

Advances in Neurosurgery 4



Lumbar Disc Adult Hydrocephalus

Edited by
R. Wüllenweber M. Brock J. Hamer
M. Klinger O. Spoerri

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Preface

The Neurosurgeons of Berlin are happy to welcome their colleagues from Germany and from foreign countries to our Annual Meeting, being held in this city once again after many years. The external appearance of the city may have changed in many respects since our winter meeting in 1965. This is not the case, however, as concerns the outstanding quality of its cultural life. We hope that you take as much profit of it as possible.

When choosing the scientific themes of this congress, we were led by the idea that problems should be discussed which are not dealt with at special symposia this year. Thus, the problems related to **lumbar disc surgery** and its complications were chosen as one main topic. This important chapter of neurosurgery worries (and not seldom depresses) us in our daily work. A joint statistic analysis has been made, for which we are indebted to the colleagues from the following university clinics: Essen, Freiburg, Graz, Hannover, Heidelberg, Kiel, Köln, Mainz, Würzburg, Berlin-Charlottenburg, Berlin-Steglitz, of the Neurosurgical Department of the BG-Unfallklinik Frankfurt/Main, of the Neurosurgical Department Wagner-Jauregg-Krankenhaus Linz, of the Neurosurgical Clinic of the Katharinen-Hospital Stuttgart, and of the Neurosurgical Clinic of the Städt. Krankenhaus Berlin-Neukölln.

The second main topic of this meeting was **adult hydrocephalus**. This problem is intriguing from many points of view: pathophysiology, diagnosis, surgical indication and prognosis. For this reason it was discussed at a joint session with the Society for Nuclear Medicine. This contributed very much to clarifying some questions which were open in the minds of the participants of both groups.

In the selection of the papers presented as **free communications** priority was given to young neurosurgeons. The papers were deliberately kept short in order to give many younger colleagues the opportunity to present themselves to our society and to report the results of their work.

For the first time the German Society for Neurosurgery had a joint session with the German Association of Neurosurgical Nurses. The subject was **rehabilitation following diseases of the spine**. It was a pleasure to welcome the nurses, whose support is an essential factor in the daily therapy of the neurosurgical patient. The papers presented and discussed in this session will be published as a separate volume.

In the name of the German Society for Neurosurgery, the organizers of the Annual Meeting in Berlin express their gratitude to Professor G. Finger of Sharp & Dohme GmbH München for generously supporting the publication¹ of *Advances in Neurosurgery* 4.

Wilhelm Umbach
Rolf Wüllenweber
Horst Wenker

¹ An exception has been made in the format of this volume: due to their immediate local interest and importance, the opening speech of R. Wüllenweber, which deals with the general situation of neurosurgeons in our country nowadays, as well as the paper by R. A. Frowein on the legal aspects of traumatic disc disease, are being published in German.



Wilhelm Umbach

Wilhelm Umbach

Wilhelm Umbach, who had originally been elected by our Society to be the President of this Annual Congress is no longer among us. He died August 10, 1976.

Wilhem Umbach was born on August 21, 1915 in Frankfurt/Main and trained in Neurosurgery by Traugott Riechert in Freiburg/Breisgau. From the very early days he dedicated a great part of his energy to clinical work as well as to research activity. In 1966 he was nominated head of the new Neurosurgical Clinic of the Jung-Stilling-Krankenhaus in Siegen. In 1969 he was appointed Full Professor of Neurosurgery and Chairman of the Neurosurgical Clinic of the Free University in Berlin-Steglitz.

All of us are aware of the difficulties this task brought with it, especially regarding the political situation at the University. Despite the many personal pressures he had to tolerate, Wilhelm Umbach secured a place among the most active representatives of our speciality. It was not a mere coincidence that we asked him to conduct this congress. His scientific work propagated his name far beyond the boundaries of our country and justifies his extraordinary international reputation. His work has profound bearing on the therapy of temporal epilepsy. Also, several other neurosurgical problems merited his interest. Numerous monographs, text-book chapters and scientific papers are a vivid testimony of this fact. German neurosurgeons have every reason to thank W. Umbach for this extensive work and to keep his memory alive.

Helmut Penzholz

Rede zur Eröffnung der 27. Jahrestagung der Deutschen Gesellschaft für Neurochirurgie

Meine sehr verehrten Damen und Herren!

Üblicherweise ranken sich Eröffnungsreden um Themen wie: „Wo steht die deutsche Neurochirurgie heute?“ Die Antwort wäre unbestritten: „Noch auf Weltniveau!“ Ich habe mir einige Gedanken über die Situation des Neurochirurgen in unserer Gesellschaft gemacht, aus der Sorge heraus, daß die erste Antwort sehr bald relativiert werden könnte. Ohne Zweifel leben wir in einem Staat, der seinen Bürgern ein Höchstmaß an persönlicher Freiheit garantiert; andererseits sind wir überflutet von Wortkombinationen des Reizwortes „Zwang“. Das geht vom Leistungszwang über den Zwang, bestimmte diagnostische oder therapeutische Methoden anzuwenden, bis zum Publikationszwang und zum staatlichen Zwang, um nur einige Zwänge herauszugreifen. Es bleibt nicht aus, sich Gedanken zu machen, wie weit man selbst schon anankastisch reagiert.

Befassen wir uns zunächst mit **den** Gruppen unserer Gesellschaft, die Zwänge intendieren, von denen wir betroffen sind. Da ist zunächst die Anspruchshaltung der, oder besser gesagt einiger Patienten, die glauben, mit der Bezahlung des Krankenkassenbeitrages einen Anspruch auf Gesundheit zu haben. Wohin das führt, weiß jeder von uns aus Haftpflichtprozessen.

Ein Beispiel: Meinem verehrten Vorgänger Arist Stender wurde manche Stunde seines Lebensabends dadurch vergällt, daß ihm eine Patientin, die er vor 30 Jahren in Breslau an einem Tumor operiert hatte, mit einem Haftpflichtprozeß drohte, weil sich mit zunehmendem Alter eine Hemiparese verstärkt bemerkbar machte. Er kam immer wieder im Gespräch auf diesen Fall zurück, und meine wohlgemeinten Trostworte nützten gar nichts, weil nicht die finanzielle Bedrohung, sondern die menschliche Enttäuschung im Vordergrund stand.

Ohne Zweifel hat jeder Patient ein Anrecht auf optimale ärztliche Versorgung, aber es gibt kein Recht auf Gesundheit und keine Garantie für das hundertprozentige Gelingen eines operativen Eingriffs. Konsequenz: Wenn sich die Anspruchshaltung der Patienten in bezug auf den operativen Eingriff verstärkt, so ist die unausweichliche Folge, daß der Neurochirurg das Operationsrisiko scheut und den vielleicht lebensrettenden Eingriff unterläßt, zumal Befangenheit dem Operationsresultat nicht eben förderlich ist.

Kann man diese Anspruchshaltung durch Aufklärung korrigieren? Sicher lassen sich bei einigen Patienten durch ein sachliches Gespräch auch prognostische Gesichtspunkte offen erörtern. Häufig bleiben aber in unserem Fachgebiet auch dem Operateur prognostische Zweifel, die er sich selbst eingestehen sollte. Die größte Schwierigkeit der ärztlichen Aufklärung liegt darin, daß viele Patienten vor einer neurochirurgischen

Operation in einer psychischen Ausnahmesituation sind, in der sie und ein großer Teil der Angehörigen nur das verstehen wollen, was ihre Hoffnung bestätigt, und alles andere verdrängen. Ich fühle mich nicht befugt, einem inkurabel Kranken den letzten Hoffnungsfunken zu nehmen.

Eine andere Form der Aufklärung beruht darauf, aus ideologischen Gründen, einem Wahrheitsfanatismus oder welchen Motiven immer, dem Patienten und seinen Angehörigen alle Komplikationsmöglichkeiten bis ins letzte Detail aufzuzeigen, einem Tumorpatienten beispielsweise eine Glioblastom-Statistik vorzulegen. Ich halte dieses Vorgehen für unärztlich, ja für inhuman, und für nichts weiter als eine Flucht aus der ärztlichen Verantwortung in Formalismen. Fazit: Wir bleiben unter dem Zwang, weitere Haftpflichtprozesse in Kauf nehmen zu müssen, wenn wir keine Gesundheitsingenieure werden wollen.

Lassen Sie mich nun etwas zum Thema Leistungszwang bzw. zu der Erwartungshaltung einiger jüngerer Kollegen sagen. Die Gesellschaft, die uns bezahlt, und zugegebenermaßen nicht schlecht bezahlt, erwartet dafür eine Leistung, die das Optimum dessen zu sein hat, was jeder auf Grund seines Ausbildungsstandes, seiner Veranlagung und seiner Erfahrung zu bringen imstande ist. Ich halte das für ein absolut legitimes Verlangen unserer Gesellschaft und keineswegs für einen Zwang. Sieht sich jemand nicht in der Lage diese Leistung zu erbringen, so gibt es eine Menge Möglichkeiten, eine verfehlte Berufswahl zu korrigieren. Die Erwartung, in etwa 6 Jahren zum Facharzt ausgebildet zu werden, setzt nicht nur äußere Dinge wie Betten- und Operationskapazität voraus, sondern auch Eignung und ein Engagement für die Neurochirurgie, das sich nicht in einer 40-Stunden-Woche erschöpft. Jeder von uns weiß, daß die Krankenversorgung in unseren Kliniken während der Urlaubszeit nicht zusammenbricht. Man kann also nicht davon ausgehen, daß alle Mitarbeiter einer Klinik grundsätzlich bis zur sogenannten physischen und psychischen Erschöpfung überlastet sind. Mit dem Argument, daß die Krankenversorgung gefährdet sei, wenn nicht ständig neue Stellen geschaffen werden, setzt man nur neue Zwänge, nämlich auf die Sozialpolitiker, und man trägt erheblich zur Kostenexplosion im Gesundheitswesen bei.

Zum Thema „Wissenschaftliche Arbeit“ ist als bekannt vorauszusetzen, daß die Universitätskliniken neben der Krankenversorgung Lehre und Forschung zu vertreten haben. Das weiß jeder, der sich um eine wissenschaftliche Assistentenstelle an einer Klinik bewirbt. Publikationszwang heißt zunächst nichts anderes, als der Gesellschaft, die die Universitäten bezahlt, die Effizienz der Forschung zu dokumentieren. Auch das ist in meinen Augen ein legitimer Anspruch der Gesellschaft. Ich halte es allerdings für Auswüchse dieses sogenannten Publikationszwanges und kann es nur als Etikettenschwindel bezeichnen, wenn die immer gleiche Arbeit mit leicht veränderten Titeln und in anderen Sprachen publiziert wird, oder wenn aus der Reihe der Autoren eine Gefälligkeitsliste der persönlichen Freunde gemacht wird. Ich bin nicht der Meinung, daß diejenige Klinik die leistungsfähigste ist, die die höchste Zahl an Publikationen pro Jahr aufweist; vielmehr scheint die Quantität nicht selten auf Kosten der Qualität zu gehen, ein Trend, der nicht allein in deutschsprachigen Zeitschriften zu beobachten ist. Ein Grund dafür ist zweifellos die Angst, daß einem andere mit ihren Forschungsergebnissen zuvorkommen könnten. Ich will meine Klinik dabei keineswegs ausnehmen und weiß, wie schwierig es ist, jemand zu bremsen, der davon überzeugt ist, etwas grundlegend

Neues entdeckt zu haben, auch wenn die Sache unausgegoren ist. Ich möchte unseren jüngeren Mitarbeitern nur empfehlen, die Arbeit ein halbes Jahr in der Schreibtischschublade zu lassen und sie dann zu überarbeiten. Sie werden sich wundern, wie viele Dinge man dann mit anderen Augen und klarer sieht. Die Ansicht, daß der Wahrheitsgehalt von wissenschaftlichen Publikationen und Kongreßmitteilungen eigentlich im Gegensatz zu deren Umfang steht, ist schwer zu widerlegen. Wenn aber beispielsweise auf internationalen Symposien völlig konträre, aber mit der gleichen Untersuchungsmethode gewonnene Ergebnisse vorgelegt werden, so sollte sich jeder von uns zur Kritik aufgerufen fühlen. Wir haben dem von Herrn Umbach als „Forum junger Neurochirurgen“ bezeichneten Teil im Programm so viel Platz eingeräumt, um jüngeren Kollegen Gelegenheit zu geben, sich in unserer Gesellschaft vorzustellen, ein begrenztes Thema präzise darzustellen und in der Diskussion zu vertreten. Jeder von uns Älteren hat einmal zum ersten Mal auf einem solchen Podium gestanden, und die Befangenheit verschwand in dem Maße, in dem einem das Wohlwollen des Auditoriums entgegen schlug. Dieses Wohlwollen kann sich nur in einer fairen und sachlichen Diskussion ausdrücken, die das spüren läßt, was man als „intellektuelle Redlichkeit“ bezeichnet. Das ist der einzige Weg, um ein Abgleiten des wissenschaftlichen Niveaus zu verhindern.

Politische und staatliche Zwänge werden durch Presseveröffentlichungen vorbereitet und unterstützt. Einige Autoren werden nicht müde, in mehr oder weniger geschickt verbrämter Polemik, die Hochschullehrer pauschal als die Ursache allen Übels an den deutschen Universitäten zu verdammen, sie als die privilegiertesten Bürger der Nation hinzustellen, die sich in elitärer Arroganz in ihren Elfenbeinturm zurückziehen und die sie tragende Gesellschaft negieren. Auf diese Weise werden Personalentscheidungen beeinflusst, die parteipolitischem Opportunitätsdenken entspringen und offensichtlich vergessen lassen wollen, daß Sachkenntnis auch für demokratische Mehrheitsentscheidungen die Beurteilungsbasis sein muß. Wenn die Habilitationsleistung eines jungen Wissenschaftlers heute mancherorts damit belohnt wird, daß man ihn per Universitätsgesetz vor die Tür setzt, dann ist das sicher kein Anreiz für effiziente Forschung. Die Ursachen für die Blockierung der Hochschullehrerstellen liegen in den Fehlern der Vergangenheit begründet und sind schwer zu korrigieren. Das jetzt diskutierte Modell der Heisenberg-Professuren scheint nach den bisherigen Überlegungen nicht für die Medizin gedacht zu sein. Ich halte die Einrichtung Wissenschaftlicher Ratstellen für eine annehmbare Lösung. Natürlich kann nicht jede dieser Stellen mit einem eigenen großen Etat ausgestattet werden. Sie sollten aber einen Anreiz bieten, sich z. B. intensiv mit Subspezialitäten, wie der Stereotaxie, der Mikroneurochirurgie, der Behandlung peripherer Nervenläsionen oder bestimmten experimentellen Fragen zu beschäftigen. Dazu ist es absolut nicht notwendig, die Kliniken in Mini-Abteilungen zu zerhacken, die sich dann in einen Wust von Kompetenzschwierigkeiten verstricken. Notwendig ist eine verstärkte Zusammenarbeit zwischen den einzelnen Kliniken und eine Koordinierung der wissenschaftlichen Arbeit, wie sie etwa in unseren Arbeitsgemeinschaften geschieht. Ich möchte diese Gelegenheit nicht versäumen, den Mitarbeitern dieser Arbeitsgemeinschaften für ihre Initiativen herzlich zu danken. Wieviel Mühe und Arbeit darin steckt, scheint nur wenigen bekannt zu sein. Im Hinblick auf die Zukunft unserer Mitarbeiter müssen wir uns Gedanken machen, ob es sinnvoll ist, unentwegt weiter Fachärzte auszubilden, denen schließlich nichts anderes übrigbleibt, als sich niederzulassen. Auch der Bedarf an niedergelassenen Neurochirurgen wird bald gedeckt sein, und der dann einsetzende Konkurrenzkampf könnte den einen oder anderen zur Scharlatanerie

verleiten. Ich kann Ihnen auch keine Patentrezepte für die Zukunft anbieten, meine aber, daß wir uns als Gruppe Neurochirurgen über das hinaus, was bisher von einzelnen schon getan wurde, stärker in der Standespolitik engagieren sollten.

Als Beispiel staatlichen Zwanges sei der Entwurf einer Ausführungsbestimmung des Landeskrankenhausgesetzes Berlin erwähnt, der sich mit den Aufgaben sogenannter „Ärztlicher Kommissionen“ befaßt. Im Entwurf heißt es unter anderem: „Gegenstand der Kommissionsarbeit soll beispielsweise sein: Die nachträgliche Überprüfung der Notwendigkeit operativer Therapieformen ... Die zu fassenden Beschlüsse werden durch Abstimmung verabschiedet...“ Am Beispiel meiner Abteilung würde das bedeuten, daß eine Mehrheit von Nichtneurochirurgen über die Notwendigkeit operativer Therapieformen zu entscheiden hätte. Ich glaube, jeder kann sich vorstellen, was das bedeutet: Totale Verbürokratisierung des ärztlichen Handelns, die Lähmung jeder Eigeninitiative, der Ersatz der persönlichen ärztlichen Verantwortung durch anonyme, inkompetente Mehrheitsbeschlüsse. Man fragt sich natürlich nach den Motiven derartiger staatlicher Eingriffe in ärztliches Handeln. Mir fallen nur zwei Antworten ein: Entweder ist es der Zwang, alles völlig verbürokratisieren zu wollen, oder ein immer noch tiefverwurzeltes Mißtrauen in die „Halbgötter in Weiß“, deren Hybris die der antiken Götter zu übersteigen scheint. Ich sehe nur zwei mögliche Reaktionsweisen: Entweder man gibt die Neurochirurgie auf, oder man arbeitet weiter und negiert die Bürokratie, die dann natürlich den Geldhahn zudrehen kann.

Ich kann mir kaum, um ein anderes Modewort zu gebrauchen, etwas „Transparenteres“ vorstellen, als eine neurochirurgische Klinik. Wenn etwas diagnostisch oder operativ mißlingt, dann läßt sich das nicht verheimlichen; oder nimmt der Gesetzgeber an, daß jede Schwester, jeder Pfleger und jeder Arzt, außer dem verantwortlichen Chef, mit Blindheit geschlagen ist? Warum läuft nicht jeden Tag eine Schwester zum Gericht, wenn all das in unseren Kliniken verpfuscht wird, was die Presse aufbauscht? Die Antwort ist sehr einfach: auch die jüngste Schwesternschülerin sieht sehr schnell, wie bei aller menschlichen Unzulänglichkeit, die niemand abstreitet, jeder einzelne sich um jeden einzelnen Patienten Tag und Nacht quält; sie sieht, daß trotz allen ärztlichen, pflegerischen und technischen Einsatzes unserem Handeln Grenzen gesetzt sind, und daß der Mensch eben keine Maschine und der Arzt kein Gesundheitsingenieur ist. Auch die jüngste Schwester erlebt sehr schnell das, was man als Solidarität unseres Faches bezeichnen kann, eine Solidarität in der gemeinsamen Arbeit und nicht im Vertuschen. Daß es dieses Zusammengehörigkeitsgefühl gibt, ohne das es wahrscheinlich keine Schwester länger als 4 Wochen in der Neurochirurgie aushalten würde, möchte ich in diesem Kreise dankbar anerkennen, dankbar dafür jedem einzelnen, der dazu beiträgt. Mancher mag – besonders in der Arbeit auf den Intensivstationen – gelegentlich den Eindruck haben, daß an technischem Einsatz zu viel geschieht, und damit komme ich zum letzten Punkt: dem Zwang der Intensivmedizin. Ohne Zweifel führt der Entscheidungszwang in der Intensivmedizin häufig zu einer Gewissenskollision, wobei die Entscheidung zum Handeln der bequemere Ausweg sein kann gegenüber der Entscheidung zur Unterlassung. Wir wissen alle, daß absolute Sachkompetenz die selbstverständliche Voraussetzung für diese Entscheidungen ist, und daß die Entscheidungen nicht frei von Emotionen sind. Bei allem Bemühen um Realitätsbezogenheit, Objektivität und Distanzierung vom Einzelfall glaube ich nicht, daß es sinnvoll, ja für ärztliches Handeln wünschenswert wäre, diese Emotionen ganz auszuschalten. Es gibt

nur einen Weg, den Entscheidungszwang zu bewältigen: die Gewissensentscheidung oder, anders ausgedrückt, die Bereitschaft, den Zwang zur persönlichen Verantwortung jederzeit zu akzeptieren.

