4.2 centimeters). Complications included pin tract infections (8), superficial wound infection following the second stage (2), and loss of motion (8). The mean loss of knee motion was 12°°. Two patients required an osteotomy for angular malunion, and delayed union occured in 2 patients (required revision fixation). Two patients had a fracture during rehabilitation. The authors conclude that early removal of the fixator is desirable when using the Wagner technique.

Macnicol MF, Catto AM. Twenty-year review of tibial lengthening for poliomyelitis. *J Bone Joint Surg* 64b:607-611, 1982.

Twenty-four patients with a predicted discrepancy was greater than 4 centimeters, were treated by tibial lengthening. The procedure was performed at a mean of 12 years of age, and the followup was 21 years. A two-stage lengthening was performed. First, a distal tibio-fibular synostosis was created to protect the ankle from a progressive valgus deformity. The second stage involved a tibial osteotomy, and the patient was placed in an Abbott frame with 2 Steinmann pins above and 2 pins below the osteotomy site. An initial distraction of 5 millimeters was applied in the operating room, and lengthening was started 2-3 days later at a rate of 1.5 mm/day. After the appropriate length was obtained, the patient was maintained in the frame for several more weeks to allow for consolidation. They were then placed into a long leg cast incorporating the pins, and no weight bearing was allowed. After 2 months, if consolidation had occured, patients were placed in an ischial-bearing caliper. All patients healed without malalignment, and the mean length gained was 5.5 centimeters (4.0-8.5 cm.). A host of other bony and/or soft tissue procedures were required in this population either before or after the lengthening. Fourteen of the 24 required a lower extremity brace at followup, and 14 had cold intolerance. Mild pain was experienced in the ankle (2), the knee (2), and the hip (1). The long term function at the knee and the ankle did not deteriorate, althugh valgus deformity at the knee was seen in 25% of patients. Instability did not occur as a consequence of the lengthening. Subjectively, only 1 patient was dissatisfied with the results.

Millis MB, Hall JE. Transiliac lengthening of the lower extremity. A modified innominate osteotomy for the treatment of postural imbalance. *J Bone Joint Surg* 61a:1182-1194, 1979.

"Postural imbalance" associated with pelvic obliquity may be due to suprapelvic (decompensated scoliosis), intrapelvic (hemisacral agenesis, iliac hemihypertrophy, or congenital wedging of the first sacral vertebra), or infrapelvic (limb shortening due to polio, other causes) pathology. The authors employed transiliac lengthening in 20 cases and discuss the indications and results. The Salter innominate osteotomy is modified by inserting either a rectangular or trapezoidal graft, which lengthens the hemipelvis and may also improve coverage in cases of coexisting hip dysplasia. An iliopsoas tenotomy is performed, and the osteotomy is distracted with a laminar spreader while traction on the extremity is maintained (with distally directed pressure on the iliac crest) until the graft is secured in place. If traction is not maintained, then proximal migration of the proximal fragment may occur, by motion throuh the sacroiliac joint. Up to 3 centimeters of lengthening can be achieved in an adult. Two threaded Steinmann pins are used to secure the graft. These are inserted through the proximal fragment in a posterior and inferior direction, and go through the graft an into the ischium behind the hip. The patient is then placed on bedrest in balanced suspension traction (2 - 4.5 kg. longitudinal traction), and exercises are started. Twenty patients from 5-25 years of age were treated, with a variety of primary diagnoses. An average of 2.3 centimeters of lengthening was achieved (1.6 - 3.0 cm.), and a balanced stance waas achieved in 75%. The remainder required a shoe

lift. Complications included 3 wound infections, one loss of lengthening due to bone graft settling, and one femoral neck fracture in a patient with polio who fell. One patient had a partial sciatic nerve palsy that resolved following reoperation with trimming of the bone graft. The authors recommend this technique for selected patients with a non-fixed pelvic obliquity, including those with acetabular dysplasia and ipsilateral shortening of the limb, pure leg length discrepancy, and scoliosis with lateral trunk shift.

VIIE. Foot/Ankle

Asirvatham R, Watts HG, Gillies H. Extensor hallucis longus coaptation to tibialis anterior: A treatment for paralytic drop foot. *Foot Ankle* 14: 343-346, 1993.

Eight postpolio patients with paralysis of the tibialis anterior were treated by coaptation of the extensor hallucis longus (strength at least 4/5) to the tibialis anterior. A transverse incision was made over the anterior aspect of the ankle, and the two tendons were sutured together with each pulled to maximal tension with the foot at a neutral position. A short leg cast was worn for 6 weeks, and then the patients were allowed to ambulate without an orthosis (unless required for instability or deformity). Although the initial results demonstrated antigravity strength in dorsiflexion, at a mean followup of 7.8 years only 2 patients retained this motor function. In addition, 2 patients had recurrent dorsiflexion deformity of the great toe. The authors speculate that failures resulted from stretching out of the transfer over time, and that the results may have been improved by protecting the transfers with an ankle-foot orthosis for 6 months following the procedure. Additionally, they suggest that anchoring the tendon into the navicular may improve the fixation.

Asirvatham R, Watts HG, Rooney RJ. Tendoachilles tenodesis to the fibula: A retrospective study. *J Pediatr Ortho* 11:652-656, 1991.

The goals of tenodesis of the tendoachilles to the fibula are to improve calcaneocavus deformity, to stabilize the ankle, and to promote longitudinal growth of the distal fibula. The procedure was performed in 48 patients (52 limbs) with polio, and indications included limbs that were flail below the knee, had no muscles available for transfer, and required a brace for ambulation. Ideally, patients have a stable subtalar joint, neutral rotation of the tibia, and slight hyperextension at the knee. The tendon is transected 10 centimeters proximal to it's insertion, and sutured to the fibula while the ankle is in 10-15°° equinus. A T-shaped incision is made in the periostium, and the periostial flaps are sutured over the transfer. Alternatively, the tendon may be secured through a drill hole in the fibula, or may be split with one limb passed through the fibula and sutured back on the other. The tenodesis provides a checkrein on dorsiflexion, and improved stability at the knee. A short leg cast is worn for 6 weeks. The mean age at transfer was 10 years, and most patients had additional procedures performed to improve their ambulatory potential. The followup was 5.5 years. Ambulation was improved in 15 patients, and 4 were able to discontinue bracing. Forty percent of those with a stable subtalar joint improved their gait, in contrast to only 22% who had an unstable subtalar joint. The most common complication was excessive equinus (35% had > 25°°). This can be avoided by performing the procedure after 12 years of age. Equinus may be salvaged by lengthening of the tenodesis. Stretching of the tenodesis occured in 6 cases, and the repair pulled out in a single case. If the subtalar joint is unstable and hindfoot alignment is in valgus, the foot can dorsiflex at the midfoot. In these cases the subtalar joint should be stabilized prior to tenodesis.

Bernau A. Long-term results following Labrinudi arthrodesis. *J Bone Joint Surg* 59a:473-479, 1977.

Forty patients (50 feet) were treated by triple arthrodesis using the Lambrinudi technique at a mean age of 17.6 years, and followed up at a mean of 18.2 years after the procedure. A preoperative drawing (based upon a lateral radiograph in maximum plantarflexion) was used to determine the size and shape of wedges to be removed. A final angle of 100°° between the foot and the tibia (10°° equinus) is desirable, and in the case of knee instability or leg length discrepancy a slightly higher angle is preferable. An oblique incision is made from the medial aspect of the talonavicular joint across the dorsum to the below the lateral malleolus. Wedges are resected, and a slot is made in the base of the navicular into which the talar head will be

placed. Fixation is achieved with 3 Kirschner wires. The hindfoot should be in slight valgus, and the forefoot in mild abduction and pronation. An above knee cast is applied at 4-6 days following the procedure, and the K-wires are removed. After 6 weeks a short leg cast is applied, and is maintained until bony union. The results were graded as good or fair in 94% subjectively, and in 84% as graded by the surgeon. Better results were achieved in flexible deformities, and the age at surgery did not influence the results. All patients who wore below knee braces were brace free. Eleven patients had difficulty with shoewear because of shortening. Both ambulation and exercise tolerance were improved in all patients, and 37 returned to work. Complications included delayed healing and superficial infection in several cases, and 2 asymptomatic talonavicular pseudarthroses. Five patients had pain, which responded to shoe modifications. Two patients had symptomatic ankle arthritis, and were treated effectively by arthrodesis. Contraindications to the procedure include lateral ankle instability (as seen on a preoperative AP radiograph with the forefoot in supination), trophic skin changes, age less than 11 years, ankle arthritis, and severe knee instability.