Rolf Wüllenweber

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List of Senior Authors

AGNOLI, A. L.: Institut für Radiologie, Justus Liebig-Universität Gießen, Klinikstrasse 29, D-6300 Gießen (Federal Republic of Germany)

ALTENBURG, H.: Neurochirurgische Abteilung der Chirurgischen Universitätsklinik, Jungeblodtplatz 1, D-4400 Münster (Federal Republic of Germany)

BIRG, W.: Neurochirurgische Klinik der Universität Freiburg, Hugstetter Strasse 55, D-7800 Freiburg i.Br. (Federal Republic of Germany)

BLACK, P. M.: Department of Neurosurgery, Massachusetts General Hospital, Boston, MA 02114 (USA)

BROCK, M.: Medizinische Hochschule Hannover, Neurochirurgische Klinik, Karl-Wiechert-Allee 9, D-3000 Hannover-Kleefeld (Federal Republic of Germany)

CASPAR, W.: Neurochirurgische Universitätsklinik, D-6650 Homburg/Saar (Federal Republic of Germany)

CLAR, H.-E.: Neurochirurgische Universitätsklinik, Hufelandstrasse 55, D-4300 Essen 1 (Federal Republic of Germany)

DOMMASCH, D.: Neurologische Universitätsklinik im Kopfklinikum, Josef-Schneider-Strasse 11, D-8700 Würzburg (Federal Republic of Germany)

EBHARDT, G.: Institut für Neuropathologie, Klinikum Steglitz der Freien Universität Berlin, Hindenburgdamm 30, D-1000 Berlin 45 (Federal Republic of Germany)

ELIES, W.: Neurochirurgische Abteilung im Zentrum für Chirurgie, Calwerstrasse 7, D-7400 Tübingen (Federal Republic of Germany)

FAUPEL, G.: Neurochirurgische Klinik, Universität Mainz, Langenbeckstrasse 1, D-6500 Mainz (Federal Republic of Germany)

FROMEIN, R. A.: Neurochirurgische Universitätsklinik, Joseph-Stelzmann-Strasse 9, D-5000 Köln-Lindenthal (Federal Republic of Germany)

FUCHS, E. C.: Neurochirurgische Klinik des Klinikums Charlottenburg der Freien Universität Berlin, Spandauer Damm 130, D-1000 Berlin 19 (Federal Republic of Germany)

GAAB, M.: Neurochirurgische Universitätsklinik im Kopfklinikum, Josef-Schneider-Strasse 11, D-8700 Würzburg (Federal Republic of Germany)

- GERSTNER, L.: Neurologisches Institut, Schwarzspanier Strasse 17, A-1090 Wien IX (Austria)
- GRIMMER, A.: Neurochirurgische Klinik des Klinikums Charlottenburg der Freien Universität Berlin, Spandauer Damm 130, D-1000 Berlin 19 (Federal Republic of Germany)
- GRUMME, Th.: Neurochirurgische Klinik des Klinikums Charlottenburg der Freien Universität Berlin, Spandauer Damm 130, D-1000 Berlin 19 (Federal Republic of Germany)
- GRUSS, P.: Neurochirurgische Universitätsklinik im Kopfklinikum, Josef-Schneider-Strasse 11, D-8700 Würzburg (Federal Republic of Germany)
- HAMEL, E.: Neurochirurgische Universitätsklinik, Joseph-Stelzmann-Strasse 9, D-5000 Köln-Lindenthal (Federal Republic of Germany)
- HAMER, J.: Neurochirurgische Abteilung des Chirurgischen Zentrums der Universität Heidelberg, Kirschnerstrasse 1, D-6900 Heidelberg (Federal Republic of Germany)
- HARTMANN, A.: Neurologische Universitätsklinik, Vosstraße 2, D-6900 Heidelberg (Federal Republic of Germany)
- HEMMER, R.: Neurochirurgische Klinik der Universität Freiburg, Hugstetter Strasse 55, D-7800 Freiburg i. Br. (Federal Republic of Germany)
- HÖEFER, T.: Medizinische Hochschule Hannover, Neurochirurgische Klinik, Karl-Wiechert-Allee 9, D-3000 Hannover-Kleefeld (Federal Republic of Germany)
- KIM, Y. K.: 201, West Mc.Dowell St., Morgantown, NC 28655 (USA)
- KLETTER, G.: Neurochirurgische Universitätsklinik, Alserstrasse 4, A-1079 Wien (Austria)
- KLINGER, M.: Neurochirurgische Klinik der Universität Erlangen-Nürnberg, Krankenhausstrasse 12, D-8520 Erlangen (Federal Republic of Germany)
- KRAINICK, J.-U.: Neurochirurgische Klinik der Universität Freiburg, Hugstetter Strasse 55, D-7800 Freiburg i. Br. (Federal Republic of Germany)
- KRÜGER, J.: Zentrum der Neurologie und Neurochirurgie, Abteilung für Neurochirurgie, Universitäts-Klinikum, Schleusenweg 2-16, D-6000 Frankfurt/Main (Federal Republic of Germany)
- KÜHNER, A.: Neurochirurgische Abteilung des Chirurgischen Zentrums der Universität Heidelberg, Kirschnerstrasse 1, D-6900 Heidelberg (Federal Republic of Germany)
- LEYENDECKER, K.: Neurochirurgische Abteilung im Städtischen Krankenhaus Neukölln, Rudowerstrasse 56, D-1000 Berlin 47 (Federal Republic of Germany)
- MAUERSBERGER, W.: Neurochirurgische Klinik des Klinikums Charlottenburg der Freien Universität Berlin, Spandauer Damm 130, D-1000 Berlin 19 (Federal Republic of Germany)
- MEINIG, G.: Neurochirurgische Abteilung der Universitätsklinik Mainz, Langenbeckstrasse 1, D-6500 Mainz (Federal Republic of Germany)

- MENZEL, J.: Neurochirurgische Abteilung des Chirurgischen Zentrums der Universität Heidelberg, Kirschnerstrasse 1, D-6900 Heidelberg (Federal Republic of Germany)
- MILTNER, F.: Neurochirurgische Universitätsklinik im Kopfklinikum, Josef-Schneider-Strasse 11, D-7800 Würzburg (Federal Republic of Germany)
- NAU, H. E.: Neurochirurgische Universitätsklinik, Hufelandstrasse 55, D-4300 Essen 1 (Federal Republic of Germany)
- OBERSON, R.: Service de Radiologie, Centre Hospitalier Universitaire Vaudois, Bugnon 15, CH-1011 Lausanne (Switzerland)
- OLDENKOTT, P.: Neurochirurgische Abteilung im Zentrum für Chirurgie, Calwerstrasse 9, D-7400 Tübingen (Federal Republic of Germany)
- OPPEL, F.: Neurochirurgische Klinik, Klinikum Steglitz der Freien Universität Berlin, Hindenburgdamm 30, D-1000 Berlin 45 (Federal Republic of Germany)
- PALMA, A.: Neurochirurgische Universitätsklinik, Annaberger Weg, D-5300 Bonn-Venusberg (Federal Republic of Germany)
- SATO, O.: The Kanto Tershin Hospital, 5-chome, Higaski-Gotanda, Tokyo (Japan)
- SCHPELMANN, F.: Institut für Neurochirurgie der Justus Liebig-Universität Gießen, Klinikstrasse 29, D-6300 Gießen (Federal Republic of Germany)
- SCHLARB, H.: Neurochirurgische Abteilung im Städtischen Krankenhaus Neukölln, Rudowerstrasse 56, D-1000 Berlin 47 (Federal Republic of Germany)
- SCHÖTER, I.: Neurochirurgische Universitätsklinik, Annaberger Weg, D-5300 Bonn-Venusberg (Federal Republic of Germany)
- SCHRAMM, J.: Neurochirurgische Klinik, Klinikum Steglitz der Freien Universität Berlin, Hindenburgdamm 30, D-1000 Berlin 45 (Federal Republic of Germany)
- SIMON, G.: Neurochirurgische Abteilung im Krankenhaus Heidberg, Tangstedter Landstrasse 400, D-2000 Hamburg 62 (Federal Republic of Germany)
- SOLLMANN, H.: Neurochirurgische Abteilung des Klinikums Günzburg der Medizinischen Hochschule Ulm, Reisenburgerstrasse 2, D-8876 Günzburg (Federal Republic of Germany)
- SPOERRI, O.: Neurochirurgische Klinik und Poliklinik, Kliniken der Universität Göttingen, Gosslerstrasse 10, D-3400 Göttingen (Federal Republic of Germany)
- SPRING, A.: Neurochirurgische Abteilung des Klinikums Günzburg der Medizinischen Hochschule Ulm, Reisenburgerstrasse 2, D-8876 Günzburg (Federal Republic of Germany)
- SPRUNG, Ch.: Neurochirurgische Klinik des Klinikums Charlottenburg der Freien Universität Berlin, Spandauer Damm 130, D-1000 Berlin 19 (Federal Republic of Germany)
- TERHAAG, D.: Neurochirurgische Universitätsklinik Köln, Joseph-Stelzmann-Strasse 9, D-5000 Köln-Lindenthal (Federal Republic of Germany)
- THAL, H. U.: Medizinische Einrichtungen der Universität Düsseldorf, Moorenstrasse 5, D-4000 Düsseldorf (Federal Republic of Germany)

THOMALSKE, G.: Abteilung für Funktionelle Neurochirurgie im Zentrum für Neurologie und Neurochirurgie, Schleusenweg 2-16, D-6000 Frankfurt/Main 71 (Federal Republic of Germany)

TSCHABITSCHER, M.: Abteilung für Neurochirurgie der Universität Wien, Alserstrasse 4, A-1090 Wien (Austria)

WALLENFANG, Th.: Neurochirurgische Universitätsklinik, Langenbeckstrasse 1, D-6500 Mainz (Federal Republic of Germany)

WASSMANN, H.: Neurochirurgische Universitätsklinik, Annaberger Weg, D-5300 Bonn-Venusberg (Federal Republic of Germany)

WEIDNER, A.: Medizinische Hochschule Hannover, Neurochirurgische Klinik, Karl-Wiechert-Allee 9, D-3000 Hannover-Kleefeld (Federal Republic of Germany)

WICKBOLDT, J.: Neurochirurgische Universitätsklinik im Kopfklinikum, Josef-Schneider-Strasse 11, D-8700 Würzburg (Federal Republic of Germany)

WIEGAND, H.: Medizinische Hochschule Hannover, Neurochirurgische Klinik, Karl-Wiechert-Allee 9, D-3000 Hannover-Kleefeld (Federal Republic of Germany)

WÜLLENWEBER, R.: Neurochirurgische Klinik des Klinikums Charlottenburg der Freien Universität Berlin, Spandauer Damm 130, D-1000 Berlin 19 (Federal Republic of Germany)

YASARGIL, M. G.: Neurochirurgische Klinik der Universität Zürich, Kantonsspital, Rämistrasse 100, CH-8006 Zürich (Switzerland)

Lumbar Disc

Differential Diagnosis of Sciatica Analysis of 3000 Disc Operations

A. L. AGNOLI, H. POPOVIĆ, M. POPOVIĆ, R. SCHÖNMAYR and F. SCHEPELMANN

The following report on differential diagnosis of sciatica will be limited to the analysis of the role played by anomalies of the caudal dura sack root pockets and epidural vessels as a causative factor of sciatica.

The results are based on the analysis of approximately 3300 patients suspected of having lumbar disc herniation, the majority of whom were operated upon.

Case histories, X-ray pictures and operative findings were analysed with the aid of a questionnaire containing 160 questions. The obtained data were submitted to statistical analysis by computer.

1. Megacauda

The description of megacauda found in literature is based on autopsy and radiological findings. Its quantitative definition has not been established. For the purpose of this study the megacauda was defined as follows: the sagittal and coronal width of the caudal sack was measured on the myelogram, and the values multiplied. The theoretical diameter of the cauda was calculated in this way in 1520 patients, and its mean value and variance were established. The diagnosis of megacauda was attributed to cases in which the diameter of the caudal sack was greater than twice the variance of the mean value. According to this definition, a megacauda was found in 165 cases (11% of patients examined). In 8.5% of patients the megacauda was present additionally to a herniated disc. It is well known that the widening of the caudal sack may cause difficulties in diagnosing a herniated prolapse by myelography. In 2.5% of the examined cases the megacauda was not accompanied by a herniated disc. In such patients one may suppose that the sciatica is caused by a disproportion between the width of the caudal sack and that of the spinal canal.

2. Widening of the Nerve Root Pocket

Although widening of nerve root pockets is an anomaly of the cauda sack, some authors have named this condition a cyst. The fact that the widening of the nerve root pocket is demonstrable by myelography suggests that this is a diverticulum-like anomaly and not a cyst. Widening of a nerve root pocket was found in 181 of our cases (6%). The form of the widening was not uniform, and its size varied between 0.5 and 30.0 mm.

¹ This paper includes parts of the M.D. thesis of H. Popović and M. Popović.

A herniated disc was demonstrated by myelography or found at surgery additionally to the widening of the nerve root pocket in 5.4% of the cases. In 0.6% of the patients examined widening of the nerve root pocket alone was present. These figures support the view that widening of the nerve root pocket can cause sciatica. Such cases, however, are not frequent and the pathogenetic importance of this anomaly should not be overestimated.

3. Anomalies of the Site of Origin of the Nerve Roots

These anomalies are well known: common origin, common exit through the intervertebral foramen, y-shaped origin, horizontal course of the nerve root and interradicular connections. These anomalies most often involve the roots of L 5 to S 1 and S 2, and are usually detected during surgery. We were able to diagnose these anomalies preoperatively on 2 occasions with the aid of myelotomography. In our material, anomalies of nerve root origin were present in 1%. In 0.7% they were associated with a protruded disc, considered to cause of sciatica. In 0.3% the anomalous nerve root origin was the only finding at surgery. Histological examination of the sensory roots resected on 2 occasions revealed degenerative lesions.

4. Epidural Venous Anomalies

In a number of patients operated on with the clinical and myelographic diagnosis of protruded disc epidural venectasies and anomalies were found. Although the surgeon's judgement on the degree of venectasy is relatively subjective, 18.9% of the patients operated on were reported to have venectasies. In 15.9% they were accompanied by a protruded disc. In 3% venectasy was the only abnormal finding.

Because of their relatively frequent occurrence venectasies should be taken into consideration for the differential diagnosis of lumbar disc.

5. Angiomas

As compared to venectasies, the role of lumbosacral angiomas in causing sciatica is almost negligible. In our material they were present in 15 patients (0.5%) with sciatica. In none of them a disc herniation was found. The clinical picture was similar to that of a herniated disc. Myelography revealed the herniation in all cases. Xanthochromic CSF is an important differential factor. One should consider the possibility of an angioma in the patient with sciatica and xanthochromic CSF. In such cases selective spinal arteriography is indicated in order to establish preoperative diagnosis.

In 6.9% of all patients with sciatica anomalies of the dural sack, of nerve root pockets, or of epidural vessels constitute the only cause of signs and symptoms.

Table 1. Frequency of lumbosacral anomalies with and without herniated lumbar disc

	Total No.	With herniated disc No.	Without herniated disc No.
Megacauda	160	124	36
Widening of the root pocket	181	164	17
Abnormal origin	30	22	8
Venectasy	246	190	56
Angioma	15		15

Table 2. Relative frequency (in %) of lumbosacral anomalies with and without herniated lumbar disc

	Total %	With herniated disc %	Without herniated disc %
Megacauda	11.0	8.5	2.5
Widening of the root pocket	6.0	5.4	0.6
Abnormal site of origin	1.0	0.7	0.3
Venectasy	18.9	15.9	3.0
Angioma	0.5		0.5

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Fig.1

Fig.2

Fig. 1. O.K., 43 years. M. Low back pain for 15 years and sciatica for 5 years. No neurological defects. Megacauda

Fig. 2. P.H., 47 years. F. Herniated lumbar disc 44/5 rt.: symmetrical widening of the nerve root pockets



Fig.3



Fig.4

Fig. 3. W.H., 22 years. M. Low back pain and sciatica for 2 years. No Neurological anomalies. Myelotomography: common origin of the roots S 1 and S 2 on the left side

Fig. 4. T.W., 19 years. M. Acute sciatica on the right side with weakness of right foot dorsiflexion. Myelography: Suspected herniated disc. At surgery epidural angioma

"Typical Symptoms of a Protruded Lumbar Disc" in Cases of Lumbar Spinal Tumors

H.-E. NAU and H.-E. CLAR

Introduction

As a rule the history and clinical symptoms of a prolapsed lumbar disc are characteristic. In some cases, however, this typical picture can also be found in other diseases, e.g. multiple sclerosis (6), spondylolisthesis (4), or spinal tumor (1, 3, 5, 8, 10, 11). In the present paper we have analysed a group of patients with lumbar spinal tumors originating symptoms of a protruded lumbar disc.

Material

During the past seven years 1956 lumbar herniated discs have been operated on at the Neurosurgical Clinic of the University of Essen. In 13 cases with typical lumbar disc symptoms a lumbar spinal tumor was found. Seven patients were male and six were female. The ages ranged from 16 to 74 years, excluding the middle age. During the period of observation, a total of 237 patients with spinal tumors was treated.

Results

Clinical History

Pain was the first symptom in all cases. Its duration varied from six weeks to thirteen years. Two patients had a lumbago, the rest a sciatic syndrome, which was bilateral in two cases. Pain course was intermittent in all cases. Pain was increased by increasing cerebrospinal fluid (CSF) pressure (coughing, sneezing, pressing) in seven cases. Severe nocturnal pain occurred only once preoperative diagnosis of a herniated disc had been established in all patients, and they were treated as such with relief of pain in four cases. Two cases had previously been treated for a carcinoma (of collum uteri and mamma).

Neurological Examination

A typical monoradicular nerve root compression syndrome was found in 7 cases. It was polyradicular in 3 with preponderance of L 5 and S 1. Only 2 patients had bilateral symptoms. Typical postural anomalies without neurologic deficit were seen in 3 cases. Bladder and bowel dysfunction was found in 5 cases.

X-Rays

X-ray studies were performed in all patients. Myelography was made in 12 cases. Local bone alterations indicating a space-occupying process were verified by plain X-rays in 6, the process itself by myelography in eleven cases.

Operative Method

Because of the clinical and myelographic findings we first performed a flavectomy. In six cases we had to extend the exposure to a hemilaminectomy to permit total removal of the tumor. In 4 cases we did a laminectomy from the beginning because of the myelographic aspect. The nerve roots were compressed in all cases; once there was a compression by a protruded disc caused by tumor infiltration, in another case the tumor invaded the nerve root, and in the rest of the cases the nerve roots were only compressed by the tumor. There was a coherence between clinical and operative findings in all cases.

Histology

Histologically the tumors were classified as sarcoma in four cases, neurinoma in three cases, carcinoma in two cases, and one case each of plasmocytoma, enchondroma, angiomatous bone cyst, and dermoid cyst.

Postoperative Course

The most impressive fact following decompression of the nerve root was the relief of pain. There was also a decrease in the preoperative motor and vegetative deficit in all patients.

Discussion

There are only a few publications dealing with the preoperative differentiation between protruded lumbar discs and spinal tumors. Some authors (3, 5, 7) emphasize certain anamnestic and clinical findings. Pain was the first symptom in nearly all cases in literature. Duration of pain was not characteristic. The statements of CRAIG and co-workers (3), and of BROWN (2) that nocturnal pain is characteristic of spinal tumors could be confirmed in only one case of the present series. The increase of pain with increasing CSF pressure, typical for a protruded disc, was also observed in cases of spinal tumors. A relief of pain by conservative therapy occurred not only in cases of protruded disc, but also in four patients with tumor (11).

It was not possible to differentiate disc protrusions from tumors by clinical examinations (7). Conversely, an analysis of the plain X-ray films showed vertebral destruction or sclerosis or foraminal widening in nearly half the cases. NITTNER (9) found vertebral alteration on the X-ray films in 40% of benign and malignant spinal tumors. We found a complete myelographic block in only 4 cases, an indentation of contrast medium in seven. This agrees with the findings of CRAIG and co-workers (3). The operative approach was influenced by the clinical symptoms. We first performed flavectomy corresponding to the location as established clinically and by myelography. This procedure proved beneficial since a decompression of the nerve roots was achieved. Only in some cases we had to extend the procedure to a hemilaminectomy. A laminectomy was made only in cases with complete myelographic block.

As opposed to other authors (2, 3, 7) we believe it impossible to secure a preoperative differentiation between protruded disc and spinal tumor with the aid of clinical history and examination only. Radiological alterations of the vertebrae, however, cast doubt on the etiology of protruded discs.

Summary

Thirteen cases of lumbar spinal tumors with symptoms simulating typical protruded discs were analysed. We believe preoperative differentiation to be impossible. Only radiological findings such as vertebral destruction or sclerosis, or atrophy as a result of tumor pressure cast doubt on the etiology of a herniated lumbar disc.

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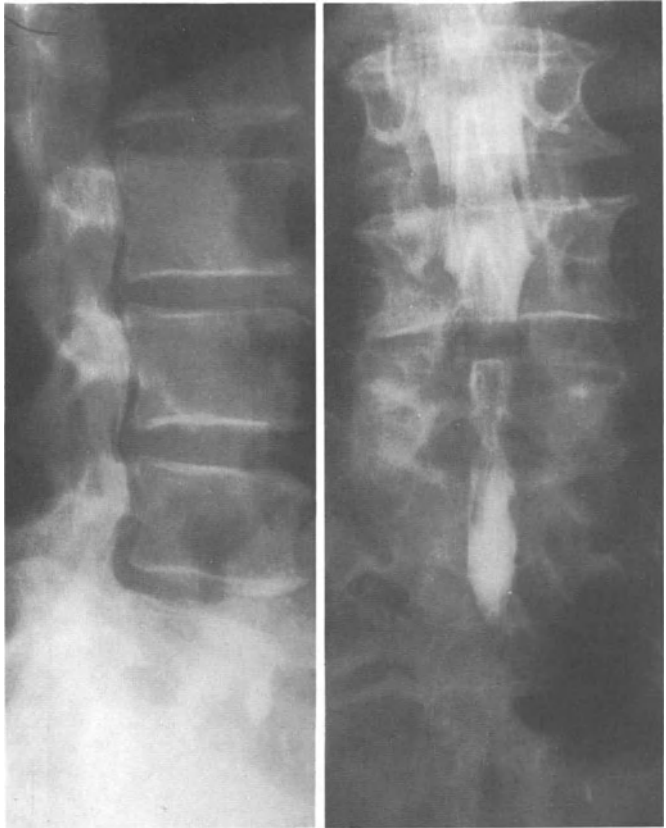


Fig. 1. Indentation of contrast medium imitating a protruded disc in a 74 years old patient with a sarcoma

Difficulties Encountered in the Differential Diagnosis of Prolapsed Lumbar Intervertebral Disc (Vertebral Metastases - Polyneuropathy)

G. SIMON

In this paper the differential diagnosis between lumbar disc prolapse and two diseases which simulate this condition is discussed. The first is the vertebral metastasis, which, similar to the protruded disc, may cause irritation and compression of the nerve root; the second is a primary polyneuropathy due to metabolic disorders, in the course of which a herniation of the intervertebral disc may occasionally develop.

Vertebral Metastases

It is unusual to find vertebral metastases in the lumbar region of the spine, and this is certainly one of the reasons why there was hardly any need for us to consider it under the aspect of a differential diagnosis. However, since we have extended the indication of surgery to include higher age groups, we must expect the diagnosis of vertebral metastases to increase. Experience has shown that metastasis occurs mainly in the cervical and thoracic regions of the vertebral column and that they lead to a neurological deficit ranging to paraplegia. In the lumbar region of the vertebral column the spinal canal is wide and the space-occupying process may extend considerably before giving rise to manifest compression syndromes. Only a short segment of the nerve root may be affected at an early stage. In such cases neurological and myelographic findings are frequently obtained which - if no signs of bone destruction are detected - suggest the diagnosis of a "slipped disc", mainly if there is a history of vertebral disease.

In about 2,000 patients operated on for lumbar disc herniation between 1970 and 1975, a vertebral metastasis was diagnosed in the neighbourhood of the protrusion in eight cases. In three instances it involved vertebral arch of the 4th, in four cases that of the 5th and in one case that of the 5th lumbar vertebra and the sacrum. Among these patients 5 were female and 3 male, aged between 56 and 68 years. The syndrome, the neurological findings of root damage and myelography provided reliable evidence as to the presence of a herniated disc in all cases. The general findings were inconclusive and by no means such as to suggest primarily the existence of a malignancy. The surgical findings - and this is probably the most important aspect - confirmed the clinical suspicion of a protruded disc in all cases. Bulging and partly extruded disc material was found. The operating field resulting from the usual fenestration did not reveal anything remarkable. Histologically the tissue obtained from the intervertebral space and the protruded disc tissue revealed the typical degenerative changes. The postoperative course was uneventful. Radicular symptoms quickly subsided. A single symptom remained, which did attract attention and which, eventually, led to the final diagnosis: the persistend dull pain in the region operated on. With no exception all patients complained about this circumscribed pain in the operating area which increased under

strain. At subsequent examinations between the 6th week and the 4th month radiographic evidence of a homolateral destroyed arch was obtained. At surgery the metastasis was then found. Histological examination revealed an undifferentiated anaplastic carcinoma in 5 cases and a metastasis of a bronchial carcinoma in 3 patients.

It goes without saying that we subsequently asked ourselves whether the primary diagnosis of protruded disc had been correct. There was no doubt about it to judge from both the clinical as well as from the surgical findings. If further time had been allowed to elapse, the bony metastasis would have been detected at radiography, and tumor as well as tissue would probably have been found at surgery. I therefore believe that actually both diseases had been present.

Polyneuropathies

The second disease which is important from the point of view of differential diagnosis is diabetic polyneuropathy. In such cases we have the picture of a confirmed polyneuropathy which has existed for some time, which has also received treatment, but still causes symptoms. In the further course of the disease, unilateral radicular deficit and pain develop and worsen progressively. The initial diagnosis was still considered correct when re-examining the findings. Only a renewed clinical examination, and additional neuroradiological findings on myelography led to the diagnosis of a protruded disc.

We had to face the difficult question of surgical indication in eleven cases. Findings were unequivocal at the roots L5, S1 and L4 in the 6 male and 5 female patients aged 50 to 64 years. At surgery we found protruded intervertebral discs in eight cases, four of which were situated mediolaterally and had affected 2 roots. In the remaining cases, narrowing of the spinal canal as a result of massive spondylotic changes played a far more important role and root compression was present at two levels uni- and bilaterally.

Patients presenting with a lumbar disc should give rise to considerations leading to the differential diagnosis with vertebral metastasis and polyneuropathy. The reason for this is that surgical indication is being extended to older patients. The statistical comparison of two patient series, from 1965 to 1969 and from 1970 to 1975 suggests this approach.

Lumbar Disc Protrusion in Childhood and Adolescence

I. SCHÖTER and W. ENTZIAN

Degenerative lesions of the vertebral column are rare in children and adolescents. The basis for the development of disc protrusions is established early in life. The disc of a new-born child still has some regular blood supply by vessels (11) which obliterate within the first four years (2). Thereafter the nutrient process is merely by diffusion, what corresponds to the beginning disc involution (14). JOCHHEIM, LOEW and RÜTT described regressive alterations in the annulus fibrosus of 15-year-old patients. In our opinion the onset of disc degeneration may occur much earlier.