Caldwell GD. Correction of paralytic drop foot by hemigastrosoleus transplant. *Clin Orthop Rel Res* :81-84, 19

Fourteen feet in 13 patients with drop foot were treated with hemigastrosoleus transfer, and the average followup was 22 months. A triple arthrodesis is performed first. One half of the tendon is detached distally and medially, and is mobilized proximally up to the middle of the muscle belly. The tendon is passed through a subcutaneous tunnel across the anteromedial ankle and sutured into a trough in the medial cuneiform. The limb is immobilized for 6 weeks, and then rehabilitation is started. Several lateral gastrocsoleus transplants were performed, but functioned only as a tenodesis. All 10 of the medial transfers could dorsiflex to neutral or above. The author speculates that the medial transfer has a more direct line of pull.

Carayon A, Bourrel P, Bourges M, et al. Dual transfer of the posterior tibial and flexor digitorum longus tendons for drop foot. Report of thirty-one cases. *J Bone Joint Surg* 49a:144-148, 1967.

Thirty-one patients with paralysis of the common peroneal nerve (leprosy or trauma) were managed by anterior transfer of both the tibialis posterior and the flexor digitorum longus. Both tendons are passed through the interosseous membrane, and the tibialis posterior is sutured into the tibialis anterior, while the flexor digitorum longus is transferred to the extensor hallucis longus and extensor digitorum longus tendons. These are sutured with the foot (and toes) in maximum dorsiflexion. Eleven of 31 had excellent results, with active dorsiflexion of $\geq 15°°$ and active plantarflexion of $\geq 30°°$. Good results were seen in 6 feet (dorsiflexion 5-10°°), and fair results in 2 feet (no active dorsiflexion but correction of foot drop), and poor in 3 (foot remains in plantarflexion). Most failures were due to loss of tension on the transfer. Three to six months of rehabilitation is needed to obtain the best results. A short leg cast was applied with the foot in dorsiflexion, and this was removed after 16 days.

Crego CH, McCarroll HR. Recurrent deformities in stabilized paralytic feet. A report of 1100 consecutive stabilizations in poliomyelitis. *J Bone Joint Surg* 20a:609-620, 1938.

In this large series of cases treated by triple arthrodesis, 212 recurrent deformities were observed (20%), and 7% of these warranted additional surgical intervention. Etiologic factors in all but 10 deformities included muscle imbalance, associated deformities within the extremity, or a young age (< 7 years) at the time of arthrodesis. Muscle imbalance was felt to be important in 73% of recurrent deformities, and half of these involved strong peroneal muscles in the setting of weak anterior or posterior tibial muscles. Treatment involves transfer of the peroneals and the tibialis posterior to the calcaneus, assuming that the toe extensors are of sufficient strength to enable dorsiflexion during swing phase. With paralysis of the toe extensors, the peroneals are transferred to the midtarsal region. If the gastrocsoleus is weak, then all muscles are transferred to the calcaneus, even in the abscence of sufficient strength in dorsiflexion. The tibialis anterior and/or tibialis posterior muscles were also responsible for a subset of deformities. For a varus deformity, the tibialis anterior is transferred laterally to the midline, and the tibialis posterior and the peronei are excised if the gastrocsoleus complex is

normal in strength. If this complex is weak, then the tibialis posterior and peronei maybe transferred (if adequate strength) to the calcaneus. For a varus deformity with a nonfunctional tibialis anterior, the tibialis posterior and peroneals are transferred to the calcaneus, with transfer of the EHL to the first metatarsal neck and interphalangeal arthrodesis. Transfer of the tibialis posterior to the midline on the dorsum of the foot was not found to function well. A calcaneus deformity is treated by transfer of the tibialis anterior, tibialis posterior, and the peronei to the calcaneus. If the toe extensors are functional, then the EHL is transferred to the first metatarsal neck and the interphalangeal joint of the great toe is fused. Associated deformities of the extremity include external tibial torsion (usually with varus feet) and genu valgum (with both varus and valgus feet). In these cases a tibial osteotomy is required to correct the angular or rotational deformities following stabilization of the foot.

El-Batouty MM, Aly El-S, El-Lakkany MR, et al. Triple arthrodesis for paralytic valgus- A modified technique. *J Bone Joint Surg* 70b:493, 1988.

Triple arthrodesis may be technically difficult through a lateral approach when treating valgus deformities, as a medially based wedge needs to be removed. The technique of lateral inlay grafting described by Williams and Menelaus addresses this difficulty. A modification of the Williams and Menelaus technique is suggested, in which a pin is inserted through the calcaneus into the talus to stabilize the hindfoot in neutral while the trough for the inlay graft is cut. This helps to avoid overcorrection into varus. Fixation is with staples, and K-wires are not placed across the midtarsal joints. The technique was successful in 17 of 18 cases at 22 months followup.

Faraj AA. Review of Elmslie's triple arthrodesis for post-polio pes calcaneovalgus deformity. *Foot Ankle* 34:319-321, 1995.

Twelve patients with calcaneovalgus deformities (16 years old) were treated by triple arthrodesis and followed for 2-4 years. Preoperative symptoms included difficulties with shoe wear, calcaneus gait, and cosmetic concerns. The Elmslie technique involves 2 stages. The first stage is performed through a medial and a lateral incision, and the talonavicular joint and the calcaneocuboid joints are resected (dorsal wedges) and fixed with staples, correcting the cavus component of the deformity. The second stage is performed 6 weeks later, and involves a posteriorly based wedge resection of the subtalar joint through a longitudinal incision just medial to the tendoachilles. The patient is placed in a cast with the foot plantarflexed 20°° for 6 additional weeks. Three cases of dynamic calcaneus deformity were treated by transfer of one or both peroneal tendons to the insertion of the tendoachilles. Prior to transfer, an attempt to reduce the subtalar joint by gradual manipulation using a Steinmann pin inserted into the calcaneus. The results were good in those treated by arthrodesis, however all 3 patients treated by tendon transfer for dynamic deformity failed.

Fernandez-Palazzi F, Medina JR, Marcano N. Transfer of half the calcaneal tendon to the dorsum of the foot for paralytic equinus deformity. *International Orthopaedics (SICOT)* 12:57-59, 1988.

Eighty-eight patients (mean 8 years 6 months) with equinus deformity (68 cerebral palsy, 19 postpolio) were treated by transfer of one-half of the tendoachilles through the interosseous membrane to the middle cuneiform. Indications included the ability to walk without an orthosis, a strong gastrocsoleus complex, and the abscence of bony deformity. At a mean followup of 1 year and 9 months, 87% of those with cerebral palsy had an excellent or good result, however in the polio population 87% had fair or poor results.

Srinivasan H, Mukherjee SM, Subramaniam RA. Two-tailed transfer of tibialis posterior for correction of drop-foot in leprosy. *J Bone Joint Surg* 50b:623-628, 1968.

39 limbs with drop foot in 33 patients (14-53 years) underwent transfer of the tibialis posterior with an average followup of 12 months. The tendon is split into 2 limbs, both of which are transferred anteriorly through the interosseous membrane. Two incisions are made over the dorsum of the foot, the medial of which is made over the extensor

hallucis longus tendon, and the lateral incision is made over the tendons of the extensor digitorum longus. The two limbs of the transfer are pulled through subcutaneous tunnels and sutured into the extensor hallucis longus, and the extensor digitorum longus or peroneus tertius, with the foot in 10°° of dorsiflexion. A short leg cast is worn for a total of 6 weeks, and after 3 weeks the cast is bivalved to facilitate rehabilitation. A lengthening of the tendoachilles was often required as well. At followup 22 patients could dorsiflex the foot above neutral, and 12 had dorsiflexion just to the neutral position. Fifteen patients had an active range of motion of greater than 25°°. Failure was observed in 5 cases, due to infection, tendoachilles contracture, and inadequate rehabilitation.

Waugh TR, Wagner J, Stitchfield FE. An evaluation of pantalar arthrodesis. A follow-up study of one hundred and sixteen operations. *J Bone Joint Surg* 47a:1315-1322, 1965.