During the last 30 years we operated upon 5236 patients who suffered from a degenerated vertebral disc, 4695 of them being lumbar and 541 cervical. Among the patients with a lumbar disc protrusion there were 56 children and adolescents (22 girls and 34 boys) from 11 to 20 years of age, corresponding to 1.2%. Two fusions of the cervical spine were performed in juveniles aged 15 and 17.

In disagreement with the literature (4, 8, 15) we found exactly the same signs of radicular compression in children as in adults:

- lumbar stiffness and positive LASEGUE in 46 cases;
- asymmetric reflexes in 30 cases;
- paresis in 16 patients, among whom 6 of the 7 youngest children;
- alterations of sensibility of radicular distribution in 32 cases;
- syndrome of the cauda equina in 2 patients;
- positive findings in 28 of 33 myelograms;
- augmented CSF-protein in 20 of 33 examined cases.

The protrusion of the fifth lumbar disc occurred most often: in 9 girls and 16 boys. Eight girls and 11 boys were operated upon the fourth lumbar disc, 5 girls and 6 boys on both of them. The third lumbar disc was degenerated in one girl and one boy. A second operation for recurrence was necessary in 5 cases: once at the same level while in 4 patients the neighbouring disc had degenerated subsequently. All histological examinations revealed degenerated disc tissue.

Follow-up extends from 5 months to 22 years: two thirds of the operated patients are free from pain and neurological symptoms. Paresis is regressive in all cases. One third still has some lumbar pain upon physical efforts.

Among the total of 4695 operated patients, the lumbar disc protrusion occurred far more often in the male than in the female both in children and adolescents as well as in adults up to an age of 83. Male predominance in disc degeneration should be discussed. Among other factors, it may be related to:

- loss resistant connective tissue (12)
- trauma (1, 3, 5, 6, 8, 10)
- rapid growth during adolescence or muscular inadequacy (10).

The greater physical strain more common among males is considered to be of importance (9, 13).

Summary

Lumbar disc protrusion in children and adolescents was observed in 1.2% of 4695 operated patients. Clinical, myelographic and CSF-findings are identical with those of adults. In juvenile disc degenerations the fifth lumbar disc is involved most often. Two thirds of the patients have no complaints after surgery. The greater physical strain common among males is considered to be of importance for the male predominance in disc degeneration.

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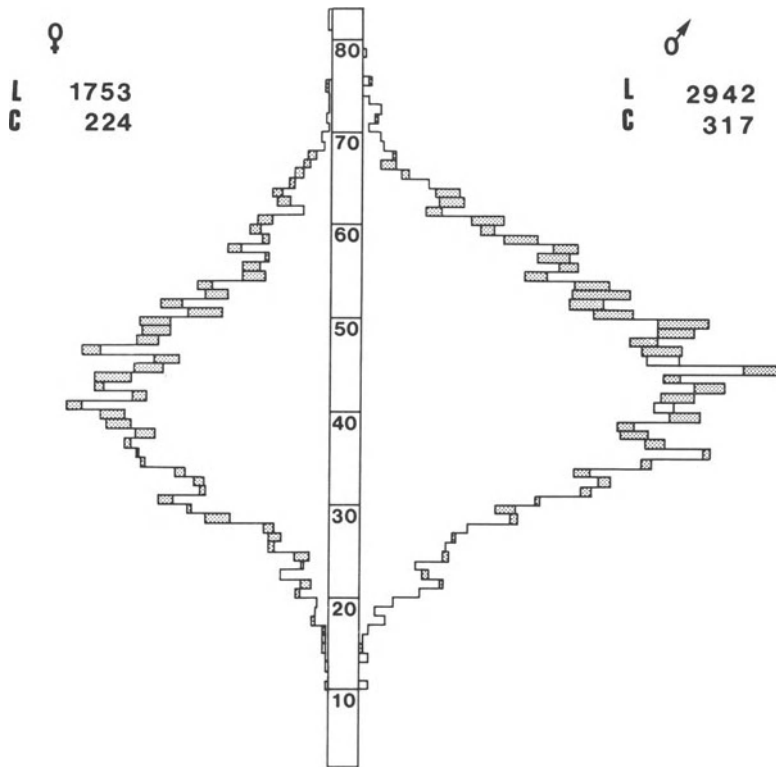


Fig. 1. Distribution of age, sex and location among 5236 cases of disc degeneration (hatched = cervical fusions)

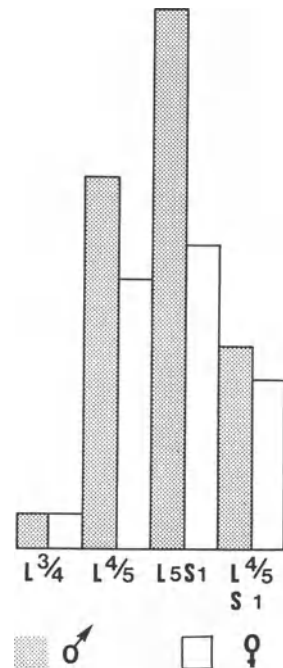


Fig. 2. Location of disc protrusion among 56 children and adolescents operated on (hatched = males)

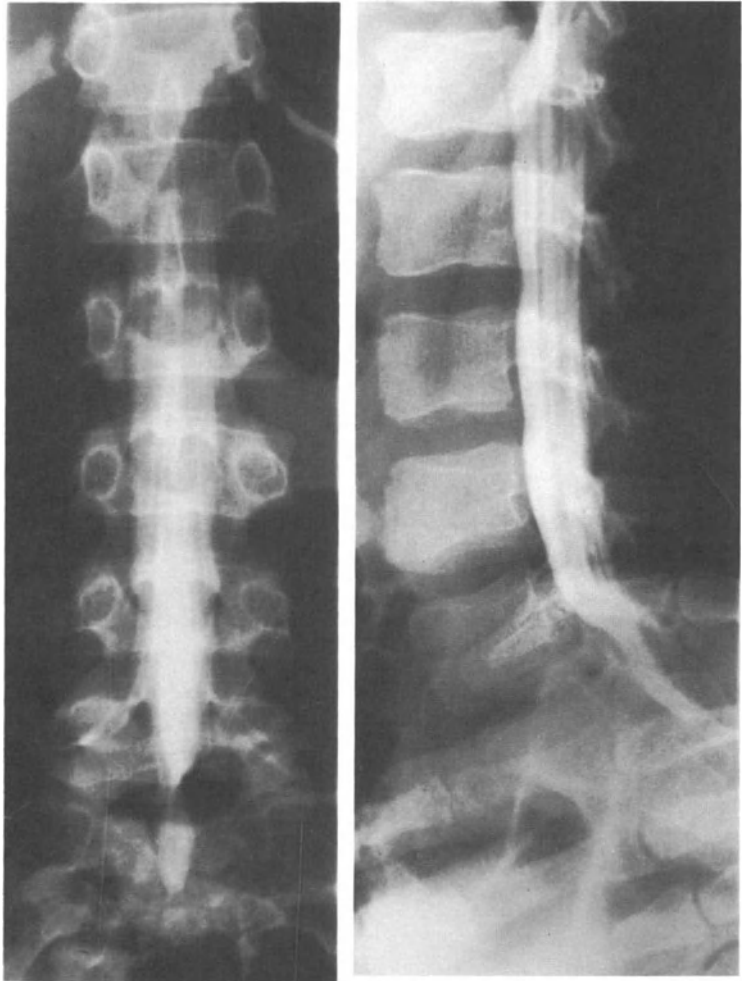


Fig. 3a and 3b. 11-year-old boy with protrusion of the fifth lumbar disc on the left side

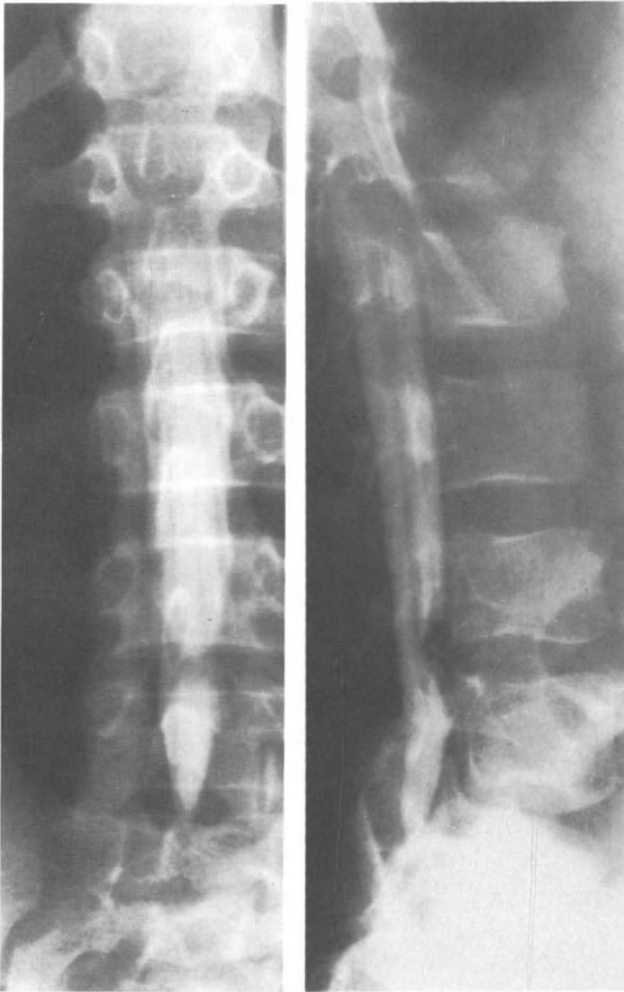


Fig. 4a and 4b. 14-year-old boy with protrusion of the fourth lumbar disc on the left side



Fig. 5. 20-year-old girl with protrusion of the fifth lumbar disc on the left side and syndrome of cauda equina

Lumbar Disc Protrusion in Advanced Age

K. LEYENDECKER, TH. HINZPETER, E. FLIEDNER, E. PFINGST, M. SCHIRMER, and
F. SCHÖNBERG

The hydrodynamic properties of the human intervertebral disc are determined by the water binding capacity of its nucleus. Due to the continuous decrease of the colloid osmotic pressure within the nucleus pulposus, its rupturing force and its elastic tension decline with increasing age.

Ageing and dehydration of the nucleus would make one expect that the disc of the old patient is incapable of giving rise to extrusion of soft gelatinous material.

3166 patients of the neurosurgical departments of Berlin-Neukölln and Hamburg-Altona operated on for lumbar nerve root compression were therefore analysed. Of these, 135 (4%) were older than 64 years (Fig. 1). Of these, 48 were older than 70, 3 older than 80. Ten patients underwent surgery for recurrent disc. The remaining 125 patients older than 64 and operated on for the first time were divided into two groups according to the anatomical and pathological findings at surgery:

A. Among 46 patients the nerve root compression was found to be caused by osseous changes only in 17 cases. Twenty-nine showed a soft disc protrusion in addition to these osteochondrotic changes (Fig. 2).

B. In 79 patients (63% of the total of 125) a so-called 'soft disc' without marked osseous changes was demonstrated at surgery. More than half of these (44 cases) had perforated the posterior longitudinal ligament.

The high incidence of soft disc protrusions which, on macroscopical and microscopical examination, were similar to those of younger patients, is somewhat surprising.

At surgery the usual practice of interlaminar fenestration proved sufficient in 89 patients (66%). In 21% a hemilaminectomy, in 13% a laminectomy was necessary. The number of L4/L5 discs by far outnumbered the lumbosacral ones (73% versus 20%). In a third of our patients the operative risk was increased by diabetes mellitus, arterial hypertension, cardiopulmonary insufficiency, or recurrent thrombophlebitis. Three patients (2%) died postoperatively, two of these from cardiopulmonary complications. One female patient suffered a cerebral infarction with hemiplegia on the 5th postoperative day and died 4 months later. CSF leakage was observed in one case, 4 patients had wound infections. In one patient a space-occupying epidural hemorrhage caused progressive compression of the cauda equina. After evacuation of the hematoma by laminectomy the patient recovered without neurological deficit. Few patients showed transient states of confusion lasting for 2 to 3 days. All patients were mobilised as early as possible. Despite a slightly prolonged convalescence, the results were satisfactory. 10 patients with predominantly osteochondrotic changes did not benefit

from the operation. In 82 patients (65%) a typical rapid improvement of the painful nerve root compression was observed. These results corresponded to those seen in younger age groups, when a soft prolapse is found at surgery in addition to neurological and myelographic findings.

Discussion

Apart from osteochondrotic, spondylotic, and spondylarthrotic changes of the vertebral column, typical disc protrusions can occur in old age. Eleven patients over the age of 70 had extruded disc material and perforation of the posterior longitudinal ligament. Dehydration and degeneration of the nucleus pulposus are typical changes associated with old age. Despite this fact, fissures in the slackening annulus fibrosus make it possible for the remaining nucleus material to extrude even in patients over the age of 80.

This seems to apply particularly to the segment L4/L5, while the stressed lumbosacral segment shows marked osteochondrosis and is usually 'burnt out'.

Nerve root compression caused by spondylotic changes alone may respond favorably to surgery when the lesion can be localized accurately both clinically and by myelography, and when extensive decompression is achieved.

The overall mortality appears low, the changes of alleviation or relief of pain are high. The surprising number of typical soft disc lesions even in advanced age seems to justify a more aggressive approach.

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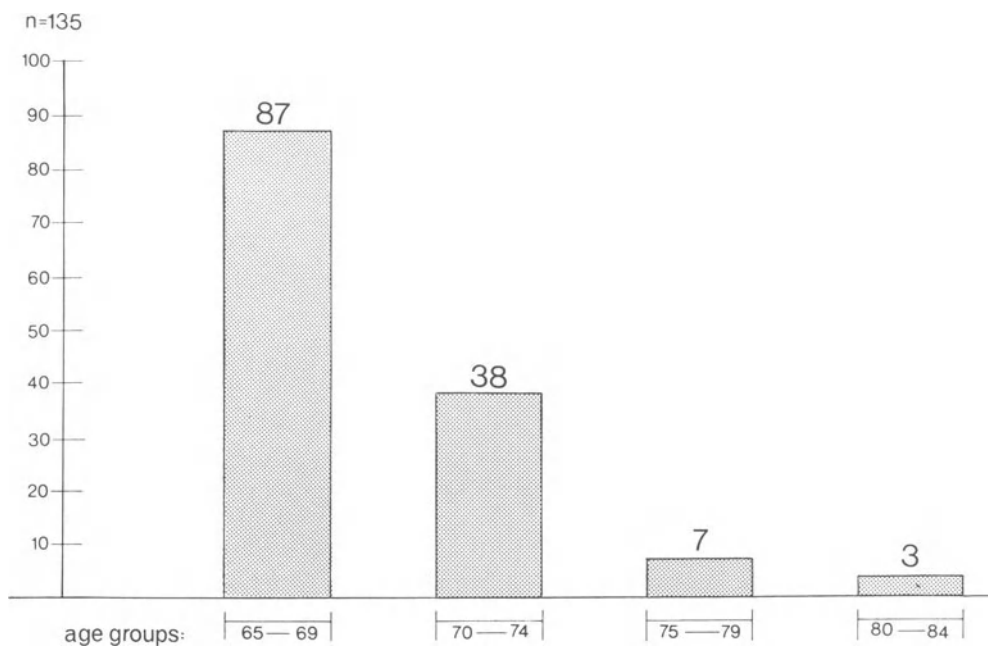
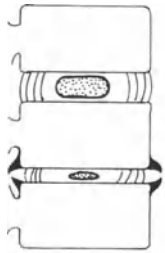


Fig. 1. Lumbar disc operations after the age of 64



Fig. 2 (above). Lumbar disc prolapse after the age of 64

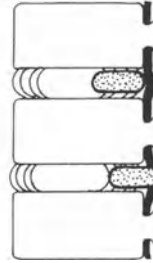


Fig. 2 (below). Segmental localization of typical prolapse after the age of 64





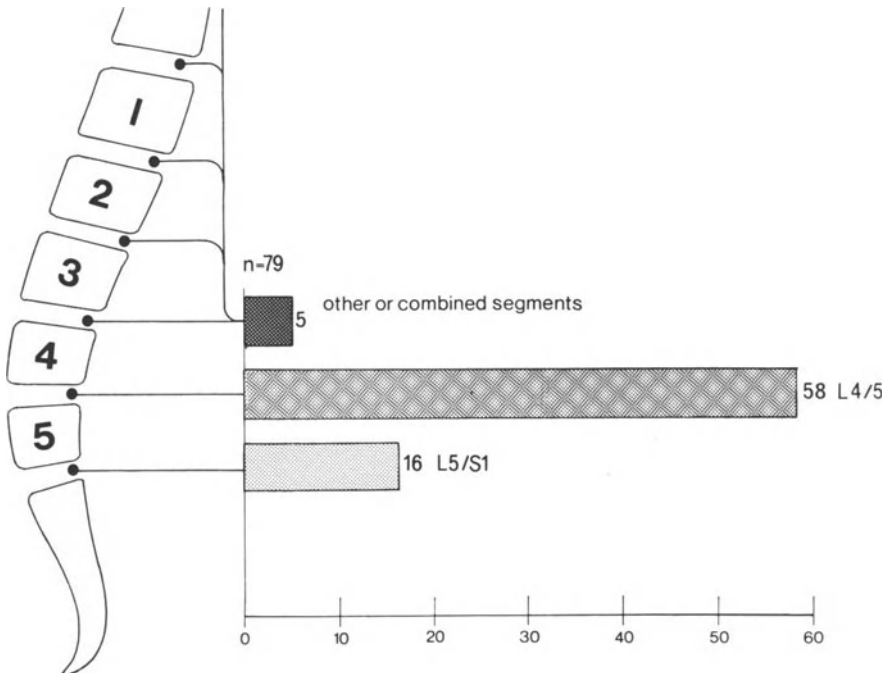
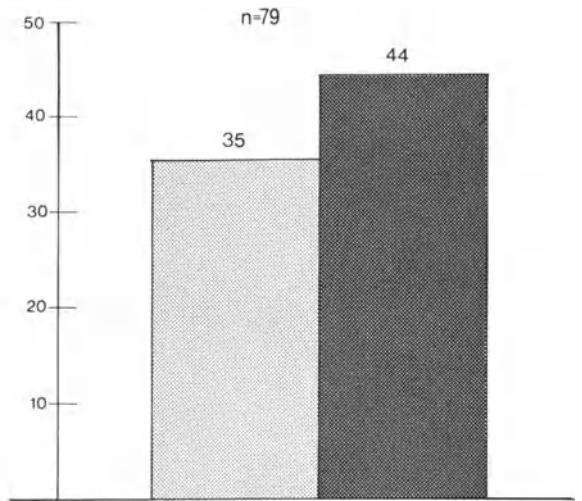
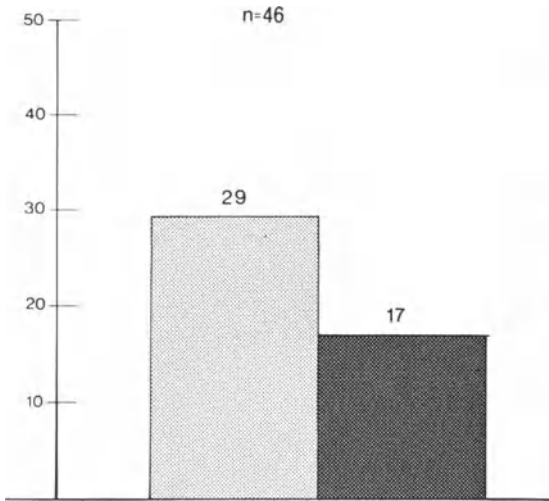
WITH osseous compression of the nerve root

 only osseous compression
 combination of prolapse with osseous compression



WITHOUT osseous compression of the nerve root

 typical prolapses without
 with perforation of the lig. longitud. posterius



Critical Comments on a Comparison of Two Series (1000 Patients Each) of Lumbar Disc Surgery

G. THOMALSKE, W. GALOW, and G. PLOKE

Introduction

In 1973, together with KÖNIG and MOHR (2) we published a review of the clinical observations and results of surgical therapy in 1000 patients with lumbar disc lesions, in which the records as well as follow-up studies were evaluated. The results of this series were surprisingly favorable, especially with respect to the relapse frequency. However, the question remained open as to what extent wandering away of patients with a poor postoperative course to other clinics might have been a source of error in the evaluation.

Material and Methods

A questionnaire was, therefore, prepared and sent to further 1328 patients operated upon after the first series. 1039 patients (=78%) answered the questionnaire. The first 1000 answers of this series were evaluated anew and compared with the earlier series of 1000 patients. The questionnaire contained 13 questions on the current state of health of the patients and on the postoperative course hitherto. Special allowance was, therefore, made for the subjective assessment by the patients.

Results and Discussion

The following observations were made:

In the first series the proportion of men to women was 63.5% to 36.5%, in the second series, 58.8% to 41.2%.

A comparison between the first and second series as concerns lumbar radiculography showed agreement between the radiculogram and the surgical finding in 90.0% as compared to 86.7%, no agreement in 6.3 as compared to 4.1% and an unclear result in 2.2 as compared to 0.8%. Radiculography was not performed in 1.5% of the first series and 8.4% of the patients in the second series due to the severity of symptoms (see Table 1).

The decrease in frequency of agreement between the radiculogram and the surgical findings and the rise in the number of operations without radiculogram indicate that, with increasing material, indication in the second series was not restricted as in the first. Reduction in number of unsatisfactory radiculograms indicates growing experience (2, 4).

Table 1. Correlations between radiculographic and surgical findings in both series

Finding	Number of patients	Number of patients
	Series I N = 1000	Series II N = 1000
a) Radiculogram + Surgical finding +	866 = 86.6%	862 = 86.2%
b) Radiculogram - Surgical finding -	34 = 3.4%	5 = 0.5%
a) and b)	900 = 90.0%	867 = 86.7%
c) Radiculogram + Surgical finding -	40 = 4.0%	32 = 3.2%
d) Radiculogram - Surgical finding +	23 = 2.3%	9 = 0.9%
c) and d)	63 = 6.3%	41 = 4.1%
e) Radiculogram dis- carded for tech- nical reasons	22 = 2.2%	8 = 0.8%
f) Radiculogram not per- formed because of severity of symptoms	15 = 1.5%	84 = 8.4%

Analysis of the mode of manifestation of the symptoms leading to operation also showed differences. However, these have no appreciable pro-
sological significance. It should be mentioned that acute symptoms
appearance was indisputably a result of an accident in 2.2% of cases
in the first series and 2.3% of cases in the second series. Thus con-
sistent figures for traumatic genesis were found in both series. As
regards the duration of preoperative pain, the number of patients with
a short anamnesis of a few days had fallen from 8.5% in the first se-
ries to 1.1% in the second series. A week-long anamnesis was recorded
in 13.4% of the first series as opposed to only 3.3% in the second se-
ries. Previous histories lasting months were also reduced from 24.6%
to 18.1%, while those lasting years rose from 47.5% to 70.3% (see
Table 2). It remains unsolved whether this is due to the increasing
publicity of good results. Formerly only unequivocal and recent cases
were referred to the clinic. Now the referring colleagues decide more
often to refer patients who have suffered from relapsing episodes dif-
ficult to influence therapeutically over a period of years.

Table 2. Duration of previous pain history in both series

Duration of pain history	Number of patients / % of the total	
	I N = 1000	II N = 1000
Days	85 = 8.5%	11 = 1.1%
Weeks	134 = 13.4%	33 = 3.3%
Months	246 = 24.6%	181 = 18.1%
Years	475 = 47.5%	703 = 70.3%
No precise data	60 = 6.0%	72 = 7.2%

Table 3. Age distribution of the operated patients in both series

Age (in years)	Number	%
	I N = 1000	II N = 1000
11 to 30	88 = 8.8%	81 = 8.1%
31 to 40	313 = 31.3%	294 = 29.4%
41 to 50	331 = 33.1%	350 = 35.0%
51 to 60	214 = 21.4%	202 = 20.2%
61 and over	54 = 5.4%	73 = 7.3%

Table 4. Location of the disc damage in both series

	Number of discs operated on	Number of discs operated on
	I N = 1000	II N = 1065
L 1/2	1 = 0.1%	0 = 0.0%
L 2/3	15 = 1.5%	3 = 0.28%
L 3/4	80 = 8.0%	46 = 4.3%
L 4/5	470 = 47.0%	520 = 48.8%
L 5/S 1	371 = 37.1%	459 = 43.1%
Lumbosacral transition vertebra	63 = 6.3%	37 = 3.5%
Sum	1000	1065
2 discs operated on at the same time	-	61 = 5.73%
3 discs operated on at the same time	-	2 = 0.19%

In the second series, the sum of the discs operated on is higher than 1000, since 61 patients were operated on at 2 levels and two patients at 3 levels.

Age distribution showed only insignificant shifts in both series. The majority of patients are in the age range of 31 to 60 years (85.8% of the first series and 84.6% of the second series). The number of those over 60 has risen from 5.4% in the first series to 7.3% in the second series (see Table 3). An improved anesthetic technology has extended surgical indication to comprise also older patients.

With respect to the location of the damaged disc, in the second series the frequency of its localization at L 4/5 exceeded that at L 5/S 1 by 5.7% (in the first series by 9.9%) (see Table 4). This contrasts with the data of the literature.

Free sequesters were found in 45.2% (33.2% in the first series (1)), prolapses in 22.5% (44.8% in the first series), protrusions in 31.0% (18.8% in the first series), bony compressions in 1.4% (3.2% in the first series) (see Table 5). The significantly larger number of operated protrusions in the second series may show that recently indication has been much broader than previously.

According to the patient records, the rate of complete relief was not as good at the time of release from the hospital as in the first series. This was also reflected in the results of later follow-up examinations. However, the results of the questionnaire in the second se-

Table 5. Surgical findings in both series

Type of compression	Number of discs operated on	
	I N = 1000	II N = 1065
Free sequesters	332 = 33.2%	481 = 45.2%
Lateral prolapse	345 = 34.5%	200 = 18.75%
Median prolapse	103 = 10.3%	40 = 3.7%
Protrusion	188 = 18.8%	330 = 31.0%
Osteophytes	32 = 3.2%	14 = 1.35%
Sum	1000	1065, since several discs were operated on in some cases

Table 6. Results of operation in both series

Result of operation	Number of patients	
	I N = 1000	II N = 1000
Cured	480 = 48.0%	603 = 60.3%
Improved	451 = 45.1%	329 = 32.9%
Not improved	69 = 6.9%	68 = 6.8%
Sum	1000 = 100%	1000 = 100%
True recurrence	21 = 2.1%	36 = 3.6%
Pseudo-recurrence:		
New slipped disc other than operated on before	34 = 3.4%	20 = 2.0%
Scar	9 = 0.9%	13 = 1.3%
Arachnoiditis	5 = 0.5%	2 = 0.2%

The number of true recurrences and pseudo-recurrences in the second series is larger than the number of patients classified as not improved, since various patients improved after the second operation.

ries support the assumption of a further improvement with increasing time lapse from the operation; the results (i.e. patient records and findings at follow-up examinations) were better than in the first series.

In addition, these findings indicate that patients in the second series have been given a shorter hospital treatment, i.e., they were frequently released before the symptoms of radicular irritation had disappeared.

According to hospital records and to the follow-up findings, 48% of the patients in the first series declared themselves to be "cured". In the second series, the corresponding figures were 36.4% in the hospital records and 60.3% in the questionnaire survey (see Table 6).

In the first series 45.1% were "markedly improved"; in the second series, 62% according to the patient records and 66.6% according to the questionnaire data. This high number of improved patients in proportion to the "cured" is due to the fact that patients who declared themselves to be cured frequently also answered with "yes" in the questionnaire the question as to significant improvement.

"No marked improvement" or only "transient improvement" were stated by 6.9% of the total in the first series; by 1.6% of the second series according to the patient records and by 6.8% of the cases according to the questionnaire data, i.e. to the same extent as in the first series.

The reason for this failure of the first operation were:

1. *True recurrence* of the disc already operated upon in 2.1% of the first series, and in 3.6% of the second series for patients whose first operation was performed by us. Two percent of the patients were operated upon because of true recurrence following surgery in other hospitals.
2. *Pseudo-recurrence* due to (3):
 - a) *New slipped discs other than those operated upon* before as observed in 3.4% of the first series and in 2.0% of the second series for cases operated at our unit.
 - b) *Strong scar formation* resulting in pseudo-recurrence phenomena without renewed prolapse of disc tissue as seen in 0.9% of the first series and 1.3% of the second series.
 - c) *Arachnoiditis* causing pseudo-recurrence in 0.5% of those operated in the first series, and in only 0.2% in the second series.

The reasons for the rise in the true recurrence rate from 2.1% in the first to 3.6% in the second series in the cases we operated upon are believed to be due to the following circumstances:

1. Recurrences may appear only after a rather long time.
2. Indication was posed more generously with time.
3. Appreciably more protrusions were operated upon in the second series (31.0% as compared to 18.8% in the first series).
It is well-known that in the case of a protrusion it is more difficult to clear the disc region as completely as in the presence of a prolapse or of sequestration. In the latter, the edge of the disc is frequently demarcated by degeneration, while in the presence of a protrusion they still adhere very firmly.

The results of the second operation for a true or pseudo-recurrence were as follows: 25% of the true recurrences, 30.4% of the pseudo-recurrences by a new disc lesion other than that operated on before and 36.9% of the pseudo-recurrences by hypertrophic scar formation and by arachnoiditis had a complete relief.

An improvement by the second operation was obtained in 71.9%, 69.6% and 52.6% respectively. While evaluating the questionnaire of the second series we noticed that the results of the patients from the terminal phase of the period of investigation were appreciably poorer than those recorded at its beginning (1969), and that further improvement is seen with increasing distance in time from the operation. In this context, psychic components in a negative appraisal of the surgical results must be discussed. Persisting low back pain was frequently attributed to the operation, even when they did not significantly exceed those occasionally felt by unoperated patients. Without exception, *physicians* reported good results of the operations performed on

them. There was a similar result in patients who were *already retired*. the converse was seen in *foreign workers*, almost all of whom reported poor results.- Back pain very frequently is the manifestation of a latent depression. A depressive component may well contribute to the unfavorable appraisal of the result mainly in the case of foreign workers during phase of world-wide economic depression coinciding with the end of our second investigation period.

Summary

Lumbar disc surgery provides highly satisfactory results if the intervertebral space is cleared as far as possible. We compared 1000 patients followed on the basis of our hospital records and follow-up studies with 1000 additional patients who also received a questionnaire. The correlation between diagnostic and surgical findings as well as the results of surgery are presented in tabular form and discussed. Questionnaire answers gave a more favorable picture than that conveyed by our clinical records at the time of the last examination. Only 6.9% (first series) and 6.8% (second series) of the patients showed no profound or only transient improvement following surgery, i.e. the result of operation was favorable in more than 93%.

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A Study of the Medical and Social Problems Involved in Cases of Prolapse of an Intervertebral Disc in the Lumbar Region

P. OLDENKOTT

Introduction

Today's forms of coexistence in human society exert an ever-growing influence on our health (3). This justifies our attempt to study lumbar disc prolapse as an illness in its own right, not merely under its medical aspects but by collecting material for a social anamnesis and by searching into the effects which this illness has on individual patients.

The question is: What are the medial and social problems of patients suffering from a slipped disc in the lumbar region, and what factors might possibly influence the results of treatment?

Material and Methods

One survey covers a total of 2,200 cases, including some which were analyzed in a study presented in 1971 (2). In the course of the past two decades all patients who underwent an operation at the Neurosurgical Department of the Tübingen University Hospital had their case histories coded and transferred to punched cards together with the findings of a follow-up survey. The resulting information was tabulated and evaluated by a computer. We studied the patient's subjective assessment of the success or failure of an operation and subdivided the results into groups of different social condition, i.e. civil servants, white-collar employees, self-employed persons, blue-collar workers, and housewives. The study does not include patients suffering from a recurrence.

Results

Clinical problems may arise in connection with both the exact location of an affected disc and the decision as to whether or not operative treatment is indicated. The percentage of negative surgical results appears to have remained constant over the past few years at various centres. It is conceivable that microsurgical technology and technique will further improve these results. Even so, our main concern will continue to be those patients whose pain was not eliminated by surgery. This is why we persisted in studying the possible causes of this negative selection - even more so since we were able to demonstrate that lumbalgia is especially related to the social condition of the patient and to his economic problems (1).

Since it is the pain in itself which impairs the patient's physical well-being, the patients were asked about their subjective assessment of the success or failure of the treatment (see Table 1).

Table 1

Good	No pain at all or mere occasional backache
Satisfactory	Occasional pain in back and legs Patient can live and work with it
Poor	Frequent pain in back and legs Frequent medical treatment The pain steals the patient's joy of life The patient is unable to work Worse than before surgery

According to the first study completed in 1968, medico-social inter-relations alone hardly ever influence the results of a disc operation. At least, no evidence could be found to explain why the civil servants, white-collar employees, and self-employed groups (83%), even taking into account the special characteristics of their jobs, gave assessments of the surgical results which were better by 20% than those given by blue-collar workers (66%) and by fulltime housewives (62%). When we studied the total sample of patients disregarding their social condition, we found that the incidence of negative results in the group of patients of over 50 years of age, men and women alike, was twice as high as that in the age groups from 30 to 39 and from 40 to 49. According to the most recent study, completed in 1976, results have improved by 20% (Table 2). Of the group comprising civil servants, white-collar employees and self-employed persons, 93% assessed operation results as positive (48% 'good' and 45% 'satisfactory'). The same applies to the blue-collar workers (90%) and the full time housewives (84%). Incidentally, only 26% of the housewives stated that they were entirely free from pain or suffered only from occasional spasms of lumbalgia. The same statement was made by 30% of all blue-collar workers. However, 36% of the patients who had assessed the results of their operation as good or satisfactory denied that they felt themselves fully restored physically following operation. When reminded of the pain they had suffered before surgery, 91% of this group stated that they would be willing to undergo a second operation. This attitude was shared by 60% of all members of the group who complained of negative results as well as by 73% of the civil servants, white-collar employees, and self-employed, but by only 44% of the blue-collar workers.

At the time of writing, 6% of the patients who had made positive statements regarding their surgical results are under medical attendance, as opposed to 21% from the negative group. Correspondingly, in the latter group, 37% of the patients found the 3 to 6 weeks' postoperative treatment to be too short in duration. 11% claimed disablement benefits on ground of their back trouble. This corresponds exactly to the percentage of patients with negative surgical results. Benefits were actually granted to only half of the claimants. Eight percent of the patients who assessed their surgical results as positive, claimed disablement as well.

When asked whether their lumbalgia had completely subsided following surgery, 22% of the positive group answered yes, and 61% confirmed a definite improvement. 31% of all patients had ceased completely to feel any pain in the back or in their legs; 51% reported improvements. 9% complained of unchanged, intense lumbalgia.

Table 2

Social condition	Result of operation							
	Good - Satisfactory				Poor			
	1971		1975		1971		1975	
	no.	%	no.	%	no.	%	no.	%
Civil servants	212		334		41		26	
White collar employees		83		93		17		7
Self-employed persons	219		215		112		25	
Blue collar workers		66		90		34		10
House-wives	92		135		57		25	
		62		84		38		16
Total	523		684		210		76	
		70		89		30		11

Discussion

The question which has to be asked is: What specific problems are actually involved in a survey of this nature? Since, however, our results so far are incomplete, it is impossible to give any final interpretation or assessment. We are aware of the uncertainty factors involved in any follow-up survey, and we know how they tend to obscure objective results. This was duly taken into consideration. It goes without saying that other parameters were also considered, such as the level of vocational training, changes of profession or employment, both before and after surgery, potential earnings and broken time, the strain imposed by a protracted pre- and postoperative treatment, etc. All these factors, together with the results described above, will not yield a final result until the control examinations now being performed on specially selected groups of patients are concluded. ¹

The difference between the results obtained from groups of different social condition seems to indicate that other than purely medical factors influence the results of lumbar disc surgery. For the time being, it is worth mentioning that, despite our efforts, there still are 9.5% of all patients complaining of lumbalgia either unchanged or even more intense than before. SPANGFORT (4), in a similar study, found continued lumbalgia in 31% of his patients. A reason for this pain syndrome might be an instability of one or even several lumbar segments after a disc operation.

Summary

Part of the results of a catamnestic survey of 2,200 patients operated on for prolapse of an intervertebral disc in the lumbar region are presented. These cases were treated between 1955 and 1975. A simple statistical subdivision into cases with good and poor results will not yield concrete information. For this reason, the total cases were classified into groups of different social condition. Subsequently,

¹ In cooperation with "Abteilung für Medizinische Psychologie (Prof. Dr. S. Goepfert) der Albert-Ludwigs-Universität, Medizinische Fakultät", D-7800 Freiburg i.Br.

we analyzed the subjective assessments of the surgical results given by these groups. Assessment criteria were: Complete or satisfactory freedom from pain or either pain unchanged by treatment. The groups showing the least satisfactory results on a general level were the blue-collar workers and, to a much greater extent, the full-time housewives. We expect a series of control examinations now being performed on selected groups of patients to show the reasons for these findings.

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Re-Operations Performed on Patients Suffering from an Intervertebral Disc Prolapse in the Lumbar Region

H. SCHLARB and H. WENKER

As a rule, a patient who is not free of symptoms or who even complains of an aggravation of his condition after he has been operated on for a prolapse in the lumbar region will seek neurosurgical advice at a relatively early date. What is the prognosis if it is decided to perform a re-operation?

Material

Until the end of 1975, 1,360 lumbar disc operations were performed in our department on a total of 1,272 patients in the course of 7 1/2 years. 132 patients (10.4%) had to undergo one or several re-operations. In 6% of these cases the first operation had been carried out in our hospital, and in 4.4% elsewhere.

A statistical subdivision of the total number of patients undergoing re-operation according to sex and age (Fig. 1) shows that of 132 patients 53 were women and 79 men. This means that the women/men ratio of 1:1.3 first operation has shifted slightly towards the mens' side, being now 1:1.5 for the cases undergoing re-operation. Only in patients of more than 50 years of age is there a preponderance of women over men for the first operation. The peak of the age curve of male patients undergoing re-operation occurs ten years later, namely between 40 and 49 years of age.

Indications for Re-Operation

Local postoperative spinal syndromes caused by loosening of segments can be very obstinate and have always been treated conservatively. We know of only two cases in which orthopaedic surgeons decided to perform an arthrodesis. In some cases in whom objective clinical determination of radicular damage was difficult, electromyograms were used to facilitate examination. All patients, even those in whom segmental location of the root compression was clear, were examined by myelography. We encountered no difficulties when examining cases of prolapse demonstrable by myelography at a level different from that on which the first operation had been performed. It was interesting to see whether the present pseudo-relapse had already been noticeable on previous myelograms and had merely been neglected because there were no clinical findings. It is nearly impossible even for a genuine relapse to be obscured by the marking of the radicular zone, which will normally be much reduced after the operation, anyway. Therefore, even a genuine relapse will show up at least in one of six X-ray paths.

Differential diagnosis should concentrate on distinguishing cases of recurrences accompanied by considerable extra- or intradural adhesion from pure cicatricial processes, which, as we know, cannot be influ-

enced by surgery. Since both cicatricial processes as well as recurrences will affect the contrast column, it is sometimes impossible to identify individual caudal fibres. In such cases, it is even possible that thick layers of scar tissue cause the impression indentation of the contrast column. Neuroradiological diagnosis becomes difficult whenever the contrast medium flow is partially stopped or whenever the contrast medium cannot enter the caudal subarachnoid space at all. In all such cases surgery was indicated.

Operative Method and Postoperative Treatment

As for the first operation, the patients were placed in the knee-chest position, and a generous segment of the root was exposed. Due to the dense layers of scar tissue, interlaminar fenestration proved to be sufficient only in very few cases. In 42% of all cases of re-operation, hemilaminectomy was necessary, laminectomy being performed only in 10% of the cases of first operation. Performing a thorough radicolysis was more important than preserving the articular process. All intervertebral spaces involved were submitted to a curettage as complete as possible. Postoperative treatment included 3 to 5 days of rest in bed followed by balneological physiotherapy. If patients made good progress, postoperative treatment could be terminated after 18 days even in cases of re-operation.

Results

Fig. 2 shows the anatomical findings of all 132 cases of re-operation classified into individual groups. It also shows the length of time elapsed between operations in each group. There are 79 cases of true recurrence and 53 cicatricial processes. Further analysis according to sex and age yields the same relative figures for recurrences and pseudo-recurrences as for the first operation. A relatively high number of patients (27 males and 26 females) showed cicatricial processes. Among the women, especially those up to 39 years of age are prone to develop cicatricial processes. However, the actual figures available are too limited to allow final conclusions.

The results of re-operations are assessed by three parameters simultaneously. These three parameters are the patient's subjective impression, his neurological condition, and his return to work. The results of re-operations performed on cases both of recurrences and pseudo-recurrences were satisfactory in 68% of all cases. In 76% of all cases, cicatricial processes alone were present and remained unaffected or even showed some worsening. It did not matter whether the time elapsed between the first and the second operation was a few months or some years.

Discussion

All lumbar disc operations bear the risk of causing excessive adhesions, at least extradurally, no matter how carefully and painstakingly performed. Proliferation is by no means initiated by removing old disc sequesters alone. Since in most cases of re-operation the dura is not opened intentionally, arachnopathy can only be diagnosed by myelography. Cicatricial processes may extend to the opposite side and even affect neighbouring segments. Discomfort and neurological symptoms may return after a few weeks only or after years. In the latter case they are probably associated with an osseous restriction. Nowadays the ci-

catricial processes causing such symptoms are treated surgically only in very special cases, the objective being to eliminate the compression of a nerve root elsewhere.

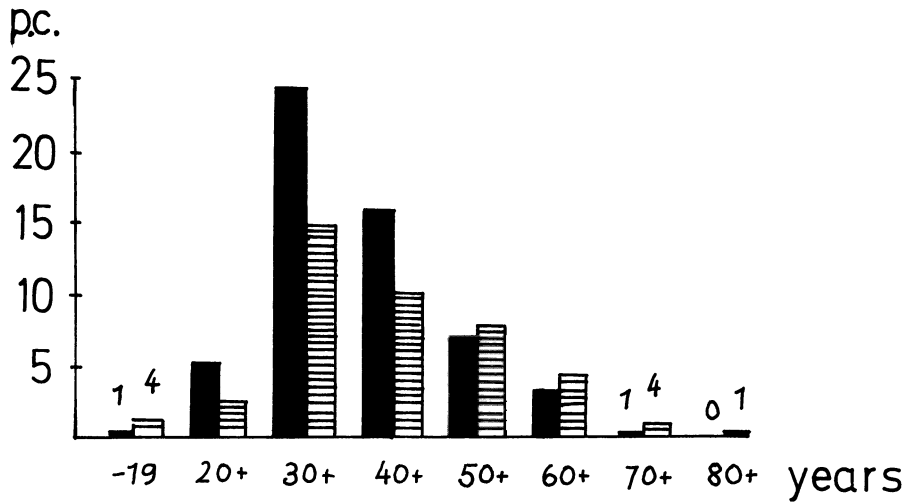
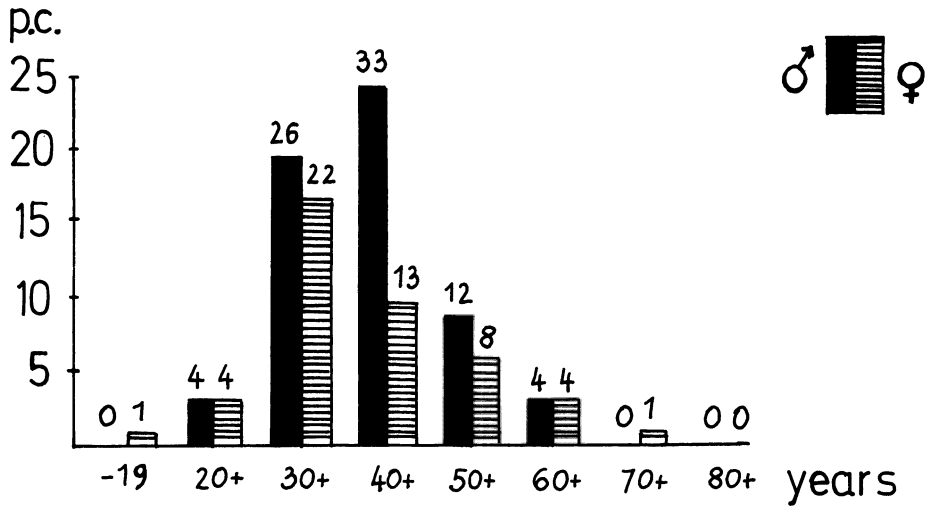


Fig. 1. *Top*: Re-operation. Subdivision of 132 re-operated patients according to sex and age. *Bottom*: First operation. Comparison between the cases of re-operation and the 409 primary operations from 1974 and 1975

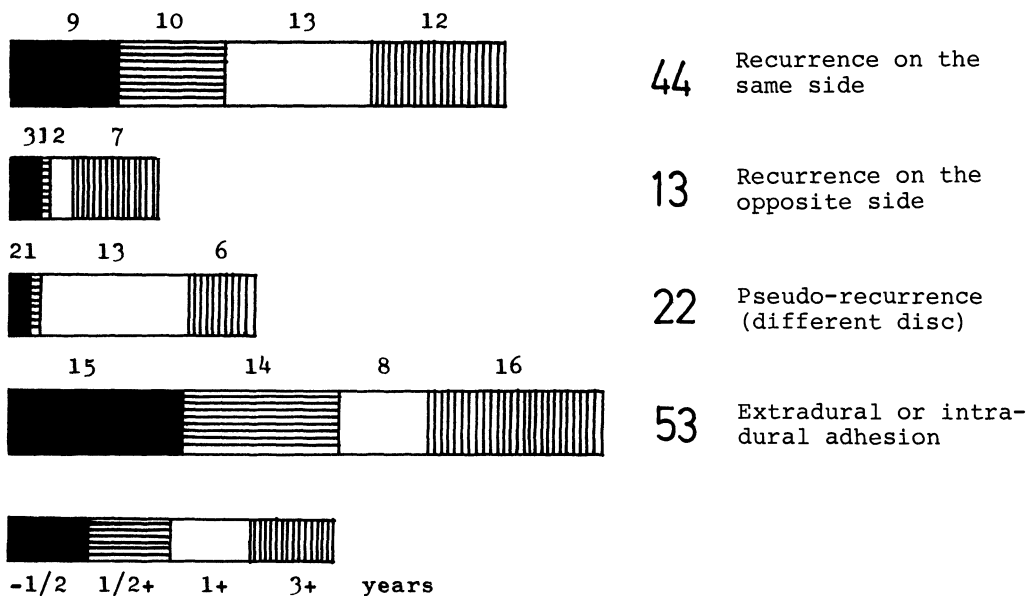


Fig. 2. Anatomical findings in 132 cases of re-operation. *Left side:* Time intervals between first and second operation

Results and Complicated Course After Surgery for Lumbar Disc Herniation

F. OPPEL, J. SCHRAMM, M. SCHIRMER, and M. ZEITNER

With the cooperation of

B. Atay (Stuttgart), J. Becker (Freiburg), P. Becker (Würzburg), J. Bockhorn (Würzburg), K.A. Bushe (Würzburg), G. Clarici (Graz), W. Dittmann (Frankfurt), R.A. Frowein (Köln), A. Grund (Inz), K. auf der Haar (Köln), F. Heppner (Graz), B. Hübner (Frankfurt), H.P. Jensen (Kiel), A. Koulousakis (Köln), P. Lücke (Berlin), K. Marin (Heidelberg), E. Metzel (Freiburg), F. Pampus (Stuttgart), H.H. Petersen (Kiel), K. Schürmann (Mainz), B.U. Seidel (Hannover), D. Stolke (Hannover), E.W. Strahl (Essen), T. Wallenfang (Mainz), R. Winheller (Essen)

Programming and computing: J. Seehusen

Introduction

The statistics on lumbar disc operations hitherto published comprised mainly the cases of one or a few clinics during a long period of observation. This offers the advantage of a rather constant surgical technique. However, due to regional particularities and to changing social influences, a general evaluation becomes complicated. Thus, in order to evaluate a representative number of cases a joint follow-up study was initiated, 15 neurosurgical clinics of the FRG and of Austria entering their disc material of 1971 and 1972.