The authors review 116 pantalar arthrodeses (patients 7-56 years of age) followed for an mean of 5 years. A subset of cases had polio. Most patients had a single stage procedure through either an anterolateral or a Kocher incision. Most patients had either screws or staples implanted. The median duration of immobilization was 14 weeks (11-45 weeks), and of those followed for a minimum of 2 years, the pseudarthrosis rate was 14.7%. Most pseudarthroses occurred at the ankle joint, and all but 2 had internal fixation. Approximately 50% of those with pseudarthrosis had spasticity. A sliding anterior tibial graft was successful in most, although 3 patients required application of a Charnley compression device to achieve union. Wound complications were seen in 18.6%, while infection occurred in 5 patients, and all of these were managed conservatively. Wound problems were more common using the Kocher incision, which curves below the lateral malleolus. Patients retained some motion through the forefoot, and 20 patients had residual symptoms mostly due to malalignment. Varus or valgus of the forefoot may result in callosities or ulceration from the uneven pressure distribution. Excessive equinus results in metatarsalgia and callosities over the metatarsal heads. Forefoot malalignment was treated by revision in 6 cases. Despite the goal of 10-20 degrees plantarflexion, and the use of a goniometer intraoperatively, the authors found that the degree of plantarflexion was often greater at followup. Those who healed with less than or equal to 10°° of plantarflexion seemed to do the best. Genu recurvatum was an infrequent problem, and adding a heel lift to the shoe can often correct this. Nearly all patients who required a brace were able to discard this form of support following the procedure. The authors recommend fusion with the forefoot in neutral, the heel in neutral to slight valgus, and the ankle in < 10°° plantarflexion.

Westin GW, Dingeman RD, Gausewitz SH. The results of tenodesis of the tendo achilles to the fibula for paralytic pes calcaneus. *J Bone Joint Surg* 70a:320-328, 1988.

Sixty patients (66 limbs) with paralytic pes calcaneus were treated by tenodesis of the achilles tendon to the fibula. The average age was 9.1 years, and the followup was 5.7 years. Paralysis or weakness of the gastrocsoleus is generally responsible for the deformity, and the procedure is indicated when suitable muscles for transfer to the calcaneus are unavailable. Contraindications include a lack of adequate sensation. Clinically, patients lack push off power, and posterior subluxation at the ankle joint may be observed. The distal fibular physis may be proximal to the ankle joint, and is often at the level of the distal tibial physis. Goals of the procedure are to provide posterior stability to the ankle, to stimulate growth of the posterior calcaneus and the distal fibula (as well as hypertrophy of the fibula), to correct and prevent the development of ankle valgus, and to establish a more normal size to the foot. The tendoachilles should be sutured into the periostium of the distal fibula at a point 3-6 centimeters from the distal fibular physis. The tendon is sutured at neutral or slight equinus. An intraoperative lateral radiograph should demonstrate a calcaneotibial angle of 70°° or less. Immobilization in a long leg cast (knee flexed 45°°) is maintained for 6 weeks. Patients are then placed in a shoe with a wedge shaped heel to maintain plantarflexion. All patients improved radiographically, and with respect to ambulation and cosmesis. However, 38% did show some progressive equinus with time and 23% required lengthening of the tenodesis. Seven of fifteen

patients were able to discontinue bracing. The fibula increased in both circumference and length (82%), and valgus deformity was improved in 46%.

Williams P, Menelaus MB. Triple arthrodesis by inlay grafting. A method suitable for the underformed or valgus foot. J Bone Joint Surg 59b:333-336, 1977.

The authors present the technique of inlay grafting to address the the technical difficulties seen when performing a triple arthrodesis for a valgus foot through a lateral approach (a medially based wedge must be resected). Prerequisites include age > 12 years, a neutral or valgus hindfoot, and subtalar (rather than ankle) valgus. Muscle imbalance should be addressed at the same time. After anterolateral exposure and reflection of the extensor digitorum brevis, alignment may be stabilized with 2 Kirschner wires. An inlay graft is removed from the proximal tibia and impacted into a rectangular trough (across the talonavicular,calcaneocuboid, and talocalcaneal joints). The articular cartilage of the posterior subtalar facet is then removed, and the bone removed in fashioning the trough is placed into the defect. A cast is then applied, and the K-wires can then be removed. Lengthening of the tendoachilles was also performed in 4 feet. The results were acceptable in 70 patients. Nonunion of the midtarsal joint was observed in 3.5%, and in all cases the subtalar joint fused. Varus deformity was observed in a single patient.

VIIF. Spine

Eberle CF. Failure of fixation after segmental spinal instrumentation without arthrodesis in the management of paralytic scoliosis. *J Bone Joint Surg* 70a:696-703, 1988.

19 children (5-12 years old) were treated for progressive scoliosis by segmental instrumentation without fusion, with the goal of stabilizing the curve while allowing for additional spinal growth, and avoiding the need for an orthosis. Curves were typically flexible. Long "C" shaped curves were seen in nonambulatory patients, while a sharply angulated thoracolumbar curve was observed in ambulatory patients. The Luque technique was employed, and Galveston pelvic fixation was required in 7 patients. Eighteen gauge sublaminar wires were secured to ¼ inch rods. Followup was available on 16 patients at 30-36 months. This technique failed to control the deformity in 15 patients. Mechanisms of failure include rod fracture at the apex (6) and longitudinal rod migration (5), and loss of pelvic fixation (4). Upon rod removal, spontaneous fusion was commonly observed in the thoracic spine. The technique is not recommended based upon these results.

Leong JCY, Wilding K, Mok CK, et al. Surgical treatment of scoliosis following poliomyelitis. A review of one-hundred and ten cases. *J Bone Joint Surg* 63a:726-740, 1981.

Scoliosis in patients with polio may result from asymmetric muscle weakness, or from collapse of the spine due to weakness of the entire trunk. While the authors recommend bracing for deformities greater than 20°°, and surgery for curves greater than 40°°, most of their cases presented with greater degrees of deformity and no prior treatment. These curves tend to stay flexible for an extended period. Of their 110 cases, 58 had lumbar curves, 26 had thoracic curves, 8 had thoracolumbar curves, 14 had long c-shaped curves, and 4 had double major curves. Preoperative traction was helpful in stiffer curves (>80°°). The treatment evolved to both anterior and posterior procedures with instrumentation to maximize both curve correction and rates of union. For lumbar curves, the authors employed Dwyer instrumentation anteriorly and Harrington instrumentation posteriorly. Pelvic obliquity is a problem in this subset of curves, and in such cases the anterior implant was extended to L5 and the posterior fixation to the sacrum. The curve correction was between 64 and 96%, while pelvic obliquity was corrected 52-108%, depending upon curve magnitude and stiffness. Pseudarthrosis was observed in 7% using the combined approach. Thoracic curves were treated by either posterior spinal fusion (+/- Harrington implants) or anterior and posterior spinal fusion (+/- Dwyer and Harrington implants). The results suggested that these curves are best managed by posterior spinal fusion, factoring in the higher complication rate using the combined approach, although the pseudarthrosis rate was 25%. The long c-shaped curves were treated by either posterior fusion (+/- Harrington instrumentation) or anterior and posterior spinal fusion (+/- Dwyer and Harrington instrumentation). These patients

often have trunk imbalance and pelvic obliquity, and using the combined approach the correction was 57% in severe curves. Posterior instrumented fusion alone demonstrated inferior curve correction. The combined approach with anterior and posterior instrumentation was also better in correcting pelvic obliquity, and fusion should extend down to the sacrum. The pseudarthrosis rate was 12.5%, versus 50% for posterior fusion alone.

Luque ER. Segmental spinal instrumentation for correction of scoliosis. *Clin Orthop Rel Res* 163: 192-198, 1982.

The Luque technique is described, and the results presented in 65 patients (40 with poliomyelitis). Prior to placing implants, concave soft tissue release is performed, in addition to bony removal at the apex, complete fascetectomies, and removal of the ligamentum flavum at each level. Sublaminar wires (1.22 mm) and 3/16 inch rods are employed, and the end of each rod is bent to a 90°° angle to prevent migration. The bent section is introduced through the spinous process of the end vertebrae, or into the sacral ala. The cephalad portion of one rod, and the caudal end of the other rod, are secured to the spine, and bending forces are used to correct the deformity. No bracing is required postoperatively. Each lamina is then secured by a wire, and 2 cross links are employed. The average correction was 72%, with a loss of correction of 2% at 18 months followup. Complications occured in 12/78 procedures, including 2 early infections, 7 postoperative parasthesias (all resolved within 2 weeks), and 2 pseudarthroses.