Material and Methods

It was the purpose of this paper to include a great number of lumbar disc operations. The main point of interest was the so-called "complicated course", which can be defined by the following criteria: preceding discectomy or recurrence surgery; false diagnoses (no herniation found intraoperatively); persisting complaints or inability to work more than 3 months postoperatively; and fatalities. The period of observation extended until April 1976. Each clinic classified its cases into normals and those with the so-called complicated course. All the complicated cases were submitted to a control examination. For the patients with complicated course a comprehensive data collection sheet (with more than 300 parameters), and for the normal cases a shorter one (with 30 parameters) was filled in. The term 'recurrence operation' also covers surgery due to a prolapse at another level.

A total of 3238 cases was evaluated by computer. There were 248 normal and 757 so-called complicated courses. 206 cases (6.4%) were complicated because the operations during the investigation period had already been performed for recurrence. This leaves 551 cases to be considered complicated according to the aforementioned criteria. The first part of this paper deals with data pertaining to the total of cases (3238). Since the findings of patients who underwent previous disc surgery will be different from those of patients operated on for the first time, the second part concentrates on patients who had their first operation during the period of investigation (3238 - 206 = 3032).

The third part describes the differences between patients with and without recurrences. Pre- and intraoperative data were used of those patients whose first operation and whose recurrence operation were during the period of observation, and were sufficiently well documented (N = 114). The postoperative and late findings of patients who had a disc surgery prior to the period of investigation (N = 206) and those who had a sufficiently documented recurrence operation during the period of observation (93, i.e. altogether 299 cases) were evaluated. They were compared to 416 well-documented complicated courses, where neither a previous operation nor any recurrence surgery had been performed. Thus, we were able to compare pre- and intraoperative data of recurrences with those of cases that did not recur. Furthermore, it was possible to compare the late results of recurrences with the late results of other complicated courses which had not been considered a recurrence.

Results

1. The Entire Collective

In this chapter, general factors as known from earlier papers shall be discussed for the total number of 3238 cases.

There is a preponderance of men, without relevant relation to age. The youngest patient was 11 years old, the oldest 80. Two thirds of the patients belonged to the age group of 30 to 50 years (Fig. 1). Myelography was performed in 65.1% with 69.2% water-soluble and 9% oil-containing contrast media. Allergic or incompatibility reactions were seen in approx. 1% of the myelographed patients, a meningitic irritation occurred in 3.2%. Fig. 2 shows the differences between normal and complicated courses as related to clinical, myelographic and intraoperative findings. These statements, of course, are highly subjective.

In our patients, the discs L4/5 (60.2%) and L5/S1 (55.5%) were most frequently prolapsed. The upper segments predominate in males (Fig. 3). The association of prolapses at L4/5 and L5/S1 was observed in 19.3% men and 19.7% women. In 1.8% there were simultaneous prolapses at L3/4 and L5/S1. The incidence of epidural varicosities was 6.9%, that of medial mass prolapses was 9.2%.

Surgical Procedures

- a) 71.1% were interlaminar fenestrations, 50% of which at one level and 43% at two levels.
- b) 27.3% were hemilaminectomies, 55% of which of one vertebra, 41% of two.
- c) 4.5% were laminectomies, 53.1% of which of one, and 34% of two vertebrae.

In 77.5% discectomy was performed on one, in 17.2% on two, and in 0.9% on 3 discs (4.4% missing observations). A dural opening occurred in 5.9%. Postoperative hospitalization lasted 3 weeks in average. Due to the different hospitalization times of different clinics we found it difficult to draw conclusions related to the surgical procedures.

2. The So-Called Complicated Course

Since patients with unsatisfactory postoperative course deserve special interest, we investigated the possible causes and consequences. For definition of a complicated course see the chapter on Material and Methods. It must be mentioned that a wound infection alone does not count as complicated course according to our definition. Since pre- and intraoperative findings of patients with a previous discectomy are basically different from those undergoing surgery for the first time, we subdivided the group of 757 complicated courses into 206 with previous operations (6.4%), and 551 following a first operation, thus amounting to 18.2% of 3032 first operations.

Considering all operations, mortality is less than 0.3% (Table 1). The number of ventral perforations with damage to large blood vessels is extremely low (0.06%). For first operations the incidence of recurrence surgery was 4.3%, that of false diagnose 1.1%.

Table 1. Incidence of major complications for all operations and for all first operations

	All operations n = 3038		All first operations n = 3032	
	%	n	%	n
Previous discectomy (prior to 1971)	6.4	206		
Relapse operations (after 1972)	4.9	160	4.3	130
No prolapse on oper- ation (erroneous diagnosis)	1.6	52	1.1	32
Spinal tumor	0.06	2	0.06	2
Exitus letalis	0.28	9	0.29	9
including postoper- ative deaths	0.25	8	0.26	8
Ventral perforation with damage to blood vessels	0.06	2	0.06	2

The Consequences of Complicated Courses

The most important single factor of a complicated course is the lack of relief of complaints. More than half of the patients with complicated course, i.e. 9.5% of all first operations, have not become free of symptoms. This, of course, does not mean that these patients have persistent complaints. The second important factor is a sickness leave of more than 3 months, which occurred in 43% of complicated courses, i.e. 7.8% of first operations (Table 2). 2.2% of the patients stated that their complaints could not be satisfactorily treated by conservative means. In approx. 1% of all patients further pain therapy was necessary (plaster cast, DCS etc.). It should be emphasized, however, that more than 80% of the patients had become free of symptoms. From the social consequences, presented in part 2 of Table 2, it is evident that disc surgery backed up by a network of social legislation does involve high expenses for follow-up treatment, but does not have a great number of significant social consequences. The number of premature retirements is less than 1%.

Table 2. Incidence of some of the factors contributing to a complicated course. More than one statement can be true. Therefore the figures cannot be simply added

	All first operations n = 3032		Complicated course n = 551
	%	n	%
Change of occupation	2.0	62	11.3
Receiving pension	0.9	28	5.1
Partial invalidity	2.5	76	13.8
Rehabilitative after-treatment (cure)	7.7	234	42.5
Sick leave exceeding 1 year	2.9	88	16
Sick leave exceeding 3 months	4.9	150	27.2
Aftertreatment exceeding 1 year	4.7	141	25.6
Persisting complaints	9.5	289	52.5
Therapy resistant complaints	2.2	67	12.2
Immobilization in plaster cast	0.9	26	4.7
DCS or TNS	0.1	4	0.7
Concomitant psychiatric diagnosis	3.4	104	18.9
subdivided into:			
Complaints without adaequate neurologic findings	1.8	56	10.2
Persisting pain with depression	1.7	53	9.6
Persisting pain with pension neurosis	0.3	10	1.8

Table 3. Incidence of unimproved or worsened findings at a later follow-up examination. Since more than one statement can be true, the sum is larger than the figure given in the first line

	All first operations n = 3032		Complicated course n = 551
	%	n	%
Findings changed for worse on late follow-up examination	7.1	214	38.8
Subdivided into			
New marked paresis	0.7	20	3.6
New impairment of micturition	0.3	8	1.5
New atrophy	0.8	24	4.4
Relapse operation	4.3	130	23.6
Increase in degree of paresis	0.3	10	1.8
Pre-existing impairment of micturition unchanged or worse	0.6	17	3.0
So-called therapy resistant complaints	2.2	67	12.2

18.9% of the complicated courses had an accompanying psychiatric diagnosis with a strikingly high number of depressions (9.6%). The third most frequent factor for the occurrence of a complicated course is a deteriorated (neurologic) finding at the follow-up examination in 38.8% (Table 3). The largest share of deteriorated findings is that of recurrence surgery, followed by pains resistant to therapy in 12%. Genuine neurological deterioration amounts to less than 1% considering the first operation.

Comparison Between Normal and Complicated Courses

As concerns complicated courses following a first operation, there are no sex differences between normal (62.3% men) and complicated courses (60.4% men). There is no difference in age distribution in both groups either, i.e. age and sex do not influence the result of surgery. There are, however, distinct differences in surgical technique. Significantly more patients with late complications had been fenestrated at more than one segment and significantly more had been hemilaminectomized in one or more segments. They had suffered laminectomy more often, too (Fig. 4). Surgical intervention, therefore, had been more extensive in patients with later complications. Complicated courses comprised more multiple removals than normal courses. Although more extensive surgical procedures were more frequently associated with complicated courses, it cannot be concluded that this is so because the patients had a more severe operation. The number of medial mass prolapses in patients with complicated courses (Table 7) is 3 times higher than in those with normal courses, what confirms that they also have a more severe intraoperative finding. Complicating findings (peridural varicosity, etc.) frequently occur in patients with complicated postoperative course. The same goes for preoperative myelographies and meningism. If one takes into account that myelography serves to check or confirm a diagnosis which, clinically, is not quite certain, the conclusion can be drawn that the group of patients with complicated course contains a greater number of patients with unclear clinical pictures.

Poor Late Results

Some findings occasionally associated with a poor end result had a very low incidence in the group of 551 complicated courses, so that a significant role as causative factor for a poor end result seems unlikely: root cysts, small caudal sac, megacauda, pseudospondylolisthesis, all on the preoperative X-ray films, intraoperative root cysts and postoperative meningism, all of which occurred in less than 1%.

When relating the various follow-up parameters with the factor pain resistant to therapy it is found that a history of rheumatic disease and osteophytic spurs on preoperative X-ray films are significantly more frequent in patients with persistent pain. Sex, epidural varicosity, opening of the dura, severe intraoperative hemorrhage, removal of osteophytic ridges, and the surgical technique, however, have no influence on the presence of this factor. Accompanying diseases, therefore, appear to be of more relevance for persistent pain than surgical techniques and concomitant intraoperative findings.

Complicated Course

Mortality and complications from lumbar disc surgery are low. The recurrence rate is 4.3% for first operations. More than 80% of patients are free of symptoms or improved to such an extent that they do not return for additional treatment. Of those who do return, i.e. those with complicated course, 53% come because of pain, 43% were on a sickness leave for more than 3 months, 19% suffered from accompanying psychiatric symptoms and 15% had augmenting neurologic deficit. Patients with complicated courses had more preoperative myelograms, more severe operations, more frequent multiple removals and more accompanying complicated findings. Age and sex were of no significance for the outcome.

3. Recurrences

Figure 6 shows the groups to be discussed. Of the 130 initial operations from 1971/72, 114 cases had at least one relapse up to April 1976. In 93 of these we also have complete data on the recurrence surgery. Together with the 206 cases which had already undergone recurrence surgery in 1971/1972 there is a total of 299 patients with recurrence operations. Therefore, it is possible to answer the question as to what is characteristic for patients who, at some later stage, will have a recurrence and, on the other hand, it is possible to describe the findings and late sequelae of patients operated on for recurrences. For the sake of comparison there are 416 complicated courses without recurrence and 2481 normal courses. The recurrence ratio at the same level as compared to recurrences at another level was 75 : 25%.

Age and Sex

Age varies significantly in the individual groups. The peak incidence for normal courses is between 40 and 49, and between 30 and 39 years for the future recurrences (Fig. 7). There is a shift in age incidence to lower ages for the group of patients with later recurrences. This becomes even more evident if the groups are split into those up to 50 and those above 50 years of age. Similar essential differences occur in the individual groups as concerns sex. We observed a male to female ratio of 62.6 : 37.4% for the patients with normal course as compared to 65.1 : 34.9% for those with late recurrences and to 60.1 : 39.9% for the complicated courses without recurrence. While men have recurrences far more frequently, women tend to have complicated courses without recurrence.

Pre-Operative Diagnosis

A proportion of 77.2% of myelographies in the group of future recurrences as compared to 72.6% for the complicated courses without recurrences and to 62.6% for normal courses, suggests that the group of future recurrences is submitted to more intensive diagnostic procedures. The incidence of pathologic myelographic findings is impressively higher in the recurrence group, including 71% of contrast column indentations as compared to 62.6% in the group without recurrences. The same applies to the ratio of 34.2% : 18.3% for root pouch amputations. A myelographic circular constriction did not differ in both groups (2.6%). A complete stop occurred in 4.4% of the patients with late recurrence and in 11.3% of those with complicated courses with recurrence.

Previous trauma, myelographic findings of megacauda and narrow spinal canal, as well as scoliosis, spina bifida occulta, spondylosis, spondylolisthesis, and pseudospondylolisthesis were of no relevance for the frequency of recurrences.

Diagnosis, Surgical Findings, and Surgical Technique

The most significant differences between the groups examined are found in the surgical field (Table 4). For the level L4/5 there is a discrepancy of 23% between diagnosis and operation. The level L4/5 was operated on most frequently. Thus, with a total of 8.9% of all operated levels, the segments L3/4, L2/3 and L1/2 were more frequently affected by subsequent recurrences than in cases with normal course,

Table 4. Overview of the segments diagnosed and operated on as compared to intraoperative findings. Special emphasis is deserved by the discrepancy between diagnosed and operated level in the patients with recurrence at L4/L5, as compared to the correspondence of clinical, surgical and myelographic findings in cases where myelography had been performed. Notice the high number of multiple removals in patients with complicated course as compared to those with a normal course. There is a preponderance of medial mass prolapses and fresh prolapses, as well as least extensive surgical procedures in the group with recurrences. Much more extensive are the surgical interventions for recurrences (bottom right, n = 93)

	Complicated courses		Normal courses	
	Relapses	Non relapses		
Diagn. segment	56.1	53.4		
Operat. segment	58.8	61.3	54.4	L5/S1
Diagn. segment	46.5	50.0		
Operat. segment	67.5	66.6	57.5	L4/L5
Diagn. segment	1.8	4.1		L3/L4+
Operat. segment	8.8	11.6	5.2	L2/L3+ L1/L2
Correspondence of findings in:				
Clin. exam. + on op.	66.7	65.6	88.9	
Myel. a. op.	64.0	51.7	53.3	
Myel. a. clin.	46.5	35.8	43.7	
Number of discs:				
1	65.8	57.9	81.1	
2	30.7	36.3	16.1	
3	2.6	2.6	0.6	
Local findings:				
Massive prolapse	18.5	15.6	6.8	
Recent prolapse	50.4	42.6		
Strong tension of Nerve root	50.4	34.6		
Adhesions of Nerve roots	15.1	19.4		
Technique of operation:				
Fenestration	75.2	60.5	72.5	Relapse operation (n = 93) 55.9
Hemilaminectomy	22.3	35.0	24.7	35.5
Laminectomy	2.5	4.5	2.8	16.1

but still less than those with complicated courses without recurrences. Agreement between clinical, myelographic and operative findings was best in the group with late recurrence having had myelography. However, the group with a normal course predominated when clinical and operative findings agreed. The complicated courses without recurrence had the least agreement between the above parameters. This suggests that in the groups of patients with complicated course evidently there is a relatively high degree of clinical uncertainty. There is no correlation between satisfactory outcome and number of removed discs (Table 4). The group of future recurrences has the largest percentage of medial mass prolapses (18.5%). There are striking differences in the incidence of recent prolapses, tension of the nerve root, and radicular adhesions. Compression by osteophytic spurs, tumor or varicosis are without significance for the frequency of recurrences. As concerns the extent of surgery, the group with late recurrences lies below that of normal evolution (Table 4). If one considers the severity of the intervention as an expression of the severity of the findings, this will already reflect a prognosis. On 93 recurrences with complete information on the recurrence operation a similar distribution is seen: 55.9% of fenestrations, 35.5% of hemilaminectomies, and 16.1% of laminectomies. Foraminotomy or removal of bony ridges are of no significance for the frequency of recurrences. As concerns late sequelae, operations for recurrence can only be compared to the group of patients with complicated course without recurrence since, according to our definition, no data on late sequelae were collected for the group of patients with normal course.

Clinical Findings

The unchanged or worsened objective neurological follow-up findings in patients operated on for a recurrence are shown in Table 5. Note the incidence of patients with persisting complaints and pain. These figures - following surgery for a recurrence - approach those of the group of patients with complicated course but without recurrence.

Table 5. Comparison of unchanged or worsened neurological findings in patients following surgery for a recurrence as compared to the groups of patients with a complicated course and without a recurrence: apart from the persisting complaints and from the complaints without justifying neurological findings, the frequency of deficits approaches that of the patients with a complicated course and without recurrence

	Complicated courses	
	Relapses	No relapses
Loss of reflexes	48.5	52.4
Hypaesthesia	41.8	42.3
Paresis	24.7	26.2
Atrophy	5.7	5.0
Impairment of micturition	3.0	2.0
Cauda syndrome	3.0	2.4
Therapy resistant pain	11.0	13.2
Depression	13.4	12.9
Complaints without Adequate neurol. findings	7.0	12.3
Persisting complaints	47.8	59.1

Postoperative Data

Patients with surgery for a recurrence will be on sickness leave for a longer period, but will not receive longer follow-up treatment than those with complicated courses without recurrence. 42.8%, respectively 45.2% needed rehabilitation therapy. As seen in Fig. 8, physiotherapy is common in the postoperative management following disc surgery. The group of patients with complications but without recurrence shows a distinctly higher incidence of after-treatment than that of recurrences. This is statistically significant for drug therapy. Lumbar fusions, rhizotomy, chordotomy and DCS or TNS were almost entirely applied to patients operated on for a recurrence. The total of such interventions, however, is small and, in most cases, did not have the desired effect.

Social Consequences

Patients operated on for a recurrence change their job more frequently. They do not become fully or partly invalid as frequently. They are granted a pension more frequently (Table 6). They do file more law suits before social courts (4%/2.6%) and privately as well (0.7%/0.2%).

Table 6. Social sequelae in all 3238 patients, in the recurrence group and the complicated group without recurrence. Due to the fact that some numbers are counted twice, the true figures are still smaller

	Complicated courses		All cases
	Relapses	No relapses	
Change of occupation	14.7	13.0	3.0
Applicat. for pension	6.4	4.3	1.1
Pension	8.7	5.0	1.5
Partial and full invalidity	17.7	17.3	3.9

Discussion

An analysis of the results of 3238 cases of lumbar disc surgery from 15 different clinics during a period of 2 years has the advantage of permitting a representative analysis. All large statistics available up to now refer to the cases of only one or a few clinics, and study far less parameters. Only a few computer-aided statistics on lumbar disc operations have been published (5, 8). One of them gives a good overview of 160 statistics of the world literature. The present joint follow-up study differs from all other large series because the number of parameters is greater and because the emphasis is laid on patients with complicated course. These included the unsatisfactory results of lumbar disc surgery comprising surgery for recurrences and the social consequences of this problem. Only a few extensive papers studied this subject (1, 3, 4, 6, 7).

The general findings (age, sex, operated segment, etc.) in the patients with a normal course correspond to that of literature. The group of patients with complicated course was defined according to the conditions mentioned in the first part of the present paper. This included patients who were free of symptoms later or after operation for a recurrence. On the other hand, patients who fulfilled the criteria of a complicated course but were not free of complaints and were treated elsewhere afterwards were not included. Nevertheless, it was possible to demonstrate significant differences in pre, intra- and postopera-

Table 7. Comparison of accompanying findings in the patients with normal and with complicated course

	All first operations			
	Normal course n = 2481		Complicated course n = 551	
	%	n	%	n
Myelography	62	1539	72.6	400
Meningism	2.5	39	6	24
Dura opened	4.7	116	6.7	37
Complete medial prolapse	6.8	168	18.1	100
Epidural varicosis (including congestive varicosis)	4.4	108	12.5	69

tive evolution. The most severe findings exist preoperatively in the complicated courses, and extensive surgical interventions were necessary. Unsatisfactory late findings were, apart from the recurrence, persistence of complaints, particularly of pain. However, as compared to the total number of patients operated on, these numbers are very low. The findings of patients with persistent pain only indicate that the operative technique is not statistically relevant for the outcome. Patients with future recurrences have more mass prolapses and myelographic findings. When comparing the operative technique, however, the extent of the intervention is least in this group. Since there was a great discrepancy between the diagnosis and the operated level as concerns L4/5, it must be clarified if surgery at this level was performed after sufficient preoperative diagnosis and whether the group of patients with recurrences was operated on with sufficient care. The findings following a relapse operation correspond almost entirely for those of the complicated courses without recurrence, i. e. the unsatisfying late results following recurrence surgery are similar to the unsatisfying late results of patients with complicated course and without recurrence. The incidence of secondary surgery for persisting pain in this study was very low, the results were poor, but little information for comparison was found. Based on this investigation, we are convinced that our figures will take the aura of specialty from lumbar disc operations. The danger of a permanent paraplegic lesion is practically inexistent, but is not unavoidable. The incidence of social sequelae is low and not necessarily associated with a decline in social condition. We do not believe it necessary that "the patient begs on his knees for an operation", as BOESCH puts it in 1974, in order to perform discectomy, but we believe that, according to the present data, with a rate of persisting complaints lower than in other studies (9), lumbar disc surgery should be considered a successful operation. This is the more so when the damage to health and social condition in cases not operated on for fear of complications are taken into consideration.

Computer evaluation of 3238 cases comprising more than 300 parameters for the patients with complicated course cannot be fully described and discussed within the given scope. We therefore restricted ourselves to the most essential facts. Detailed findings will be published later.

Summary

A joint follow-up study of 3238 lumbar disc operations performed during 1971/72 in 15 neurosurgical hospitals was undertaken. Special interest was centered on the 757 patients with complicated course, of whom a large amount of data was collected and analyzed with the aid of a computer. Some general parameters concerning the entire collective were found to be in good agreement with the literature. The differences between patients with normal course and those with complicated courses with and without recurrences are described. Factors presumably responsible for unsatisfactory courses were discussed in detail. It was concluded that the operation is a safe procedure with a satisfactory outcome in more than 80% of the cases. The incidence of drastic social changes was very low. A later publication will give more detailed information particularly on the complicated courses.

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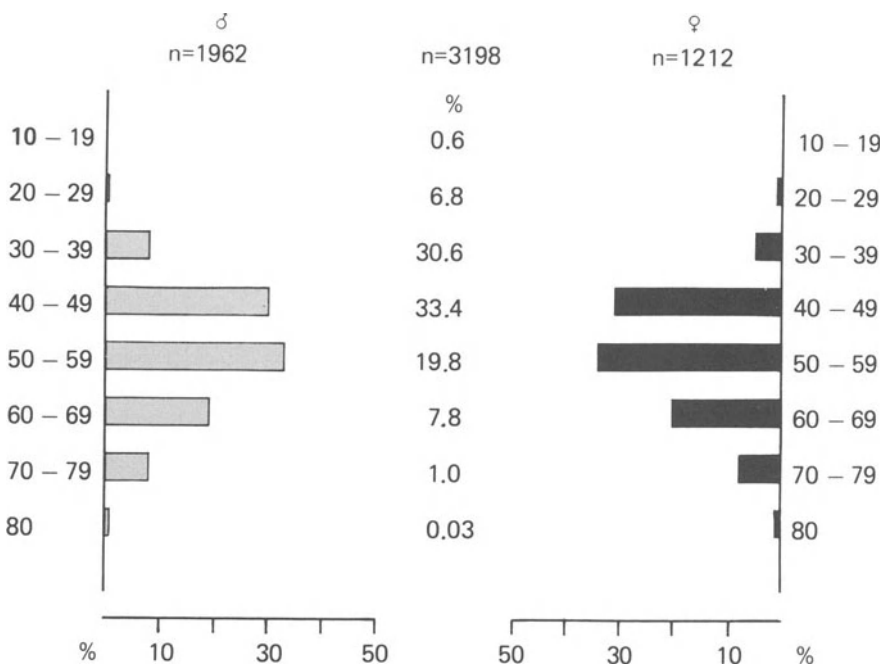


Fig. 1. Age and sex distribution of 3238 patients operated upon for lumbar disc hernia

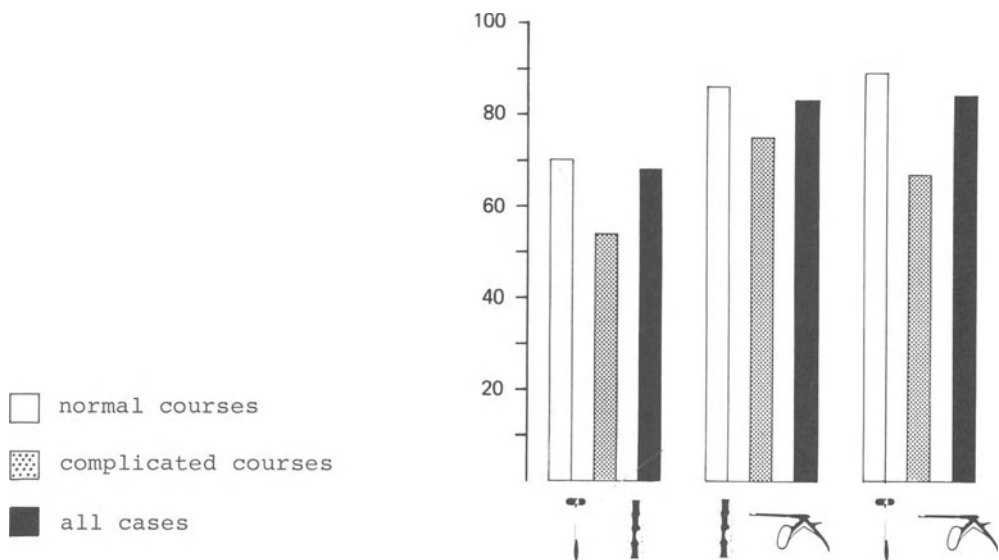


Fig. 2. Coincidence of clinical (hammer), myelographic and operative (forceps) findings in 3238 lumbar disc operations. Normal courses are shown in white, complicated courses are hatched, the total of cases in black

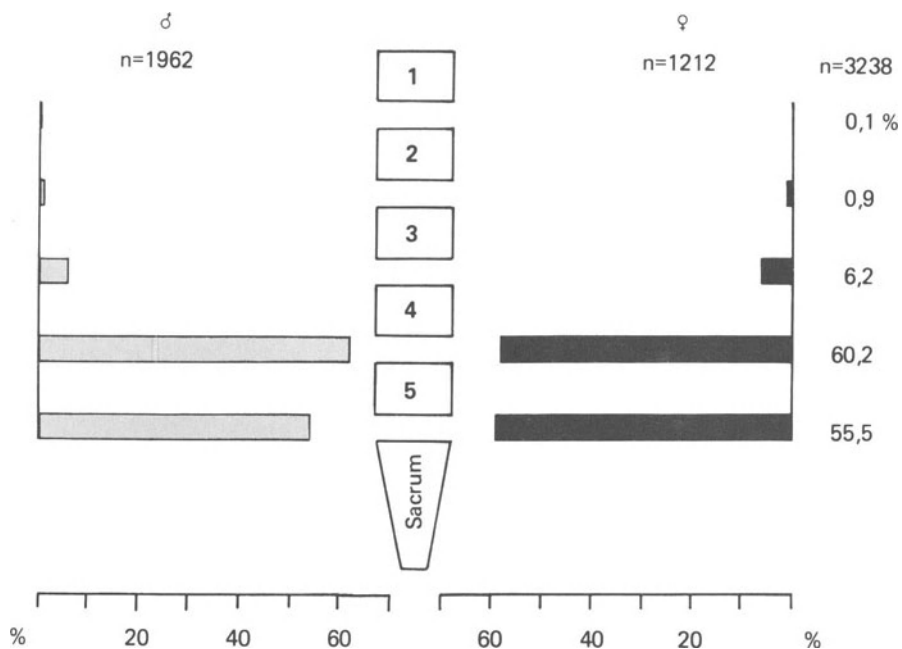
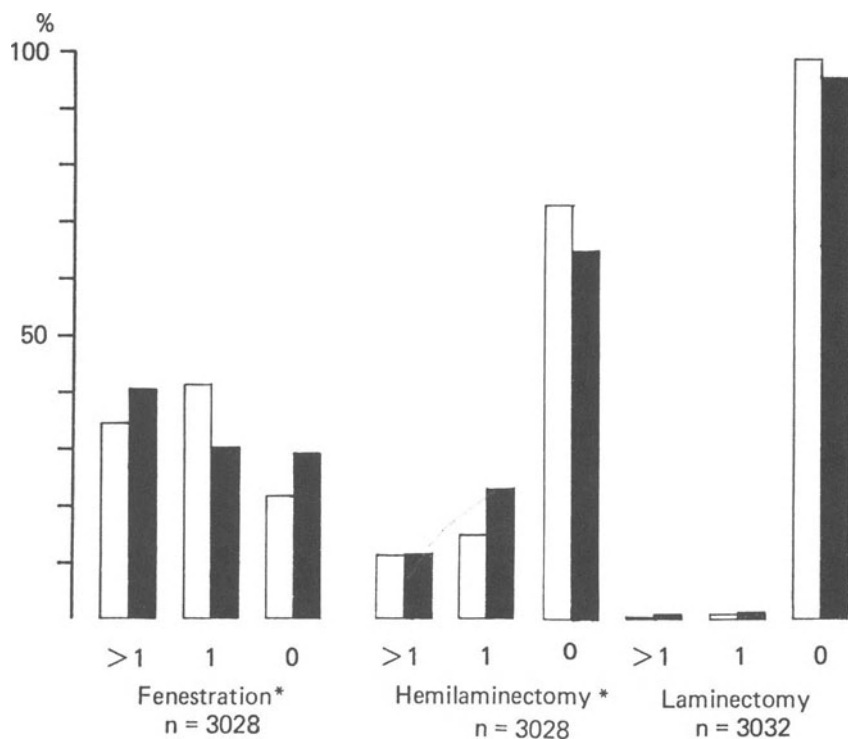


Fig. 3. Frequency of operated segments in men and women in relation to the total number of cases



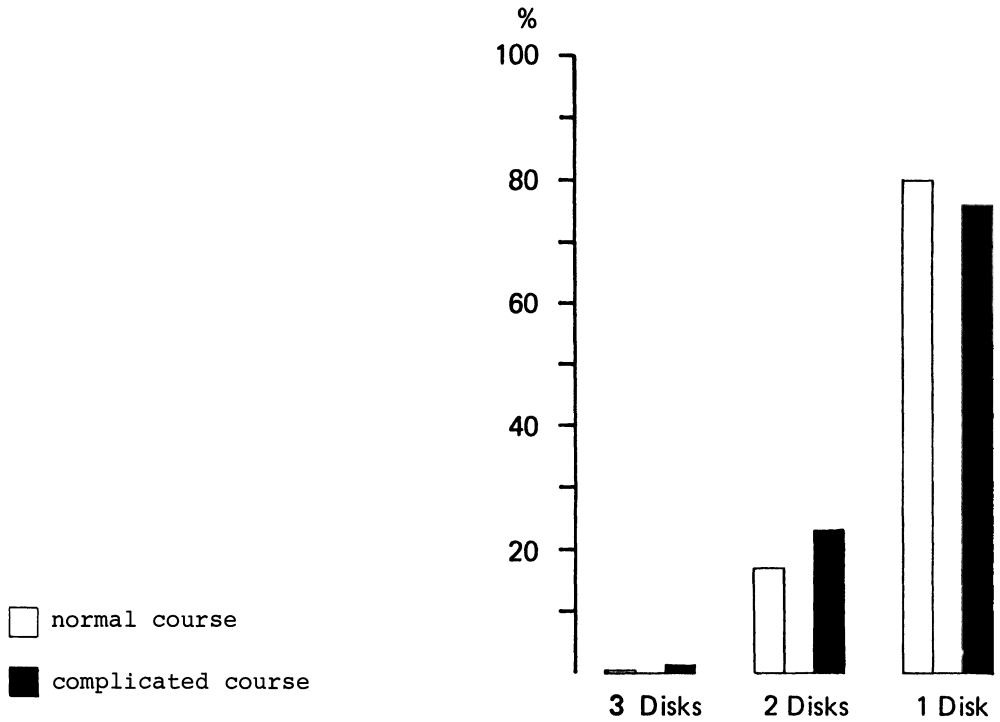


Fig. 5. Incidence of multiple disc removals in all first operations, subdivided into complicated and normal courses



Fig. 4. Operative technique at the first operation, subdivided into normal and complicated courses. Figures below the columns indicate the number of segments operated on. The incidence of laminectomies is low. Patients with normal course have fewer fenestrations in more than one segment, more fenestrations in just one segment, are less often hemilaminectomized in one or more than one segment, and less often laminectomized. The asterisk marks statistically significant differences between both groups ($p < 0.05$)

□ normal course ■ complicated course

Pre- and intra-operative data

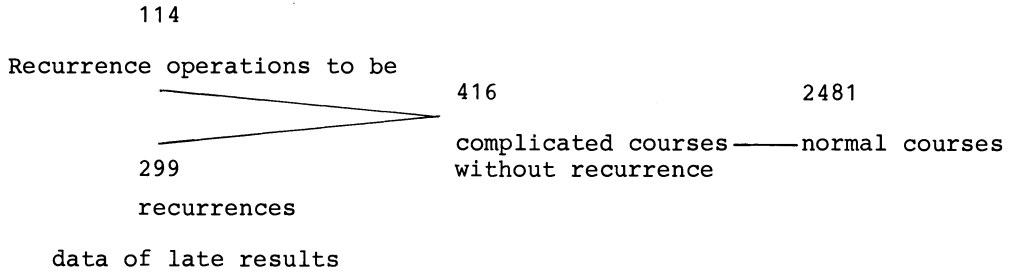


Fig. 6. Comparison of the groups before and after recurrence operation. For 114 patients who later had recurrences statements can be made about pre- and intraoperative findings at the time of the first surgery as compared to 416 patients with complicated course without recurrence and to 2481 normal evolutions. Following surgery for recurrence 299 patients were available for discussion of late findings

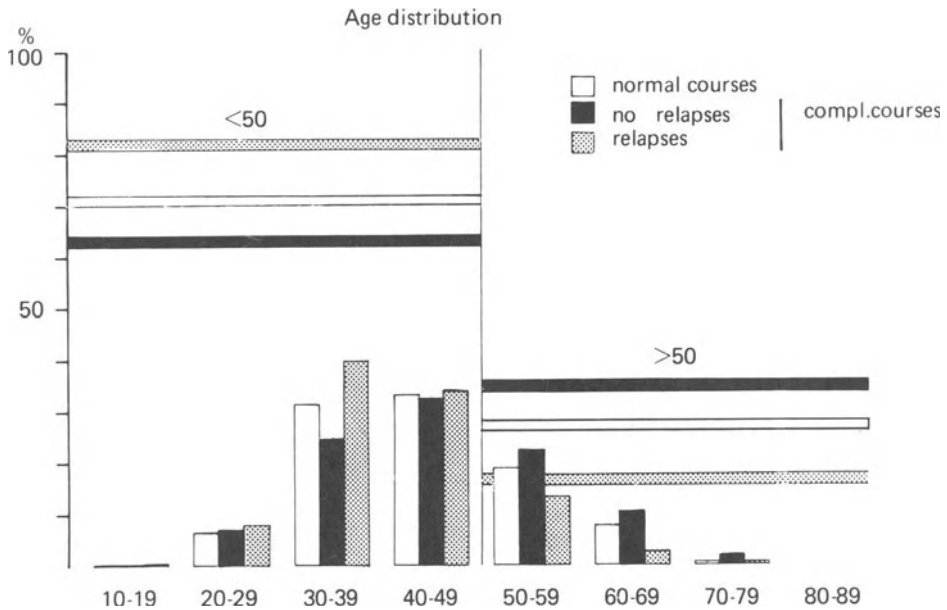


Fig. 7. Age distribution of patients with a recurrence shows a peak between 30 and 39 years of age (grid) and a tendency towards a lower age, as indicated by the bars. In patients with complicated courses and without recurrences the opposite occurs (black)

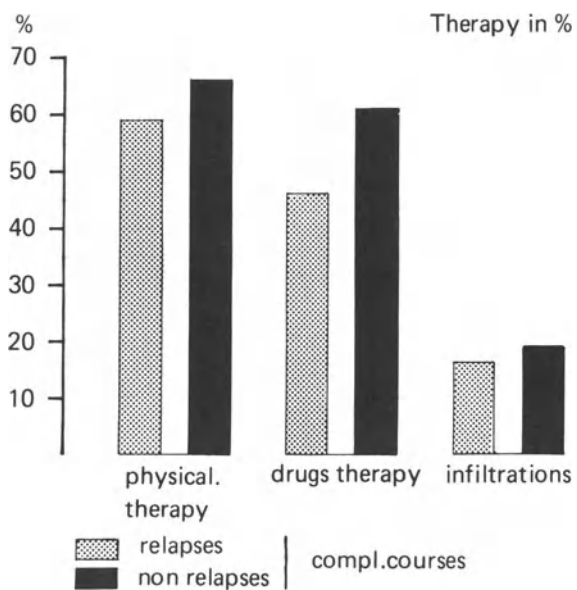


Fig. 8. Comparison between after-treatment in the recurrence group and the groups of patients with complicated course but without recurrence. Patients operated on for a recurrence (grid) show a lower percentage of after-treatment, particularly obvious for drug therapy

Complications Following Operation of Herniated Lumbar Discs

F. SCHEPELMANN, L. GREINER, and H. W. PIA

The aim of this study is to review the question of complications following operation of lumbar discs. To clarify this question 1645 operations for herniated lumbar discs performed in the Neurosurgical Clinic of the University of Giessen during the years 1960 - 1970 were analyzed.

For the purpose of this study *the material* was reduced to the total of 1492 cases: Only first operations, in which a herniated or protruded disc was doubtless and curettage of the intervertebral space was performed, were analyzed. The curettage of the intervertebral space was at L4/5 in 55.2%, at L5/S1 in 42.9%, and at L3/4 in only 2.8%. 63.3% of patients were between 30 and 49 years of age. The sex incidence was 2 : 1; 66.8% were males and 33.2% females.

Data on preoperative condition, operation, and postoperative course were collected by means of a questionnaire containing 89 questions for each case. The data were transferred to perforated cards and evaluated by electronic data processing. The significance of the results was statistically proved¹.

Disturbances of wound healing occurred in 18.8% of all cases and were the most frequent complication. They occurred most frequently in the 4th decade of life (Table 2) and more frequently in females (24.2% of the female patients) than in males (16.2% of the male patients). They were more frequent in cases laminectomized than in cases subjected only to hemilaminectomy or flavectomy (36.8% of the laminectomies, 17.8% of the hemilaminectomies and in 17.0% of the flavectomies). Among 283 cases with disturbances of wound healing there were only 8 cases with a subfascial inflammation.

Spondylitis developed in 1.5%. It occurred mostly in the 5th, 6th and 7th decade of life (Table 2); a significant sex difference could not be detected (spondylitis in 18 males and 5 females). The different surgical techniques had no significant influence on the development of spondylitis. Only in 4 out of 23 cases of spondylitis could a causal relationship to infections and inflammatory processes (meningitis, subfascial inflammation) be supposed².

Neurological defects or deterioration of neurological signs following surgery were found in 15.8%. These were reflex disturbances (6.6%), pareses (9.3%) and disturbances of sensibility (9.0%).

¹ We are indebted to Mr. O. HOFFMANN and Mr. W. MÜLLER for consultations and electronic data processing.

² A more detailed report on spondylitis as a complication of herniated lumbar disc surgery was published earlier (3).

Table 1. Frequency of complications following herniated lumbar disc surgery

Decade of life	Number	Disturbances of wound healing	Spondylitis	Urinary tract infection	Thrombophlebitis	Pulmonary embolism
10 - 19	19	2	0	0	0	0
20 - 29	218	38	1	16	0	3
30 - 39	479	110	3	52	5	1
40 - 49	468	79	11	44	13	7
50 - 59	237	39	6	32	3	5
60 - 69	65	12	2	8	1	1
70 - 79	6	1	0	2	0	0
Total	1492	281	23	154	22	17

Table 2. Relative frequency in % of complications following herniated lumbar disc surgery

Decade of life	Number	Disturbances of wound healing %	Spondylitis %	Urinary tract infection %	Thrombophlebitis %	Pulmonary embolism %
10 - 19	19	10.5	0.0	0.0	0.0	0.0
20 - 29	218	17.4	0.5	7.3	0.0	1.4
30 - 39	479	23.0	0.6	10.9	1.0	0.2
40 - 49	468	16.9	2.4	9.4	2.8	1.5
50 - 59	237	16.5	2.5	13.5	1.3	2.1
60 - 69	65	18.5	3.1	12.3	1.5	1.5
70 - 79	6	16.7	0.0	33.3	0.0	0.0
Total	1492	18.8	1.5	10.3	1.5	1.1

Postoperative urinary tract infections were found in 10.3%. They were relatively frequent in the 6th, 7th and 8th decade of life (Table 2), but it is not statistically ascertained that urinary tract infection is more frequent in the higher age group. It was more frequent in females (19.8% of the female patients) than in males (5.6% of the male patients). It is remarkable that a very high erythrocyte sedimentation rate (more than 50/100 mm) was found much more frequently in the cases with an urinary tract infection than in all the other cases (25.3% of the urinary tract infections, 11.1% of the other cases).

Thrombophlebitis occurred in 1.5% and *pulmonary embolism* in 1.1%; thrombophlebitis occurred in only one case with pulmonary embolism. Thrombophlebitis was most frequent during the 5th decade of life and pulmonary embolism during the 6th decade (Table 2) but these peak values are not statistically significant. Thrombophlebitis was found more frequently in females (2.2% of the female patients) than in males (1.1% of the male patients), but a relation between the occurrence of thrombophlebitis and sex could not be statistically ascertained. Pulmonary embolism was not more frequent in females (1.0% of the females) than in males (1.2% of the males).

The frequency of *other complications* was below 1%. An *epidural abscess* was found in 3 cases. In all there was a neurological deterioration. A *CSF fistula* occurred in only one case. *Meningitis* occurred in 3 cases. In all cases with postoperative meningitis spondylitis also developed. *Pneumonia* occurred in 9 cases but none of 43 patients which were in a bad health condition before surgery developed postoperative pneumonia.

Discussion is obviously limited to some aspects. The frequency of disturbances of wound healing in this material is at the upper limit to be expected according to GIERHAKE (2). The frequency of spondylitis following an operation for herniated disc found by other authors varies from 0.1% (5) to 4.0% (1). When estimating the postoperative neurological deterioration one has to take into account that a postoperative reduction of neurological signs was found in 87% of all examined cases. A certain number of the postoperative urinary tract infections have already existed before surgery. Part of them is probably due to bladder catheterization. In this context it is noteworthy that disturbances of rectovesical function persisted for more than 3 days following surgery in only 4.2% of all the cases. The frequency of thrombophlebitis and pulmonary embolism was of the same magnitude as reported in the literature (4).

Summary

Disturbances of wound healing (18.8%), neurological deterioration (15.8%), and urinary tract infections (10.3%) should first be taken into account when considering the possible complications following surgery for a herniated lumbar disc. Spondylitis (1.5%), thrombophlebitis (1.5%), and pulmonary embolism (1.1%) are comparatively rare. The frequency of other complications is below 1%.

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Spondylodiscitis - Lumbar Disc Removal

G. MEINIG, K. KRETZSCHMAR, M. SAMII, TH. WALLENFANG, R. HÜLSE, and
K. SCHÜRMANN

Introduction

Although there have been several communications concerning spondylodiscitis following the removal of herniated lumbar nucleus pulposus, its etiology and pathogenesis is still not completely understood. Moreover, the number of postoperative spondylodiscitis observed in our clinic appeared to increase during the last five years. This has stimulated us to investigate our clinical material with reference to disc operations and their complications.

Materials

During the period from 1955 to 1975 we performed a total of 2745 disc operations. 1290 of these, in the period from 1955 to 1970, were followed by 2 postoperative spondylodiscitis; from 1970 to 1975 15 cases of this complication followed 1455 operations.

Results

Figure 1 shows the main clinical features of spondylodiscitis as compared to the postoperative time-scale. Following a more or less painless interval, acute lumbar back pain reappeared, in average 20 days postoperatively (n = 14). This pain was accentuated by standing and by the slightest spinal motion. Sometimes it was accompanied by abdominal, inguinal and thoracal pain and by spasm of the paravertebral muscles. There was always quick relief following strict immobilization.

Sedimentation rate of more than 100 mm in the second hour appeared in average 32 days postoperatively and normalized after 6 months (n = 15). The early roentgenologic sign (Fig. 2) - irregularity of opposing vertebral surfaces and destruction of the vertebral body - appeared distinctly later, at 48 days postoperatively (n = 12). Following an increase of the destruction and lysis, accompanied by narrowing of the lumbar interspace (if the interspace was not maximally narrowed pre- or postoperatively), sclerosis, was first observed 4 to 5 weeks later. Preponderant sclerosis did not occur prior to three months. In 6 cases repair was delayed by sequestration of the vertebral body and in 6 cases by the development of spondylodiscitis in other, non operated, segments. Complete healing took an average of nearly two years.

The patients were treated with antibiotics (mostly Lincomycin), immobilized in a plaster bed (for an average of 96 days), and remobilized with a corset. No patient was treated surgically.

The retroerspective search for predisposing factors showed, in 9 cases, an increased sedimentation rate (ESR) which had been present preoperatively. More or less marked degenerative lesions of the vertebral column were seen in nearly all patients. In 5 cases there was an osteoporosis, in 1 case a status following juvenile kyphosis, in 1 case a spondylodiscitis without prior surgery, and in 1 case spondylodiscitis followed a lumbar disc removal in another hospital one year before. In one case, operated on some weeks before (1976), an infectious spondylodiscitis was found during surgery which had developed spontaneously and without preoperative roentgenologic signs. Bacteriological cultures from the disc and bone which grew *Stapylococcus aureus*. In 5 cases there were local and superficial postoperative infections. Bacteriological cultures in 4 of these cases gre *Stapylococcus aureus*.

Summary

Although the evolution in time varied considerably in our cases, all patients were without significant symptoms 2 years postoperatively. Certain predisposing factors were found in only a few cases. Since the etiology is still discussed, it is impossible to establish how to avoid this severe postoperative complication. In a suspected case, it is important to look for the most frequent signs (ESR, pain, X-ray findings, eventually tomography) in order to initiate an adaequate therapy in due time.