Mayer PJ, Dove J, Ditmanson M, et al. Post-poliomyelitis paralytic scoliosis. A review of curve patterns and results of surgical treatments in 118 consecutive patients. *Spine* 6:573-582, 1982.

118 patients with an average age of 15.9 years (7-26 years) were treated, and 84 of these had a staged anterior (Dwyer) and posterior (Harrington) spinal fusion with instrumentation. Preoperative halo-femoral traction (63 pt.) was employed if the curve was >80°°, or if both curves in a double pattern were >60°° and rigid (maximum 50% body weight). When significant pelvid obliquity was present, the anterior instrumentation was extended to L5, and the posterior instrumentation extended to the sacrum. Asymmetric traction (one femur included) was applied for significant pelvic obliquity. Curve patterns included thoracic and lumbar (92), thoracic and thoracolumbar (20), long "C" shaped curve (4), thoracic (3), thoracolumbar (2), and thoracolumbar and double lumbar (1). A modified anterior incision, which extends to the rectus sheath and then curves back laterally to end 2 cm. medial to the ASIS, was felt to improve the lower lumbar exposure (Pingtung incision). Only early postoperative followup was available. With the combined approach, correction of pelvic obliquity was 68.4% (36.5°° to 12.2°°), while correction of the upper curve was 49% (74°° to 38°°), and of the lower curve was 61% (112°° to 44°°). Complications included a single death and 5 wound infections (all posterior). For the posterior implants, 3 hooks dislodged and a single rod fractured. In the anterior implants, there were 2 vertebral fractures and pullout of 2 staples during tensioning, and the Dwyer cable fayed in 2 cases. Meralgia parasthetica was identified in 10 patients, and other complications included hepatitis (1), SMA syndrome (1), and one loss of correction requiring revision surgery. The authors felt that the preoperative traction did not improve the results.

O'brien JP, Yau AMC, Gertzbein S, Hodgson AR. Combined staged anterior and posterior correction and fusion of the spine in scoliosis following poliomyelitis. *Clin Orthop Rel Res* 110: 81-89, 1975.

Seventeen patients (9-23 years old) were treated by a combined spinal fusion and followed for 24 months. The average curvature was 93°°, and preoperative halo-pelvic or halo-femoral (7/8) traction was used for several weeks in 8 cases. The second stage was an anterior release and fusion with Dwyer instrumentation. The anterior component included as much of the primary curve as was technically feasible. The patient was then kept on bedrest or immobilized in a cast until the posterior procedure. A posterior fusion with or without Harrington instrumentation was performed several weeks later. The fusion extended to the sacrum if significant pelvic obliquity was present. The patient was placed in a body jacket for 6-9 months, and those fused to the sacrum were kept in bed for the first 3 months. Major curve correction averaged 80% in the 11 patients treated with instrumentation, and 77% in those treated by posterior fusion without instrumentation. Pelvic obliquity was corrected

by 77%. Loss of correction at followup was 2% for the major curve and 6% for pelvic obliquity. A single pseudarthrosis was identified in a case treated without posterior instrumentation. Other complications included one peritoneal perforation (pelvic traction pin), 2 superficial wound infections, and a temporary 10th cranial nerve palsy. The combined approach offers maximal correction while minimizing postoperative loss of correction. No cases of pseudarthrosis were observed in those instrumented both anteriorly and posteriorly.

O'brien JP, Dwyer AP, Hodgson AR. Paralytic pelvic obliquity. It's prognosis and management and the development of a technique for full correction of the deformity. *J Bone Joint Surg* 57a:626-631, 1975.

39 patients with scoliosis and pelvic obliquity secondary to polio were treated, with followup of up to 4 years. Paralytic pelvic obliquity may result from infrapelvic (adductors vs. abductors) or suprapelvic (trunk) muscle imbalance, or both. Deformities tend to progress, which may culminate in dislocation of the hip. The scoliosis may be primary or secondary. The typical patient had extensive paralysis of the lower extremities, and had a lumbar curve of approximately 90°° from T11 to the sacrum. Pelvic obliquity was typically in the range of 40°°. Sitting balance was significantly impaired, and the upper extremities were often required to help balance the trunk. Surgical release of hip abduction contractures was performed first, and traction (halo-femoral or halo-pelvic) was often employed to gradually correct the spinal deformity. The patient then underwent an anterior spinal fusion (Dwyer instrumentation), and many also had an instrumented posterior spinal spinal fusion several weeks later with Harrington instrumentation. Patients were placed in a body cast for 3 months. Pelvic obliquity was corrected 78% (92% in the last 10 cases). At followup, 62% remained stable, 20% lost up to 10°°, 10% lost 8-20°°, and 8% lost >20°°. Loss of correction was mainly observed early in the series, and was very infrequent with a combined fusion. The best results were observed with a combination of preoperative traction, anterior instrumented fusion extending to L5, and instrumented posterior fusion extending to the sacrum.

IX. Neglected Clubfoot

The prevalence of congenital talipes equinovarus, coupled with the limited availability of health care in many developing regions, has led to an enormous number of neglected clubfeet. Ideally, the care of clubfeet in these regions may be improved through two avenues, assuming that sufficient resources and qualified health care personel can be mobilized. The first would focus on early identification and treatment of new cases in infancy, while the second would provide care for neglected cases in childhood and adolescence.

Campaigns to raise public awareness may help to identify cases early, and adequate training of both nonmedical and medical personel at the village level may help to extend care to greater numbers of children. Additionally, the length of treatment and importance of close followup to achieve a successful result mandates that clubfeet be managed within each given community. Several published techniques should be appropriate to implement at the village level, within a setting of limited resources. The Ponseti technique has achieved considerably popularity in the United States recently, and the published results from many centers have been very encouraging. Although this method has not been applied to neglected clubfeet in older patients, the applicability and potential benefits in the developing world are significant. Nonmedical personel can be trained in the technique, which would enable more patients to be serviced. This approach is already under investigation in Uganda, and several other regions are being evaluated as training sites. The treatment method described by Sengupta has been employed in more than 5000 patients in India with adequate results.

Although published studies dealing specifically with the management of neglected clubfeet in older patients may be limited, a variety of well described options are available, some of which have been commonly used to manage recurrent deformities. The available information on natural history suggests that most patients do not experience significant pain (at least in the first several decades), and that they are able to ambulate successfully. Perhaps a greater issue is the cosmetic and sociocultural implications of this deformity. A detailed functional assessment of untreated clubfeet in older patients is not available. The recommended

surgical approaches necessarily depend upon the age of the patient, and have included the following procedures either alone or in combination: soft tissue release, osteotomy, arthrodesis, and gradual correction using the Ilizarov device or an equivalent form of external fixation. A staged approach has been advocated by several authors. Secondary procedures may be required to address tibial torsion and forefoot deformity, in addition to residual deformities or complications following the primary treatment.

For patients in childhood, options include soft tissue release with or without shortening of the lateral column, or gradual correction with an external fixator. Although a report of successful triple arthrodesis in children younger than 8 years is available, this should probably be reserved as a salvage procedure. Similarly, talectomy should be reserved for salvage.

In older patients, options include soft tissue release with osteotomy (dorsolateral wedge resection most commonly), gradual correction with an external fixator (usually with soft tissue release/ osteotomy), or triple arthrodesis. A preliminary soft tissue release, with or without serial casting, may be required prior to triple arthrodesis in severely deformed feet. Wedge resections of the hindfoot joints are usually required to achieve adequate alignment.