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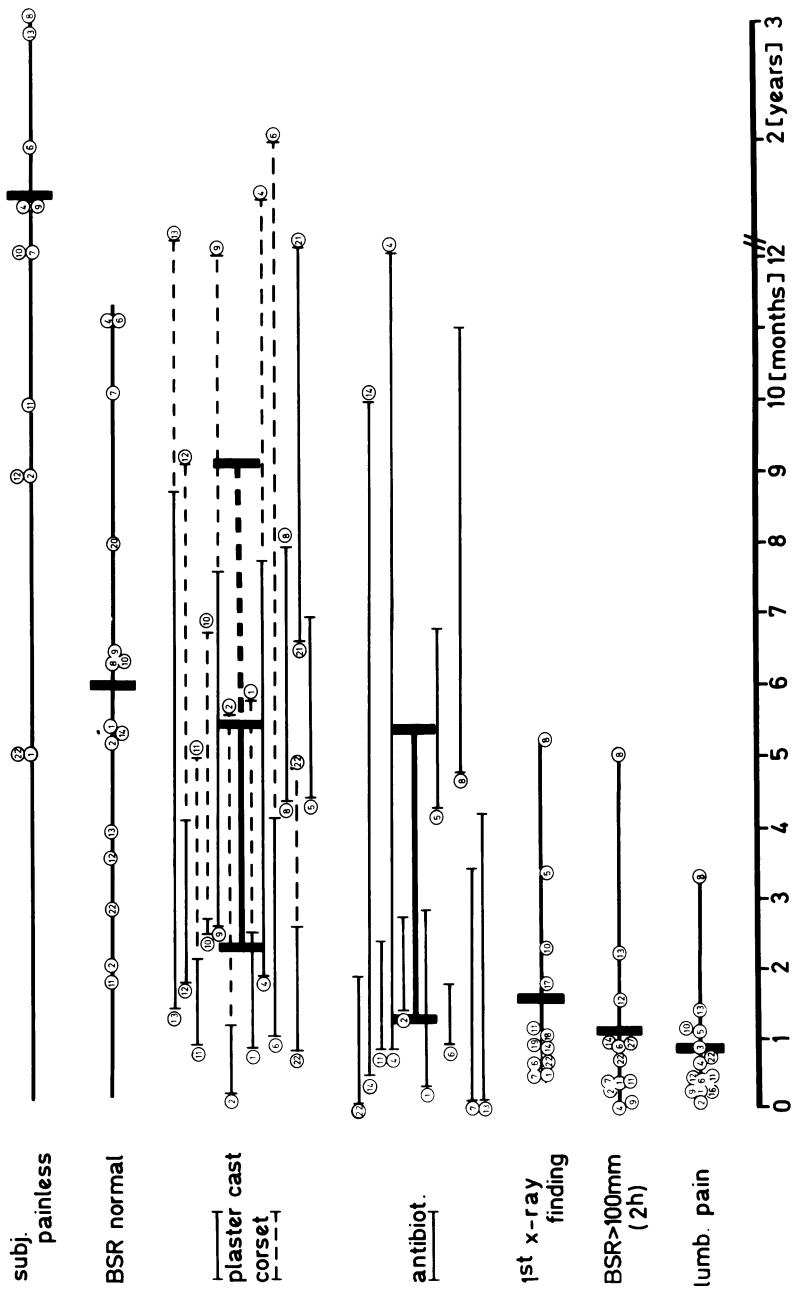


Fig. 1. Data demonstrating the clinical course of spondylodiscitis in time (see text). The number within the circle corresponds to the patient number

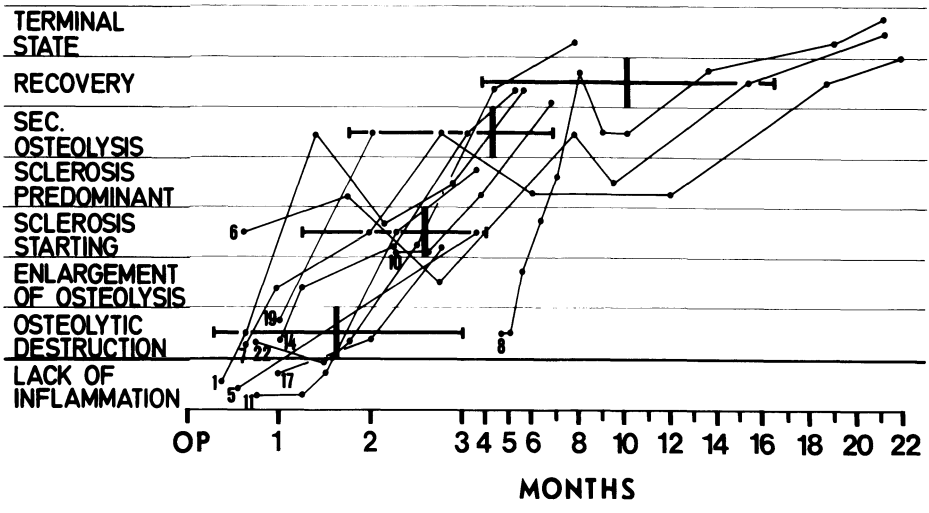


Fig. 2. Time course of roentgenologic changes in spondylodiscitis

The Influence of Lumbar Disc Disease on Psychiatric Symptomatology

A. SPRING, R. WITTEK, and R. WÖRZ

The therapy of lumbar disc herniation seems to be a surgical and physiotherapeutic problem. But even when massive disc prolapses are removed, the results of treatment are not always satisfactory. The causes of these therapeutic failures are manifold. Personality disorders or psychogenic factors may play the most important role. To cast further light on this problem, a combined psychiatric, psychological and neurosurgical study was performed.

Material and Methods

Fifty patients (32 males and 18 females) were studied. No special selection was made. The youngest was 21, the oldest 59 years - the average age being 41 years. All patients had longlasting pain and neurological disturbances caused by lumbar disc herniation. Twenty-five patients had a disc protrusion at L4/L5, 18 at L5/S1, 3 at L3/L4. The rest were combinations of two lower lumbar discs. The patients were tested preoperatively as well as 10 weeks and 1 year after the operation. The following psychological tests were applied for this study: Reduzierter WECHSLER - Intelligenz - Test, MAUDSLEY Medical Questionary (MMQ), Befindlichkeitsskala (BS) - behaviour scale, and Beschwerdenliste (BL) - list of complaints. The BS and BL were developed at the MAX PLANCK Institut für Psychiatrie in MÜNCHEN. The actual, maximal and average pain intensity were estimated by the patient with a visual analogue scale defined by STERNBACH (3). Detailed explorations were performed to detect neurotic, depressive and other psychiatric signs and symptoms. For several reasons it was not possible to perform follow-up examinations of all patients. Forty-seven patients were tested 10 weeks after the operation, 36 patients after 1 year. Taking into consideration the variety of human nature, the environmental conditions and the complexity of the lumbar disc disease, the results were analyzed by descriptive statistical methods and their percentages calculated. They point out some remarkable features of this common disease.

Results

1. Neurological Results

Prior to surgery all patients had neurological dysfunction (paresis and/or disorders of sensitivity, asymmetric leg reflexes, positive LASEGUE's sign). Ten weeks after the operation 41% of the patients had no neurological disturbances. Fifty-five percent showed an obvious improvement of the neurological findings. Two patients had the same neurological symptoms as previously. No deterioration was registered. At the follow-up examination after 1 year, 70% had no pathological

neurological findings, 24% had an obvious improvement. One patient had the same neurological signs; 1 patient underwent a reoperation. He had a recurrence after 11 months. All cases with severe residual neurologic symptoms or complaints about pain were screened by myelography. After 12 months there was no patient with positive myelographic findings. Therefore, we believe that the psychological development of our patients may be compared.

2. Psychological Results

Eighteen patients (36%), who underwent the necessary operation, were preoperatively diagnosed as neurotics. Postoperatively it was possible to classify three reaction patterns. Ten weeks after surgery 43% of the patients showed a great reduction of the psychological test scores. In this group the psychiatric state improved. Except for 1 patient, who complained about pain of the same severity, the other members of this group stated an obvious improvement of the low back pain. The second group consisted of patients who postoperatively had less low back pain and the same psychiatric results as preoperatively. The psychological tests - BS, BL and MMQ - were almost the same. This group comprised 11 patients (23%). In the third group (34%) the BS and MMQ tests were increased. The BL showed nearly the same results or even more complaints. The psychological state deteriorated. These patients showed psychological disorders such as irritability, hesitation, inability to concentrate, misery or depressive mood. They were more neurotic or depressive than before. Thirteen patients of this group reported a reduction of the previous pain. One patient had pain of the same intensity. In 2 patients pain was estimated as being worse. The follow-up examination after 1 year showed approximately the same results. The psychological state of 14 patients (39%) had improved. Forty-four percent of the patients seemed to regain their initial personality traits. Seventeen percent of the patients showed severe psychological deterioration. The low back pain had decreased further. Only 1 patient of the second group (unchanged psychological symptomatology) had more pain and 2 patients with psychological deterioration had the same pain intensity. The following results were striking: 10 weeks after surgery 30% of all patients complained about new pain syndromes and/or other symptoms (heart consciousness, gastric disorders, asthmoid complaints) which had no organic cause. The new pain syndromes (20% after 10 weeks and 30% after 1 year) were located in other regions of the body (head, neck, chest, cervical and thoracic spine), and, in some cases in the contralateral leg. It is noteworthy that 80% of the patients with non-organic complaints had been diagnosed as neurotics preoperatively. The remaining 20% were non-neurotic personalities. The latter had actual psychological traumata and conflicts which might be responsible for the new complaints. We interpret the onset of new pain syndromes and other nonorganic disturbances in the neurotic patients as a syndrome shift. It was remarkable that nearly all patients stated a significant improvement or disappearance of the low back pain.

Discussion

These results point out the psycho-physical complexity of lumbar disc disease. The objective improvement following surgery - as regards the neurological condition - seems to be a psychological stress for many patients. These patients appear to be more neurotic or depressive than before. Syndrome shifts may occur. Therefore, the indication for operations must be restricted to patients with neurological and corresponding myelographic findings (2). The frequent incidence of lumbar disc

disease and personality disorders - mainly neuroses - indicates the necessity of a psychiatric consultation in all dubious cases and, of course, in the presence of manifest psychiatric disease (1). The differentiation between alterations of personality caused either by pain or by premorbid neurosis is difficult (4). Therefore, thorough psychological exploration of the patient is necessary. If there are neurotic or psychosomatic complaints which have no causal relationship to the disc disease, a psychiatric treatment must be performed on time. This procedure saves the patient and the surgeon an unnecessary complex, time consuming efforts and reoperations. A wrong physical therapy may intensify the psychological problems and may be the somatic substrate for the conversion neurosis. As a rule psychotherapy meets with stiff opposition from the patients and his family. The patient fears that he is being misinterpreted because he believes in the somatic genesis of his complaints (4). Therefore, it is recommendable to start a therapy of the somatic symptoms with a combined physiotherapy and pharmacotherapy. Autogenic training is a method to facilitate communication between soma and psyche. In this way it is possible to convince neurotic patients that psychotherapy is indicated and would be promising.

Summary

Fifty patients with lumbar disc disease were studied preoperatively, 10 weeks and 1 year after surgery. A combined psychiatric, psychological and neurosurgical study was performed. The results indicate the psycho-physical complexity of lumbar disc disease. The objective improvement following operation seems to be a psychological stress for many patients. They appear to be more neurotic or depressive than before. Syndrome shifts may occur in neurotics. Therefore, a psychiatric exploration and therapy must be performed in time.

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On the Technique of Clearing the Intervertebral Space in Cases of Protruded Lumbar Disc – A Comparison of Two Surgical Methods

J. WICKBOLDT and K.-A. BUSHE

Introduction

The problem as to the extent of clearance of the disc affected by degeneration falls within the scope of disc surgery. It is discussed in many publications in relation to recurrence, discitis and aseptic necrosis as well as to the intra- and retroperitoneal complications which may be caused by the operation. In 1971, we altered our method of clearing the intravertebral space in lumbar disc operations. In this paper we compare one year's patients before (1969) with another year's patients after (1972) alteration of the surgical method by evaluating the clinical record material and discuss the three major points specified above.

Material and Methods

The indication for a disc operation is arrived at on the basis of the combination of anamnesis, clinical data and myelography. In both groups, access to the affected intervertebral space was as a rule unilateral via an interlaminar fenestrations as generally practised nowadays, enlarged by osteoclastic resection, especially in latero-caudal direction, or if necessary, via a vertebral arch resection. If not already torn by sequestered disc material, the posterior longitudinal ligament and the annulus fibrosus were excised and loose disc material removed with the rongeur.

In the 1969 group as much degenerated disc material as possible is removed from the intervertebral space with rongeurs and slightly bent sharp spoons. With this instrumentarium, it was by no means possible to obtain radical clearance, in which only solid portions of the annulus fibrosus are preserved.

In the 1972 group, the intervertebral space was thoroughly curetted in all directions with the SCOVILLE curette, the cartilaginous and caudal boundary surfaces included. Sometimes the bony covering plates were also affected. Especially with the right-angled "face-downward" curette it is possible to free degenerated material until the limitation by the annulus fibrosus bilaterally (Fig. 1). With this instrument, the direction of curettage is always ventralwards. The 45° "face-upward" curette is only employed for the lateral portion of the intervertebral space on the side of operation in the dorsal direction of curettage (Fig. 2). With gripping forceps of various sizes, only *completely freed* material is carefully removed (1). Following repeated alternated use of curettes and rongeurs the intervertebral space is flushed under pressure and palpated with a blunt hooklet. This procedure permits an almost radical clearance of degenerated disc tissue. In this way rongeur injury to retro- and intraperitoneal structures appears avoidable.

All clinical histories of patients operated on for the first time because of a lumbar disc prolapse were examined over a period of 3 1/2 years (calculated from the beginning of the year for the year-groups 1969 and 1972). Attention was paid to the data presented below. The period of 3 1/2 years was chosen since it was the longest possible observation period for the 1972 group. Thus the 1969 group became comparable to the 1972 group with respect to time.

Results

1. Neither in the 177 patients of the 1969 group nor in the 273 patients of the 1972 group (radical clearance) did we observe symptoms of discitis or aseptic necrosis as described by SHCARFETTER (12). From the 1969 group 32 patients (18.1%), and from the 1972 group 45 patients (16.5%) presented as outpatients and, in part, as inpatients with a suspected recurrence. The symptoms ranged from uncharacteristic back pain to typical lumbalgiform complaints and ischialgia. X-rays were made in all cases, but never gave indications of aseptic necrosis in neighboring vertebral bodies.
2. Our results concerning the frequency of recurrences are shown in Tables 1 and 2. There was an indication for operation in 17 cases of the 1969 group (9.6%), which fell to 18 (6.6%) in the 1972 group. Reoperations caused by disease at another level remained constant: 5 (2.9%) and 8 (3.0%) cases respectively. We considered as being

Table 1

	1969 - Group	1972 - Group
Primary operation	177 (100%)	273 (100%)
Recurrence	32 (18.1%)	45 (16.5%)
No Indication for Reoperation	15 (8.5%)	27 (9.9%)
Reoperation	17 (9.6%)	18 (6.6%)
Same Level Same Side	10 (5.7%)	7 (2.6%)
Same Level Opposite Side	2 (1.8%)	3 (1.1%)
Different Level	5 (2.9%)	8 (3.0%)

Table 2

	1969 - Group (2.5-3.5 years)	1972 - Group (2.5-3.5 years)	Mattmann (1971) (-15 years)
Primary operation	177	273	4120
Reoperation	17 (9.6%)	18 (6.6%)	(11%)
Reoperation at Same Level	12 (6.8%)	10 (3.7%)	-
Scars etc.	2 (1.1%)	3 (1.1%)	(1.5%)
Real Recurrence of Disc Herniation	10 (5.7%)	7 (2.6%)	6.7%

true recurrences those cases in which reoperation was at the originally operated height and prolapsed disc tissue was found here once more, irrespective of which side. MATTMANN (9) and KEYEL et al. (8) also define their true recurrences in this way. Cases in which only scar tissue, adhesions or osteophytes were found were omitted. With respect to true recurrences, we could record a decline from 5.7% (1969) to 2.6% (1972) (Table 2). Recurrences were distributed evenly among all the participating surgeons. In one case of the 1972 group, clearance of the intervertebral space had to be discontinued prematurely due to an almost uncontrollable epidural hemorrhage. There was a prompt true recurrence after half a year.

3. In neither group did we have a retro- or intraperitoneal complication as that described by GRUMME et al. (5). We have observed this twice before introduction of the surgical procedure practised since 1971. In both cases this complication was evidently caused by inexperienced manipulation of the rongeur.

Discussion

Those engaged in lumbar disc surgery are obviously concerned not to damage retro- and intraperitoneal structures. The warning against radical clearing of the intervertebral space stands in the foreground, especially when using the rongeur and the curette (5, 6, 10, 11). One is faced by the conflict between the risk of recurrence and the danger of injury (6). We are convinced that this danger, even if slight, (1 : 1000 to 1 : 6000 according to GRUMME (5)) can be reduced to a minimum (even in the hands of the beginner) by the method described above (1972 group), and that the incidence of recurrences can be reduced. The prerequisite is that only *fully free* disc material is carefully removed with the rongeur and that flushing follows fractionated curettage, as already emphasized by BUSHE (1).

We observed no case of discitis and aseptic necrosis following radical clearance, even in the years after 1972. SCHARFETTER (12) believes that, among other factors, injury to the cartilaginous and bony covering plates may be its cause. However, our own experience speaks against this, as also does the experience of surgeons who undertake a fusion, in which radical clearance is necessary (1, 3, 6, 10). RAAF (11) also recommends as extensive a clearance as possible; among 905 operated patients, he does not report a single case of this complication (10, 11). Based on experimental and clinical experience GEYER (4) recommends extensive interspace clearance to facilitate spontaneous fusion. We believe that our figures show that the incidence of recurrences can be reduced by radical clearance.

Our reoperation rates and recurrence incidence agree with other communications (6, 9), taking into account that our comparison period is relatively short for the reasons specified above. However, the general discrepancy to orthopedic publications remains open. KEYEL et al. (8) advocate deliberate avoidance of radical clearance; up to about 10 years' observation they observed 2.6% of true recurrences. HARMS et al. (7) report only 2.5% of reoperations in a period of 10 years of observation. Nevertheless, our intent was to point out the influence of radical clearance as compared to non-radical clearance on the incidence of recurrences in our own material.

Summary

The influence of changing the method of clearing the intervertebral space in lumbar disc operations from non-radical to radical on the incidence of recurrences and postoperative complications was investigated and discussed.

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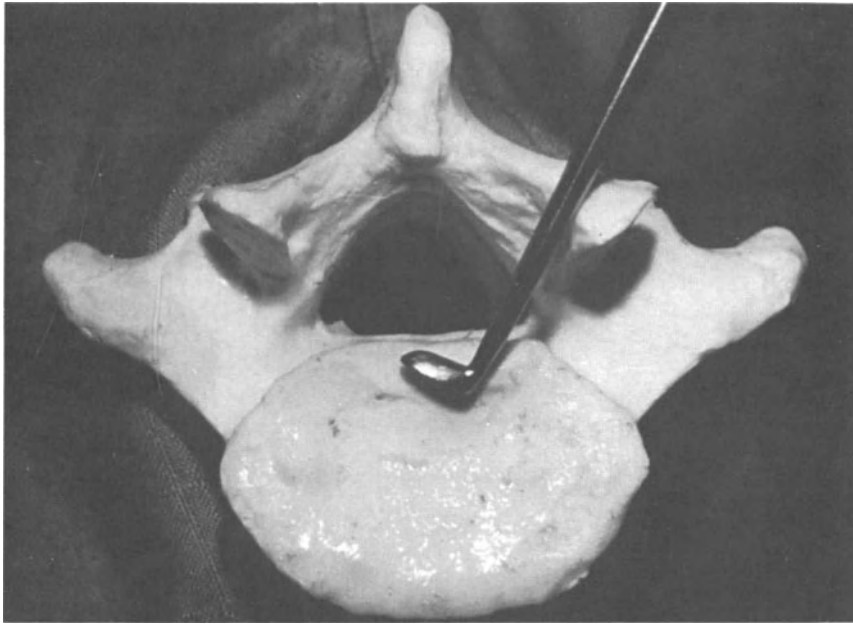


Fig. 1. Right-angled Scoville-curette "face-downward". Direction of curettage is ventralwards

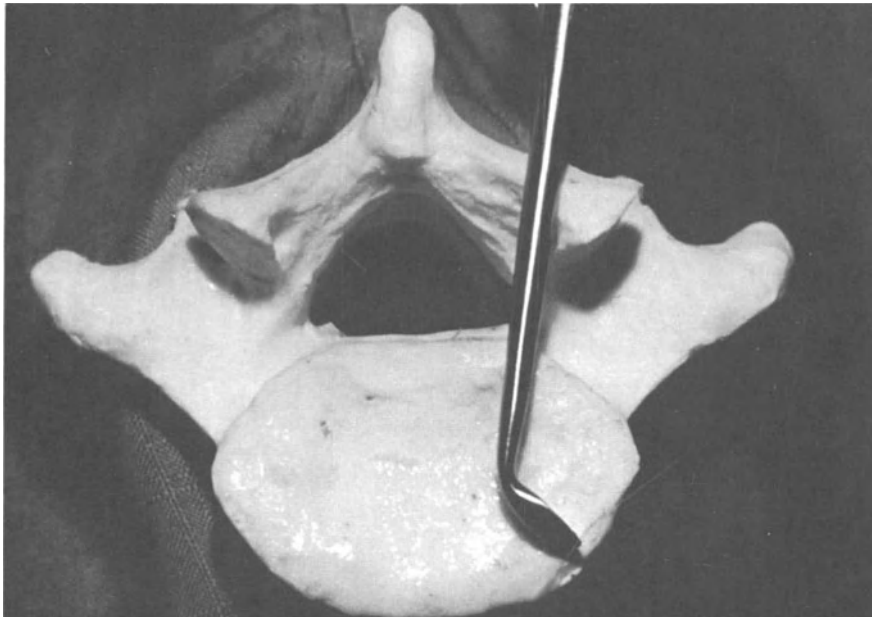


Fig. 2. 45° Scoville-curette "face-upward". Only employed for the lateral curettage on side of operation. Direction of curettage dorsalwards

Spinal Joint Syndrome and Interbody Fusion

Y. K. KIM and C. H. ROJAS

Introduction

Unlike most of the joints, the facet joint is formed side-to-side. Considering the way the spinal facet is formed, it appears that the human being was probably created to live with the spine in the horizontal position (Fig. 1). The fact that humans stand upright probably has increased the frequency of spinal trouble. As a consequence of the dynamics of the spinal column, the most frequent disorders are disc and joint diseases. Whereas the diagnostic and therapeutic measurement of disc disorders are well known, the joint disorders seem to have been much neglected.

Among 266 patients with severe lumbago and sciatic symptoms in our series between 1972 and 1975, 103 were treated conservatively and 163 surgically. Among those 266 patients, 84 (31.4%) had previously received one or more surgeries elsewhere. This figure indicates that the failure in laminectomy is considerably higher than reported in the literature. Apparently, the complications from spinal surgery are not carefully prevented or properly treated. Moreover, it is our belief that the nature of various spinal disorders, other than disc disease, is not well recognized. Based on our clinical and intra-operative findings, we analyzed the causes of back and sciatic pain from our surgical patients (Table 1).

As this analysis indicates, the most frequent failure in previous spinal surgery was the failure in recognizing the spinal joint disorders (see the first and second columns in Table 1). Therefore, we will concentrate on those joint syndromes in this paper. The first group is constituted by either intrinsic or extrinsic space occupying lesions of the spinal canal. The latter group in the Table 1 includes disorders originating from the spinal joint. The pain clinically felt to originate from arachnoiditis could not be confirmed. This group became pain free after the selected surgery. These different processes are frequently superimposed on and very difficult to separate from each other. Clinical symptoms are also identical. Therefore, it is designated here as spinal joint syndrome.