The Ilizarov device (or locally produced equivalents) may be applied in the developing world, but do require more intensive training and experience. The method is labor intensive, requires close followup, and is certainly associated with complications. Gradual correction of these severe deformities is attractive for several reasons. Shortening of the foot, as might be seen with wedge resection or triple arthrodesis, is not observed. The chance of neurovascular compromise is diminished in comparison with an acute correction, and wound related concerns (including closure) are minimized. In addition, joints are spared. Although the basic concepts are similar, published series have varied somewhat in the implants used and in the technical details of frame construction. Basically, fixation needs to be achieved at the level of the tibia, the hindfoot, and the forefoot. These anchor points may then be connected by rods which enable differential compression or distraction to affect changes in alignment between the segments. Differential distraction between the tibial and hindfoot segments enables correction of hindfoot equinus and varus, while similar forces between the hindfoot and forefoot segments addresses the adduction, supination, and cavus components. Studies using this approach have varied in their recommendations for whether or not to overcorrect the deformity, the length of time in the frame after correction is achieved, the type and length of immobilization after removal of the frame, and the use of an orthosis after immoblization is discontinued. Additionally, lateral transfer of the tibialis anterior has been suggested to help maintain correction after frame removal. This methodology may be applied in combination with soft tissue release and/or osteotomy, especially in stiffer feet that have previousely been treated surgically. When correcting these deformities without osteotomy, one relies upon achieving sufficient mobility at the involved joints to enable realignment. Additionally, bony remodelling may also play a role in the ultimate alignment achieved, especially in those under 8 years of age.

Although it seems reasonable to attempt correction of these neglected deformities in all age ranges, and the short term results in published series are promising, the ultimate function at long term followup is unknown. The optimal treatment approach remains to be determined.

Angus P, Cowell HR. Triple Arthrodesis. A critical long-term review. J Bone Joint Surg 68b: 260-265, 1986.

80 feet treated by triple arthrodesis were reviewed at 13 year followup. The mean age was 14 years, 4 months (8 years, 4 months to 23 years). 34 of these were performed for a diagnosis of clubfoot. Patients reported significant improvement in 42.5%, improvement in 49%, and no change or worsening in 8.5%. 62% of feet had residual deformities, and 18 feet had a pseudarthrosis (talonavicular in all, more than one joint in 7/18). Avascular necrosis of the talus was seen in 7 feet, and 31 ankle demonstrated degenerative changes. The poorest results were seen in the idiopathic clubfoot population. Nineteen feet were painful, and all of these had either a pseudarthrosis or degenerative changes in the ankle. 12 feet required additional surgery on the midfoot or the hindfoot. For severe equinus deformities, bony resection alone may not be adequate. Soft

tissue release (including tendoachilles lengthening) combined with bony resection should offer the best outcome.

Bradish CF, Noor S. The Ilizarov method in the management of relapsed club feet. *J Bone Joint Surg* 82b:387-391, 2000

17 feet with recurrent deformity following previous surgery were treated by the Ilizarov device. The frame was anchored proximally by 2 tibial rings (4 wires), and a forefoot half ring was applied with 2 crossed metatarsal wires (through the first and fifth metatarsals). A hindfoot half ring was applied with two wires through the calcaneus. Medial and lateral rods connected the forefoot half ring to the hindfoot half ring, and two posterior rods connected the hindfoot half ring to the tibial rings. Differential distraction of the posterior rods, simultaneously correcting the hindfoot equinus and varus, was accomplished by four daily turns (total of 2 mm/day medial, 1 mm/day lateral). Correction of the forefoot deformity was accomplished by lengthening the medial rod (1 mm/day) while simulateously shortening the lateral rod (1 mm/day). Weightbearing was allowed once the foot was plantigrade, and the overall goal was to achieve slight overcorrection. Following correction, the frame was left in place for 6 additional weeks, followed by 6 more weeks in a cast. An ankle-foot orthosis was worn full time for an additional 6-8 months. An average of 4.5 weeks was required for correction. Complications included pin tract infections in nearly all patients, and a single patient had seperation of the distal tibial epiphysis. Five patients with flexible deformities underwent tibialis anterior transfer following removal of the frame, and all had an excellent result without recurrence. Overall, 13 patients had an excellent or good result, and the three fair or poor results had a recurrence. This method of joint distraction, without concomitant soft tissue release or osteotomy, is recommended for children with some flexibility. Feet with greater rigidity may require osteotomy prior to gradual correction.

De La Huerta F. Correction of neglected clubfoot by the Ilizarov Method. *Clin Orthop Rel Res*. 301: 89-93, 1994.

12 cases in 7 patients (average 27 years old) were treated by the Ilizarov method, without concomitant soft tissue release or osteotomy. Two tibial rings were employed, and a half ring was applied to the hindfoot (wires through the calcaneus) and the forefoot (metatarsal wires). Threaded bars connected the hindfoot and forefoot half rings, and both medial and lateral posterior rods were used to connect the hindfoot half ring with the tibial rings. A single anterolateral rod was placed between the forefoot ring and the tibial rings. Differential distraction was employed at 1 mm/day (4 turns of 0.5 mm). The time in the frame averaged 5-8 months, and patients were kept in a short leg cast for an additional 6 weeks. All feet were plantigrade at the end of treatment, and three developed a recurrence of adductus at 2-5 year followup. Stiffness in both the forefoot and the hindfoot was commonly observed following treatment. All patients were satisfied with the outcome. Complications included superficial pin tract infection in 17%.

El-Tayebi HM. The neglected clubfoot: A salvage procedure. *J Foot Ankle Surg* 37:501-509, 1998.

28 feet in 18 patients from 4-14 years of age were treated by an extensive posteromedial release, lateral column shortening (trapezoidal cuboid wedge resection with or without a closing wedge osteotomy of the calcaneus distal to the peroneal tendons), and tibialis anterior tendon transfer to the cuboid. The modified Dwyer osteotomy of the distal calcaneus is made parallel to the subtalar joint (not in line with the cuboid wedge), and helps to correct varus of the hindfoot, in addition to providing greater shortening of the lateral column for the more rigid deformities. Preoperative planning on the standing AP radiograph helps to determine the amount of cuboid to be resected. The apex is the medial border of the navicular. 50% of patients achieved excellent correction and could perform all activities, while 39% had a fair result, with some restriction in activities. 10% had a poor result with residual deformity and restriction in activities. As might be expected, the worst results were seen in patients with the stiffest feet preoperatively. Salvage by triple arthrodesis may be required in some patients.

Evans D. Relapsed club foot. *J Bone Joint Surg* 43b:722-733, 1961

Although designed for recurrent deformities following treatment, the procedure was also felt to be useful in the management of neglected clubfeet. A posteromedial release coupled with a lateral column shortening (calcaneocuboid joint wedge osteotomy and fusion) is described. The ideal timing for the procedure is 6 years of age (4-8 years). 30 feet were reviewed at 4-7 years followup, and there were 6 unsatisfactory results (undercorrection, overcorrection, persistent equinus).

Galindo MJ, Siff SJ, Butler JE, Cain TE. Triple arthrodesis in young children: A salvage procedure after failed releases in severely affected feet. ***Foot Ankle*** **7:319-325, 1987.**

19 feet in 13 children (mean age 8.4 years) were followed up at an average of 4 years. Four of these patients had residual clubfoot deformites. 68% had excellent or good results, with 16% fair and 16% poor, based on function, appearance, and patient satisfaction. Pseudarthrosis was observed in 16%, and both residual deformities (incomplete correction rather than recurrence) and ankle arthrosis were associated with poor results. The average shortening was 0.81 inches. The authors feel that triple arthrodesis is an excellent alternative for salvage, as an alternative to talectomy.

Grant AD, Atar D, Lehman WB. The Ilizarov technique in correction of complex foot deformities. ***Clin Orthop Rel Res*** **280:94-103, 1992.**

The principles of the Ilizarov method, as applied to the correction of complex foot deformities, are outlined. Distraction histiogenesis results in lengthening of tissues via cellular proliferation. The indications for this method may include severe deformities in which there is likely to be a problem with skin coverage, when excessive shortening of the foot would be expected with realignment by bony resection, when chronic infection or significant scarring is present, or when a concomitant leg-length discrepancy is present. Gradual correction also decreases the chance of neurovascular problems. As applied to the foot, an unconstrained system (forces are not applied at the axis of a hinge as in a constrained system) allows correction to occur through the joints in between points of fixation. For stiff or scarred feet, correction may be best achieved through osteotomy rather than through the involved joints. Types of osteotomy are also outlined. The "U" osteotomy enabled correction of the foot in relation to the leg and to the ground. This requires a semicircular cut from the posterior talus, downward towards the subtalar joint (can extend into the calcaneus if a subtalar fusion is desirable), and then upwards to exit anteriorly through the neck of the talus. This allows for sagittal plane correction (equinus or calcaneus). The "V" osteotomy has oblique limbs, the first of which extends downward from the posterior calcaneus to the plantar surface of the calcaneus, and the second extends from the plantar calcaneus anteriorly to exit the talar neck. This osteotomy allows for angular and rotational correction (varus, valgus, supination, pronation). Adequate results were observed with minimal complications in a series of 17 feet with severe neuromuscular deformities, several of whom had recurrent clubfeet.

Grill F, Franke J. The ilizarov distractor for the correction of relapsed or neglected clubfoot. ***J Bone Joint Surg*** **69b:593-597, 1987.**

10 feet in 9 children (8-15 years old) with severe deformities were treated by application of a circular fixator, followed by gradual correction. Neither soft tissue release nor osteotomy was performed. The apparatus included two thin wires through the proximal tibia, and a wire through the calcaneus and through the distal metatarsals. Each is connected to a half ring. Distraction at 1 mm/day is started 2-3 days after the frame is applied. Distraction between the tibial and calcaneal segments, and between the calcaneal and metatarsal segments (medial faster than lateral) enables gradual correction. Between 4 and 10 weeks were required for correction, and then the device was left in place for an additional 4-10 weeks. A long leg cast was then applied for an additional 3-4 months. All feet were plantigrade at 3.3 years followup, and the only complications were superficial pin site infections. Additional procedures were performed in 5 patients, including a supramalleolar osteotomy, EHL lengthening, a tibialis posterior transfer (preexisting peripheral neuropathy), and a single arthrogrypotic foot required a repeat procedure. This technique avoids bony resection, and arthrodesis, both of which may result in significant shortening of the foot.

Herold HZ, Torok G. Surgical correction of neglected clubfoot in the older child and adult. *J Bone Joint Surg* 55:1385-1395, 1973.

44 feet in 33 patients were treated by a two staged procedure. The first stage involved medial release, resection of the abductor hallucis, release of the tibialis posterior, and tendoachilles lengthening. Serial casting was then performed weekly. A second stage procedure was required in 36 feet, and consisted of an osteotomy (tarsal wedge osteotomy or calcaneocuboid wedge resection/arthrodesis) in 13 feet, or triple arthrodesis (23 feet). Nearly half of the patients required additional procedures, mostly to correct residual forefoot deformity (metatarsal osteotomies, Fowler procedure, plantar release). Other procedures included repeat soft tissue release, and tibial rotational osteotomy. At followup of 2-6 years, the cosmetic result was acceptable in all but one foot. Although walking ability was not decreased in any patient following treatment, function was judged to be poor (rigidity, pain) in 6 feet. Several patients also developed metatarsalgia once the foot was made plantigrade, and were subsequently treated by forefoot reconstruction.

Hersh A, Fuchs LA. Treatment of the uncorrected clubfoot by triple arthrodesis. *Orthop Clin North America* 4:103-115, 1973.

80 triple arthrodeses were performed in 64 patients, more than half of whom had previous soft tissue surgery. 86% were treated between 10 and 15 years of age. Wedge resections were performed at the talonavicular, calcaneocuboid, and subtalar joints. Staples were used for fixation, and weightbearing was begun at 6 weeks. Most patients healed within 3 months. Pseudarthroses were encountered in 10% (70% of these at the talonavicular joint). Other complications included skin necrosis (17%), infection (2.5%), and symptomatic staples in 6%. 89% of patients returned to full activity without any symptoms at 1-15 years followup, and only one patient had significant discomfort after prolonged walking or standing.

Hill NA, Wilson HJ, Chevres F, Sweterlitsch PR. Triple arthrodesis in the young child. *Clin Orthop Rel Res* 70:187-190, 1970.

94 triple arthrodeses were performed in children $\leq$ 8 years of age, and results were reviewed at more than 6 years followup. Ossification of the navicular is a prerequisite. 19 of these were for clubfoot. Fixation was not used, and patients were immobilized for an average of 3 months. Clinical followup is not reported. Radiographically, pseudarthroses were found in 12% (all talonavicular, 1 calcaneocuboid), and the average shortening of the foot was 0.75 inches. 12% required subsequent surgery for heel varus, which was felt to result from incomplete correction rather than recurrence of deformity. The authors feel that as long as the navicular is ossified, triple arthrodesis can be successfully performed.

Joshi BJ, Laud NS, Kaushik A, Patankar H, et al. Controlled differential distraction for correction of complex congenital talipes equinovarus. In Simons GW (Ed.) The Clubfoot. The present and a view of the future. Springer-Verlag, New York, 1994. pp.282-288.

An external fixator, composed of K-wires (2-2.5 mm), joints, and rods was employed in the management of 16 clubfeet (neglected or recurrent, arthrogryposis and congenital constriction bands). Either two parallel pins, or one pin and two half pins, were applied to the tibia for proximal fixation. Three wires were used to secure calcaneal fixation (2 from medial to lateral and 1 inserted posteriorly along the axis of the calcaneus), and a single wire was placed through all 5 metatarsals. The pins were connected by rods, and then gradual, differential distraction was used to correct the deformity. Asymmetric distraction between the tibia an calcaneus corrects the hindfoot varus and equinus, while a similar approach is used to differentially elongate the medial column relative to the lateral column to correct the forefoot adductus (1 mm/day medial, ½ mm/day lateral). A foot plate is also employed. Correction usually requires 3-6 weeks, and the device is left in place for an additional 3 weeks prior to placing the patient in a long leg cast (6 additional weeks). Orthotics and physical therapy are used following casting. A plantigrade foot was achieved in all cases.

Pandey S, Pandey AK, Jha N. Management of neglected clubfeet. In Simons GW (Ed.) The Clubfoot. The present and a view of the future. Springer-Verlag, New York, 1994. pp.505-506.

Recommendation are made for treating neglected clubfeet in different age ranges. For those from 9 months to 3 years of age, a posteromedial and plantar soft tissue release with transfer of the tibialis posterior is performed. In patients from 3-9 years of age, a "T" osteotomy is made through the calcaneus, which corrects varus, cavus, and adduction, as well as an "oblique sliding osteotomy" (with or without removing a wedge of bone) through the forefoot/ midfoot. A triple arthrodesis (two stages in adults) is recommended for those > 9 years of age.

Salinas G, Chotigavanichaya C, Otsuka NY. A 30 year functional followup of a neglected congenital clubfoot in an adult: A case report. *Foot & Ankle International* 21:1037-1039, 2000.

Published information on the natural history of untreated clubfeet is very limited. The patient described had occasional mild discomfort on the dorsolateral aspect of the foot, where there was a subcutaneous bursa. She had no functional limitations, and as a child was able to participate in normal activitis including sports. She ambulates in high top shoes worn backwards. Examination of gait revealed a decrease in the time spent in stance phase. Overall, she tolerated the deformity well.

Sengupta A. The management of congenital talipes equinovarus in developing countries. *International Orthopaedics (SICOT)* 11:183-187, 1987.

Sengupta A, Gupta P. Follow-up study of a method of management of congenital talipes equinovarus deformities with easily available surgical facilities in developing countries. In Simons GW (Ed.) The Clubfoot. The present and a view of the future. Springer-Verlag, New York, 1994. pp.549-553.

A limited surgical approach is presented for patients from infancy through childhood. Under general anaesthesia, a percutaneous lengthening of the heelcord, and percutaneous release of the plantar fascia and the abductor hallucis, are performed under a general anaesthetic. Patients are placed in a long leg cast which is maintained for 3 weeks, and then under sedation changed to another long leg cast for an additional 3-4 weeks. An orthosis with canvas shoes attached to wooden clogs, with or without a 5 mm lateral heel wedge, is then employed. The results in more than 5000 patients (based on appearance, the ability to walk with standard footwear, and the ability to squat) were good or excellent in 95% if treatment is started within the first 3 months of life, and in 85% of those treated during the childhood years. The method requires minimal equipment, no inpatient stay, and is felt to be suitable for developing countries.

Sobel E, Giorgini R, Velez Z. Surgical correction of adult neglected clubfoot: Three case histories. *Journal of Foot and Ankle Surgery* 35:27-40, 1996.

3 adults (34,36,41 years of age) were treated by an extensive posteromedial and plantar release and a double arthrodesis (calcaneo-cuboid wedge resection and talonavicular arthrodesis). All feet were painful preoperatively. One of the three had a postoperative wound infection. At followup of 1-2 years, 2/3 feet were plantigrade (one has 10°° residual equinus), and normal shoes could be worn. All three patients were satisfied with the results, although 2 had pain with weightbearing. All three patients wore an articulating ankle-foot orthosis.

Storen H. Operative treatment of club-foot in older children and adults. *Acta Orthoped Scand* 18:232-265, 19

A 3 stage approach was employed to treat 21 neglected clubfeet. The first stage involves a medial release, through 2 incisions. The tibialis anterior is lengthened as well, or may be transferred at a later stage. One month later, a tendoachilles lengthening is performed, and the calcaneus is brought down by traction through a pin, which is incorporated into the plaster. Four to six weeks later the third stage is completed, which involves a midfoot wedge osteotomy and a calcaneal osteotomy.

Toohey JS, Campbell P. Distal calcaneal osteotomy in resistant talipes equinovarus. *Clin Orthop Rel Res* 197:224-230, 1985.

29 patients with recurrent clubfeet (39 feet) following posteromedial release were treated by revision surgery, which included lateral column shortening (dorsolateral wedge osteotomy of the distal calcaneus). Patients also had a plantar fascia release, and some had a repeat posteromedial release. Immobilization was 4-6 weeks (4 months if redo posteromedial release required), and all were placed in an AFO indefinitely. The average age was 4.9 years (2 years, 2 months - 10 years, 6 months), and the followed averaged 4.6 years. 77% had a good result, and 18% had a poor result. Poor results were commonly seen in those having multiple prior procedures, complex residual deformities, and overcorrection into valgus (3/7). The authors feel that the best age for the procedure is 4 years (allows for sufficient development of the lateral column of the foot), and that the procedure should not be performed in those greater than 7 years of age.

Torok G. Surgical treatment of the neglected clubfoot. In Lehman WB (Ed) The Clubfoot, J.B. Lippincott Co, Philadelphia, pp. 87-96, 1980.

The author presents his experience and opinions regarding clinical findings in the neglected clubfoot, on the symptoms experienced by patients, and on his strategy for surgical correction of the deformity. Although significant stiffness at the midtarsal and tarsometatarsal joints is seen in adults with untreated deformities, arthritic changes are generally absent. The dorsolateral portion of the foot bears much of the weight, and some patients may develop a symptomatic bursa or skin breakdown. Pain does not appear to be a significant complaint in most patients. Patients generally ambulate well, but have difficulties running. The author cautions against promising an improvement in function following surgery. A multistage approach is suggested for surgical correction. The first stage involves an extensive posteromedial release, including the joints along the medial border of the foot. Weekly casting is then employed for 4-6 weeks, and if correction has not been achieved a triple arthrodesis is performed (Lambrinudi technique). Wedges may have to be removed to achieve the desired correction. Other procedures may be required to deal with coexisting tibial torsion or forefoot deformity.

Wallander H, Hansson G, Tjernstrom B. Correction of persistent clubfoot deformities with the Ilizarov external fixator. Experience in 10 previousely operated feet followed for 2-5 years. Acta Orthop Scan 67:283-287, 1996.

Ten idiopathic clubfeet with recurrent deformities following operative management (1-7 surgeries) were treated with the Ilizarov device. The apparatus included two tibial rings (mid, distal), and both a calcaneal half ring and a forefoot half ring (lateral wire through 3rd through 5th metatarsals, medial wire through 1st and 2nd metatarsals). Distraction was accomplished between the rings with threaded rods, which were attached between the tibial rings and the calcaneal half ring, as well as between the calcaneal half ring and he forefoot ring. Six to twelve weeks were required to achieve the desired correction, and a short leg cast was applied for 2-3 months after frame removal. Complications included pin tract infection, seperation of the distal tibial epiphysis (1), and subluxation at the ankle joint (1). Flexion deformities of the toes were seen initially, but later prevented by the use of rubber bands connected to the fixator. Functional results (Lehman scale) were fair in 3 and poor in 7. Six of seven patients were satisfied. Six of ten feet were occasionally painful, and walking distance was mildly limited in all patients. Ankle motion was reduced to 20°° or less in 50% of feet.

Yadav SS. Observations on operative management of neglected club-foot. *International Orthopaedics (SICOT)* 5:189-192, 1981.

45 feet in 27 patients were reviewed. In patients between 8 and 11 years of age, a wide posteromedial release and a dorsolateral wedge resection, with or without release of the plantar fascia and the abductor hallucis, was performed. Soft tissue release and triple arthrodesis, with wedge resections at the subtalar and mid-tarsal joints, was recommended in those patients older than 11 years. Followup was from 6 months to 8 years, and 87% of patients were satisfied. Shortening of the feet was observed as might be expected. Residual deformities included equinus in 8 feet (2 severe), and forefoot adductus in 8 feet. Complications included superficial skin necrosis in 5 feet after triple arthrodesis, and superficial infection in 8 feet (details not discussed). Stiffness with dorsolateral resection was seen in 15 feet, which is not surprising since the resections

often entered the talonavicular joint. Overall, the goal of a plantigrade foot was achieved in most patients.

Yamamoto H, Muneta T, Ishibashi T, Furuya K. Posteromedial release of congenital clubfoot in children over five years of age. *J Bone Joint Surg* 76b:555-558, 1994.

24 feet in 19 children (6.8 years at surgery), 13 of whom had previous surgery, were treated by posteromedial release and reviewed at a mean followup of 11 years. 79% had good or excellent results using McKay's functional rating system (91% if no prior surgery, 69% of those having prior surgery). Patients were initially casted in 10°° plantarflexion, and then underwent weekly cast changes to achieve full dorsiflexion. A Denis-Browne splint was worn at night for one year, followed by an orthotic for an additional three years.

Cooper DR, Dietz FR. Treatment of idiopathic clubfoot. A thirty-year followup note. *J Bone Joint Surg* 77:1477-1489, 1995.

71 clubfeet in 45 patients were reviewed at 30 years followup, and 78% had an excellent or good outcome (versus 85% of a control group of 97 patients who had no congenital deformity of the foot) following the Ponseti method of treatment. Excessive weakening of the gastrocsoleus complex may predispose to a poor result, and both a sedentary occupation and the avoidance of excessive weight gain may improve the long term results.

Laaveg SJ, Ponseti IV. Long-term results of treatment of congenital clubfoot. *J Bone Joint Surg* 62:23-31, 1980.

104 clubfeet in 70 patients were reviewed at 10-27 years following treatment. Functional results were adequate in 88.5%, and 90% of patients were satisfied with the results, despite some limitation in motion and an incomplete restoration of alignment on radiograhs. Relapses, or dynamic supination deformity, can be treated effectively with transfer of the tibialis anterior to the third cuneiform. Functional results and patient satisfaction correlated with the degree of motion, and with the lateral talocalcaneal angle.

Morcuende JA, Weinstein SL, Dietz FR, Ponseti IV. Plaster cast treatment of clubfoot: The Ponseti method of manipulation and casting. *J Pediatr Orthop* 3b:161-167, 1994.

The Ponseti treatment method is discussed in detail

Ponseti IV. Current Concepts. Common errors in the treatment of congenital clubfoot. *International Orthopaedics (SICOT)* 21:137-141, 1997.

The Ponseti method is described, and excellent illlustrations using models are provided.

Ponseti IV.Congenital Clubfoot. Fundamentals of treatment. Oxford Medical Publications, Oxford, England, 1996.

This outstanding reference summarizes the authors extensive experience in the management of congenital clubfoot over a fifty year period. Topics include the pathogenesis, pathologic anatomy, clinical history and examination, and the Ponseti treatment method.

X. Rehabilitation/Prosthetics and Orthotics

De Ruyter K, Lelieveld O. Orthopaedic aids at low cost. *Br Med J* 289:749-751, 1984.

The authors describe various orthopaedic devices made locally in Zambia. Four types of crutches were produced, from both wood and metal. Prostheses for both above and below knee amputees are described. Sandals for patients with leprosy may be made from car tires and rubber, and the construction of calipers is also discussed.

Kay E, Dunleavy K. Community-based rehabilitation: An international model. *Pediatr Phys Ther* 8:117-121, 1996.

The goal of community based rehabilitation programs is to extend basic services to all members of a community based upon national financial restraints. The concept was initially developed for children, and has evolved over the past 20 years. An important component of each program is to empower disabled individuals, and to involve members of each community in the delivery of services. A global definition of community based rehabilitation includes 3 broad categories, namely the central level (setting and implementing national health policies), the mid-level (health professionals provide higher levels of support to CBR workers), and the local level (community members with and without disabilities institute local programs). Typical components of CBR programs include providing rehabilitation services and assistive devices, family support groups, vocational training, and activities to provide education, social integration, and recreation. In contrast to outreach programs (run by health care professionals), CBR programs are run locally by patients and nonmedical personnel. This novel approach to delivering services will undoubtably continue to expand.

Meanley S, Reed NK. An "appropriate technology" trans-femoral prosthesis, using materials available in Nepal. *Prosth Orthot Int* 22: 123-128, 1998.

The design features and techniques for construction of a trans-femoral prosthesis using locally available materials is described. Components include a SACH foot and a cycle axis knee, and the socket is made from drainage piping (high density polyethylene). Suspension is by suction and a modified silesian belt. The foot is made from local wood and microcellular rubber.

Oberg K. Cost-benefits in orthopaedic technology by using thermoplastics in developing countries. *Prosthetics and Orthotics International* 15:18-22, 1991.

In recent years, thermoplastics have been employed with greater frequency in the fabrication of orthotics and prosthetics in the developing world. Costs have become competative with metals and other materials previousely employed. The common thermoplastic materials include PVC, polythylene, and polystyrene. Using these materials, for example, prosthetics are lighter and require less energy expenditure to use. At a regional WHO meeting, all 14 centers polled (from different countries) were using thermoplastics.

O'Toole B, McConkey R. A training strategy for personnel working in developing countries. *International Journal of Rehabilitation Research* 21:311-321, 1998.

An approach to developing a community based rehabilitation program is discussed, based upon the authors experience in Guyana. The rationale for this type of model is based upon the enormous mismatch between supply and demand in the developing world, and the goal is to provide services at the community level. The needs should be met within families or the local community, as disabled individuals cannot rely upon specialty services. CBR workers interact directly with the patient and his or her family. Those with higher levels of training, such as the physical therapists, have the role of training and monitoring the work of these individuals, who are most often volunteers. The training curriculum is based upon an assessment of the needs of disabled individuals within each given community, and is thus sensitive to the local culture and specific features of each community. Those trained to be CBR workers include family members, community members, and even the patients themselves. Trainers (usually specialists) must be recruited to transmit the appropriate information and followup with the trainees. In Guyana, the CBR workers are mainly volunteers who have undergone 120 hours of training. The strategy for training that has evolved here includes 3 key elements. First, consultations with members of the community (disabled persons, local community leaders) help to determine the specific needs of disabled individuals. Second, multi-media training packages

for volunteers have been developed, and include both video presentations and handbooks. Third, local tutors are recruited to help train the volunteers. Overall, there have been numerous benefits to this successful program, which undoubtably will continue to evolve in Guyana and in other countries.

Sethi PK. The Knud Jansen Lecture: Technological choices in prosthetics and orthotics for developing countries. *Prosthetics and Orthotics International* 13:117-124, 1989.

Sethi PK. Appropriate technology for rehabilitation aids in developing countries. *Ann Natl Acad Med Sci (India)* 18(2):34-42, 1982.

The author discusses issues surrounding the transfer of technology to developing countries, and illustrates his thought process by describing the development of the "Jaipur foot". It is essential to gain a knowledge of the needs of the "rural masses", rather than the desires of a wealthy minority (who often may demand transfer of expensive western technlogy) in a given region. Technologic choices should be made based upon the resources of a given community and the sociocultural environment. He points out the significant differences between cultures, "floor sitting" (most developing countries) versus "chair sitting" (Europe and North America). The design features of "western" prostheses for amputees are ineffective for patients residing in tropical climates who need to squat and sit cross legged for activities of daily living, and who typically wear sandals or go barefoot. Additionally, mobility of the prosthetic foot is essential in areas with rough terrain and few paved roads. Using local artisans and materials available locally enable such devices to be relatively inexpensive, and easily repaired or replaced. All of these considerations led to the evolution of the Jaipur foot, which is economically feasible, culturally acceptable, and easy to maintain by local artisans. The prosthetic foot is designed to be worn without a shoe, and thus must be cosmetically acceptable while able to withstand considerable stresses. The foot is made from wood and microcellular rubber, and is reinforced by a solid shell of vulcanized rubber. A rubber universal joint is placed in the hindfoot to enable dorsiflexion and hindfoot mobility. Design modifications were made over time with feedback from the amputees, including a forefoot block which enables forefoot pronation and supination. The socket and the shank are made of aluminum, and an open-ended socket provides greater comfort. No plaster molds are employed, and the socket is shaped and fitted onto each individual. A below knee prosthesis may fit a trial limb in less than an hour. The fabrication of appliances for polio is also discussed. These strategies allow services to be provided for larger numbers of individuals as appliances are made locally and can be serviced or replaced locally. Dr. Sethi defines appropriate technology as follows: "it should meet the needs of the neediest (the rural and the urban poor)", "it should generate endogenous self-reliance (and not overdependence on external sources)", and "it should also be environmentally sound and should have its roots in the culture of the people. Then only can it be sustained".

Vossberg A. The development of orthopaedic appliances and low cost aids in "least developed countries". *Prosth Orthot Int* 9:83-86, 1985.

Orthopaedic appliances in developing countries must be developed based upon the unique features of each country, taking into account economic, social, cultural, and environmental variables. Resources are limited, and the solution is not the importation of sophisticated, expensive designs. Living conditions are different, and most patients are found in rural environments. Technical counseling should focus on the specific needs of the host environment, and should be based upon "appropriate" appliances which may be produced and serviced locally. Although some materials may need to be imported, production should be completed locally. "Appropriate" technology may result from a synthesis of locally available materials with contemporary ideas. A standardized system should be developed in order to efficiently service the volume of patients requiring orthopaedic appliances.

Werner D. Disabled Village Children. A guide for community health workers, rehabilitation workers, and families. 2nd Edition, Hesperian Foundation, Palo Alto, 1994.

Although the target audience for this well written book is not the practicing orthopaedic surgeon, there is a large amount of useful information for all health care workers involved in projects in the developing world. The information presented evolved through an extensive experience with caring for patients at the village level, and a host of experts from 27 different countries have provided input, including physical and occupational therapists, orthotists and prosthetists, rehabilitation engineers, wheelchair designers, and both patients and their families. Over 4000 drawing are included, which are essential in conveying important information to not only health care workers, but patients and their families. The book is a valuable resource for all those participating in the care of disabled children in developing regions, and there are several sections that may be of use to the orthopaedic surgeon (polio, walking aids, wheelchairs, and prosthetics). In patients with the residua of polio, those with lower extremity involvement will need strong shoulders and arms, as well as straight legs, in order to ambulate. If the patients can lift their body weight off of the ground from a seated position at least several times, chances are good that they can ultimately walk with crutches. Those with fair strength may work on daily exercises to improve this. Basic considerations relating to lower extremity involvement and locomotion are presented, including principles of bracing. Preventive positioning during the acute phases is stressed, with simple examples demonstrated. The section on walking aids demonstrates many examples of how such appliances may be constructed, including indoor and outdoor parallel bars, walkers (made of 2 x 4 cm. boards, tree branches, bamboo, or iron rods), crutches (wooden and metal), and canes. The determination of necessary wheelchair features, as well as how to construct different types of wheelchairs with a variety of adaptations, is covered in detail. Important variables include the patient's deformities and level of neuromuscular function, the local customs, the family and community situation, and the ground surface over which the wheelchair will pass. Information to help caretakers and families choose the appropriate wheelchair model and features are also discussed, including detailed charts with pictures that cover the pros and cons of each model or feature. Finally, directions are provided on how to construct wheelchairs. The section on prosthetics also has excellent detail. The clinical examination and the appropriate measurements are described, in addition to the technical details required to construct prostheses for below knee and above knee amputees. Materials include a bamboo post (or PVC tubing), plaster for the socket, and a leather knee cuff for below knee amputees. Above knee prostheses are designed using similar materials, and in older patients adding a knee joint may improve function. The construction of prosthetic feet is also described.

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