Spinal Joint Syndrome

The subluxation of the joint occurs together with a narrowed interbody space (Fig. 1). Narrowing of the interbody space, in turn, occurs following removal of the disc or after reduction of the disc volume by degeneration. Logically, oblique views of the spinal joint should more clearly demonstrate the subluxation. In practice, however, such views usually do not show the disorders because each joint has to be projected perpendicularly to the joint axis and strictly parallel to the facet plane. In most of our cases subluxation was complicated by

Table 1. Underline disorders in 266 patients with severe low back pain

Diagnosis	Previous surgery	No previous surgery
(A) Diagnosis confirmed by objective findings: Intraspinal disorders.		
1 Herniated disc	3	68
2 Large mass of scar tissue	2	1
3 Vascular abnormality	-	6
4 Hypertrophy of Lig. Flavum	-	7
5 Hypertrophy of lamina fusion	2	-
(B) Diagnosis confirmed by objective findings: Spinal joint disorders.		
1 Subluxation of joints due to collapse of disc space	41	12
2 Defective joint and subluxation of the same	18	-
3 Unstable joint due to ligaments	2	7
4 Degenerative osteoarthritis	4	7
5 Osteospondylolisthesis	1	4
(C) No objective findings but clinically suspected disorders.		
1 Facet neuralgia (painless following facet nerve block)	-	47
2 Miscellaneous (undiagnosed, psychophysiologic, systemic disorders, fibrous adhesions around the nerve roots etc.)	13	21

preceding surgery. The subluxation not only limits motion of the involved joint, causing pain, but also narrows the intervertebral foramen, and consequently the nerve root canal. Even under such circumstances, the size of the canal still should be wider than the nerve root itself. As a matter of fact, not all such cases have sciatic pain. This may be explained by individual differences in the spinal nerve "conduit", and by fibrosis around the nerve root (5). Another consideration is that sciatic pain may be manifested as referred pain from the facet nerve, rather than from direct nerve root compression (8).

Defective joint process can be congenital, but this seldom causes pain in young individuals of active age. In our cases, the most frequent sources were laminectomies (Fig. 2). Even if the herniated disc was the only disorder in the majority of cases, extensive laminectomy was carried out, thus injuring the facet ligament and the joint processes. Again, fortunately, a defective joint does not cause pain unless it is complicated with subluxation or has caused stress to the facet ligament.

The group of unstable joints includes those with which extreme movement and/or angulation is associated. FERGUSON's statistics (2) showed the lumbosacral angle to be less than 54 degrees in normal individuals. Our control group demonstrated an average 43 degree angle and an extreme flexion and extension ranging from 23 to 46.5 degrees (Fig. 3). Our measurement is based on the L5 and sacrum axis and different from FERGUSON's. In one of our cases, the joint moved up to 65 degrees. Unstable joints of this kind were successfully treated by interbody fusion.

Osteoarthritis is not uncommon. Early recognition is sometimes difficult, but by looking more closely it should not be very difficult (Fig. 4).

Symptoms are almost identical regardless of the causes. The main symptoms are back pain and limited motion. Gluteal and spino-iliac muscles are usually tender, mainly due to overstressed by painful joints. Sciatic pain may occur directly or indirectly, as mentioned previously, but motor, sensory and reflex functions are usually well maintained except for intermittent subjective hypo- and paresthesia.

Interbody Fusion

The symptoms are not easily relieved by bed rest, traction, brace, nerve block, physical therapy or even by denervations. Our past experiences with rhizotomy, chordotomy, or similar procedures to interrupt the neural pathway for pain have been discouraging. Long term results are much poorer than the initial results promise. Therefore, we adopted a direct approach to the involved joint. Recently, we introduced the facet rhizotomy by SHEALEY's method. We also had the opportunity to evaluate cases of rhizotomy performed elsewhere. It is too early for us to comment on the relative value at the present time. However, we believe that facet rhizotomy was successful, if no anatomical change of the joint is apparent and the pain is considered to originate from the facet ligament and the facet nerve. Cases involving anatomical derangement or degenerative diseases of the joint were not relieved by denervation surgery. In such cases, we chose spinal fusion. Moreover, we preferred interbody fusion to the inter-lamina or inter-transverse fusion (Fig. 5). We perform interbody fusion either by dorsal or ventral approach. With regard to the procedures, risks and results associated with each approach, we do not see any preference. The clinical results are almost the same. However, most of our cases needed a dorsal approach because additional disorders were superimposed. Ventral fusion was preferred in cases with no intraspinal mass lesion. In osteospondylolisthesis, a dorsal approach is preferred because it is better to remove the detached segment, the lamina and the inferior articular processes. If these remain, they can irritate the named facet ligament and nerve, causing pain. Preference of one surgical method to another is usually up to the surgeon; but for the following reasons, we believe interbody fusion has greater advantages.

1. The procedure is simpler.
2. Bone union is faster and almost certain. (None of our cases failed to achieve bone union).
3. Stability is greater.
4. Hypertrophy of graft may occur, but does not affect the spinal canal as is occasionally seen in the interlamina fusion.
5. Early ambulation is possible (only 3 wks. bed rest).
6. No brace or cast is needed except for multiple fusion and osteoporotic cases.
7. Widening of intervertebral foramen is better achieved.
8. Disc herniation that occasionally occurs even after posterior lamina fusion is prevented.

Clinical Results

The clinical results of interbody fusion are listed in Table 2. 80% of our patients were benefited from the surgery. 50% were able to return to work even though some of them had to change their job. The most satisfactory result was achieved at the level of L5/S1. Failure

Table 2. Results of lumbar interbody fusion in 69 cases

Spinal joint syndrome	Excellent	Satisfactory	Poor
64	33 (51.6%)	18 (28.1%)	13 (20.3%)
Osteospondylolisthesis			
5	4	1	-

to relieve pain most frequently occurs for two reasons; failure to widen the interspace or overstress of the joint next to the fused vertebral bodies. The more the larger segment moves against the adjacent small joint, the greater the chance of overstressing the joint. Another consideration is the interbody fusion by dorsal approach in cases previous multiple spinal surgery. If the dura and nerve root sleeves are already damaged, causing fibrous adhesion, any additional surgery around those nerve roots increases the hazard. In such cases a ventral approach should be used.

Conclusion

Interbody fusion is definitely not an ideal and constructive surgery. The joint syndrome can be and should be prevented during laminectomy. If joint damage occurs, there are only a few alternatives remaining. If all available surgical or non-surgical treatments have failed, the interbody fusion will become an unavoidable alternative. The interbody fusion is believed to be far superior to the interlaminar or transverse fusion.

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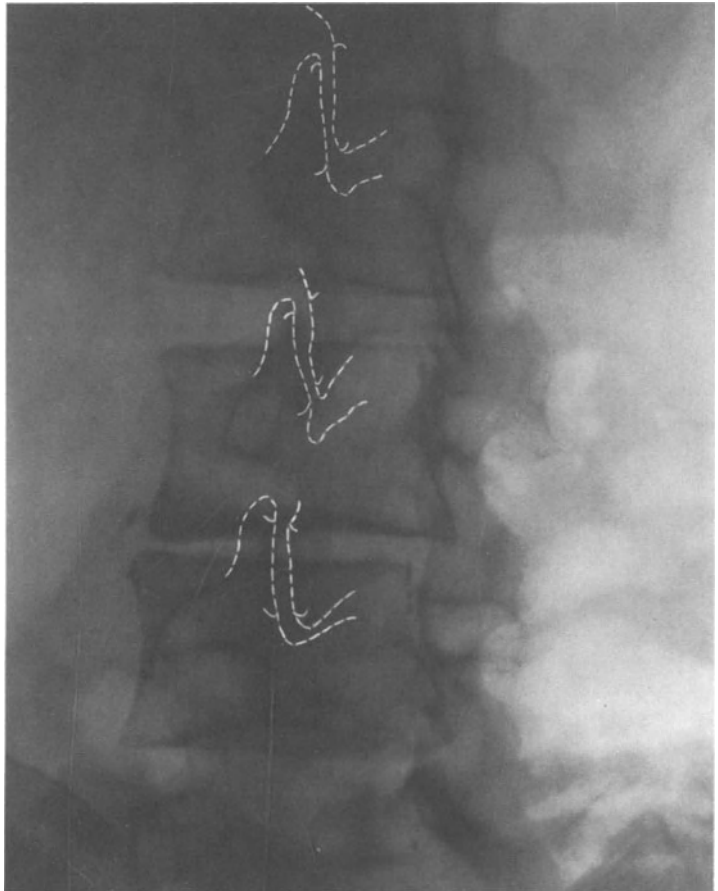


Fig. 1. The facet joints are facing side to side. Once the disc space is narrowed, this easily causes subluxation of the joint and narrowing of the intervertebral foramen in upright position



Fig. 2. Defective inferior articular process of L4 resulting from laminectomy. As a consequence, intervertebral space and foramen are narrowed and the joint unstable

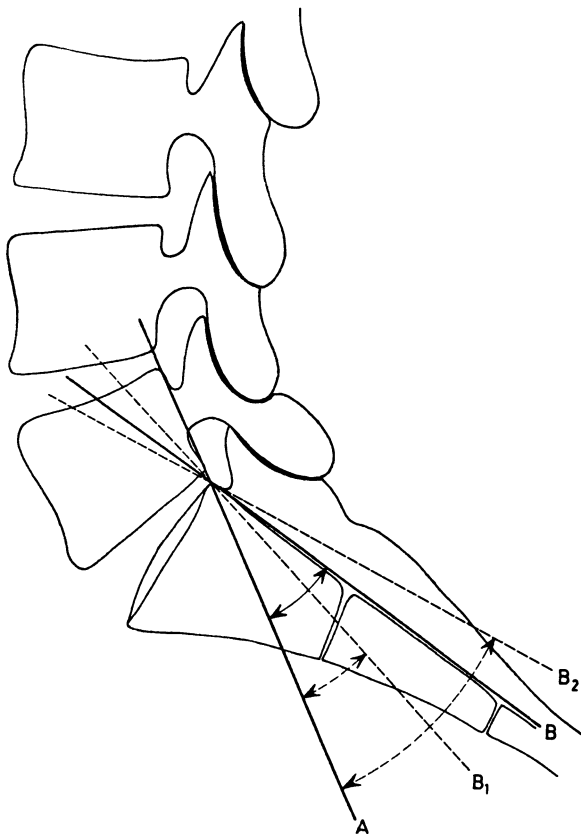


Fig. 3. Lumbo(A)-sacral (B) angle (43°), B-1-B-2 is the average range of hyperextension and -flexion ($23-46.5^{\circ}$) in normal individuals (10 cases)

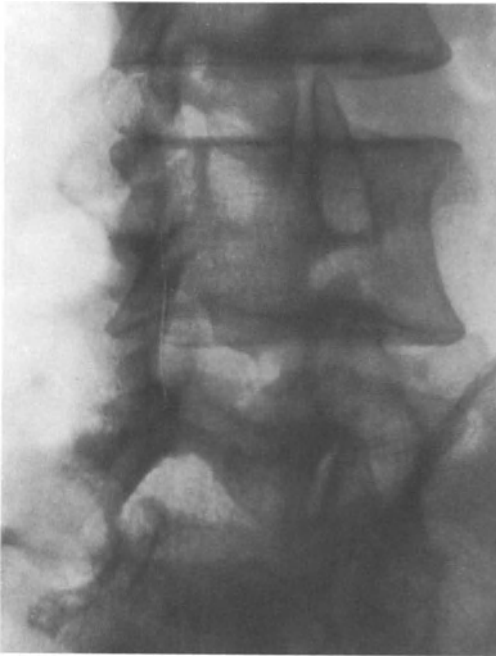


Fig. 4

Fig. 4. Deforming osteoarthritis. No history of trauma

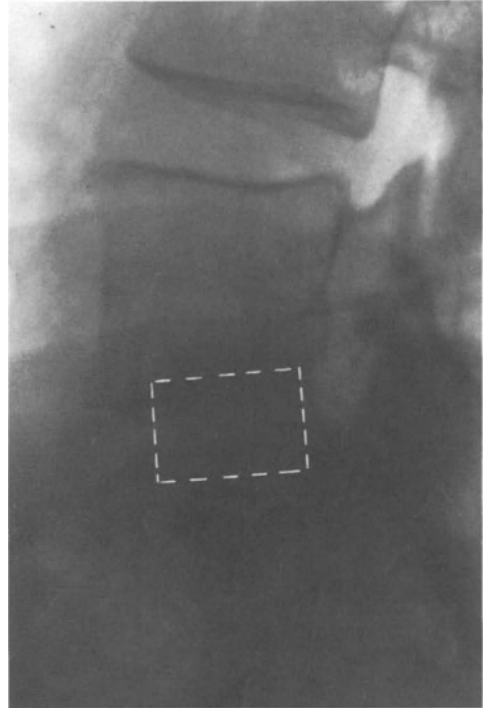


Fig. 5

Fig. 5. Interbody fusion L5/S1 by dorsal approach. Four graft blocks are inserted in parallel

A New Surgical Procedure for Lumbar Disc Herniation Causing Less Tissue Damage Through a Microsurgical Approach

W. CASPAR

Experience shows that there is an undesirably high incidence of substantial (unfortunately, sometimes also permanent) local back complaints after surgical treatment of lumbar disc herniation. The quality of the results of surgery is thereby reduced and sometimes indeed put in question. We believe that a considerable proportion of the complaints must be attributed to surgical trauma, in particular to muscle damage. This opinion is supported by the results of experienced surgeons such as KUHLEND AHL, LANGE, LOVE, YOU MANS and others (8, 9, 10, 11, 15, 19, 5, 20), who have long advocated an intervention which is as accurate, restricted in extent and as gentle as possible. It is also based on our own observations over many years. There is no doubt that the indication, extent of the surgical approach, gentle procedure and the experience of the surgeon have a direct relationship with the quality of the operation results. The hitherto practised surgical method requires a disproportionately large access as compared to the dimensions of the surgical target area (about 10 : 1 and more). This applies particularly to the generally recommended exploration of the two lower segments (1, 2, 3, 4, 6, 7, 12, 13, 14, 16, 17, 18). It is known to be unnecessary in 90 to 95 percent of the cases. The diagnostic procedures available today ensure a sufficiently safe selection of cases with several herniations. The conventional procedure employing the usual instrumentarium make considerable pulling, cutting and pressure injuries to the muscle inevitable. The consequence is irreversible damage or destruction of the morphological and functional integrity of the finely articulated back musculature system. This is evidenced by the extensive muscle fibres frequently encountered in recurrence operations.

On the basis of this experience, and taking into account theoretical considerations, an improved surgical procedure was developed to fulfil the following requirements:

1. precise monosegmental access (implying definite localization of the slipped disc;
2. minimal lesion in the approach to the actual area of surgery;
3. better visual clarity in depth and, thus, more gentle manipulation of the nerve root and dural sac.

Fulfillment of the first point necessitated routine employment of contrast-medium diagnosis (myelography, and, if necessary, discography in addition). The last two requirements could be met by recourse to a special and refined instrumentarium¹ and by employing the surgical microscope. The microscope does not only magnify, but also creates optimal light conditions. At the same time, it ensures that the assistant surgeon is able to see without hindering the surgeon.

¹ Manufacturer of the instruments (selfretaining retractors of various sizes, root retractor, various dissectors and coagulation forceps): AESCULAP Company, Tuttlingen.

Details of the Surgical Procedure

The operation is carried out with the patient in modified knee-elbow position ("Mecca positioning"). The segment to be operated on is marked by a puncture cannula with subsequent X-ray control. A midline cutaneous incision is made from about 3 cm from the upper limit of the cranial spinous process to the middle of the caudal one. The fascia lumbodorsalis is cut through 1 cm paramedially. The edge of the median fascial section is reflected to the midline and tied up by means of anchor threads. The musculature is detached obtusely with a tiny raspatorium from the midline down to the ligamentum flavum. It is advisable to start from the lateral surface of the cranial spinal process so not to go beyond the midline unintentionally.

Further bloodless detachment is effected by firmly pressing in a drawn out compress. Muscle origins and insertions on spinous processes and midline ligaments are not detached but, at most, indented at their insertion. Digital palpation of the anatomical situation informs on the breadth and course of the vertebral arches, the position of the articular processes and the interlaminar space. The musculature lying on the vertebral arches is loosened with the fingers. A suprapariosteal detachment in the angle between the spinous process and arch by means of extremely fine incision is occasionally necessary. Under no circumstances is the musculature loosened by incision.

The special speculum-like retractor (various sizes are available) is introduced with the aid of a small modified LANGENBECK hook, so that it can first be opened in the transverse direction. The interlaminar space is exposed by spreading the musculature 2 cm. Residues of connective tissue and muscle fibers are pushed away from the ligamentum flavum with stem tampons. The retractor is closed, turned 90 degrees, the handle pointing towards the assistant, and then reopened, this time in a longitudinal direction. The branches must come to lie directly above the vertebral arches so that one can see the whole interlaminar space.

A cross-shaped incision is made in the ligamentum flavum and fenestration carried out. In the presence of difficult optical conditions, this phase can be performed under the microscope. The surgical microscope (focal length of the objective: 350 mm) is usually placed in position after fenestration. If necessary, the window can be readily extended and (exceptionally) hemilaminectomy carried out under the microscope. The root can be isolated and the slipped disc cleared in the usual way. The procedure is rendered significantly easier by special designed dissectors, various retractors, incision scalpels and coagulation forceps¹.

The advantages of the microscope (better illumination, variable magnification and depth sharpness, simultaneous possibility for the assistant to observe) allow more gentle manipulation of the dural sac and root. Besides, better differentiation of anatomical structures is possible. This reduces the risk of instrumental lesion and is advantageous in the loosening of adhesions as well as for hemostasis in the peridural space. Following removal of the retractor, the musculature immediately lies against the vertebral arches and the spinous processes since its insertions were not severed. The wound is closed in several layers as usual. A further advantage is the bloodlessness of the intervention (an average of 25 ml blood is lost). Transition to conventional procedure is easily accomplished at any phase if required.

Results

Up to now, 102 patients have been operated on according to this procedure, 98 of whom at one segment. All got up on the day of operation or on the first postoperative day. Because of the very slight pain, most patients (especially the younger ones) remained mainly out of bed. About half of the patients could be released on the fifth postoperative day. In the overwhelming majority of the remainder, the in-patient treatment could be terminated when the wound had healed.

In no case was there a neurological disorder caused by the operation or a deterioration of a previously existing neurological deficit. Only one patient had to be catheterized once. Thromboembolic complications did not occur. In one case, there was an infection of an intervertebral space which was treated conservatively. Doctors and patients were equally impressed by the mildness of local complaints, the better mobility, posture and walking ability as compared to patients operated on conventionally. Physiotherapy, nursing and medication could be reduced to a minimum.

The slight discomfort, the almost complete absence of ill-feeling, the short postoperative stay in hospital and the very small surgical scar had a most favorable psychological effect in eliminating the drama of the intervention. This was especially significant in the anxious slipped-disc patient who had not been operated on before. At reoperation of one true recurrence the musculature proved to be macroscopically intact. The renewed approach to the intervertebral space was easier than usual. As expected, comparative postoperative electromyographic studies² showed that the extent of muscular damage and the accompanying functional impairment is many times less with the microsurgical procedure. At the first follow-up examination³, four to six weeks after the operation, subjective discomfort and objective findings corresponded to the favorable course of the early postoperative phase.

Postoperative local back complaints are obviously not all caused by surgical trauma. Consequently, it is no wonder that there were also a few patients with substantial and long-persisting complaints.

Summary

Microsurgical operation for lumbar disc herniation substantially reduces surgical trauma as compared to conventional procedures. It is very suitable for the monosegmental approach. It enables a large degree of morphological preservation of the finely articulated and functionally highly differentiated system of the back musculature, while protecting its vascular and nervous supply. Local complaints due to postoperative muscular insufficiency can thereby be avoided in practice. The improved optical conditions make the surgical procedure in depth very much easier. This implies better differentiation of anatomical structures and therefore also gentler manipulation of the nerve root and dural sac. The risk of instrumental lesion, which can result in radicular hypersensitivity and deficit phenomena, is thereby reduced.

² We are indebted to Prof. Dr. JELASIC and Prof. Dr. HERRMANN for the electromyographic and clinical follow-up studies.

³ We are indebted to Mr. W. ADAMS and Mrs. M. SCHMID for the graphic and photographic illustrations.

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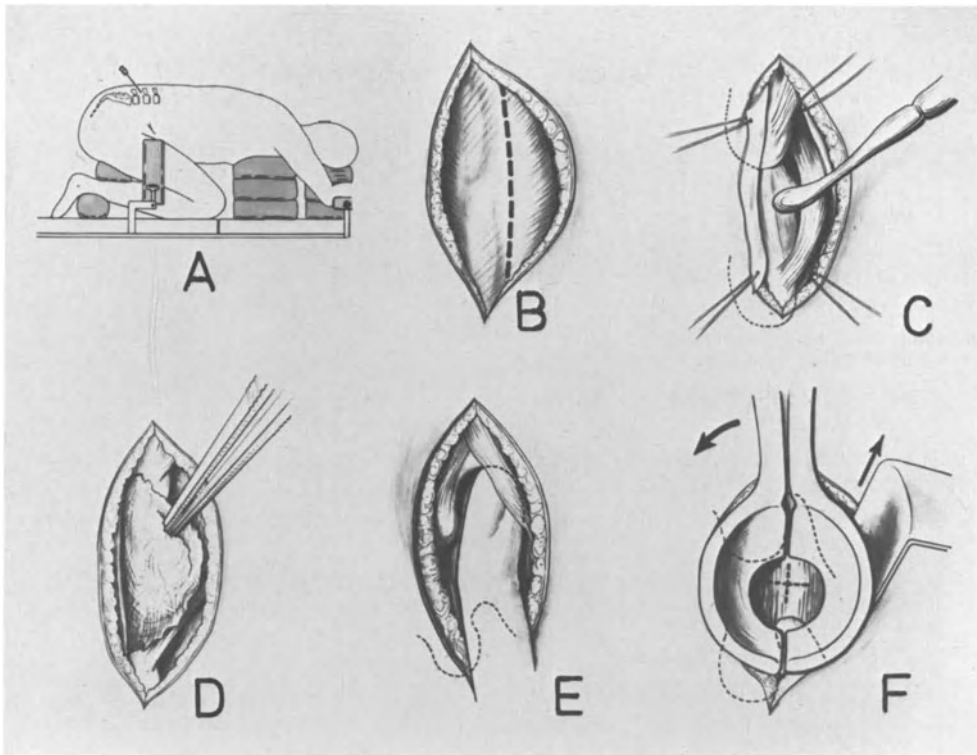


Fig. 1. A: Location and marking of the segment to be operated on by means of a puncture cannula and X-ray control
 B: Median cutaneous and paramedian fascial incision (natural size)
 C: Reflection of the medial fascial edge to the midline and attachment of the muscle from the supra- and interspinal ligaments and the lateral surface of the spinous processes
 D: Widening of the obtuse bloodless detachment by pressing in a drawn out compress
 E: Digital palpation of the topographical-anatomical situation and pushing of the musculature away from the vertebral arch; if necessary, a small periosteal incision in the angle between the base of the spinous process and the insertion of the vertebral arch
 F: Introduction of the special retractor (various sizes) with the aid of a modified Langenbeck's hook. The musculature is pushed aside by propping in a transverse direction (2 cm). The ligamentum flavum is outlined. The retractor is closed, rotated by 90° towards the assistant and opened again

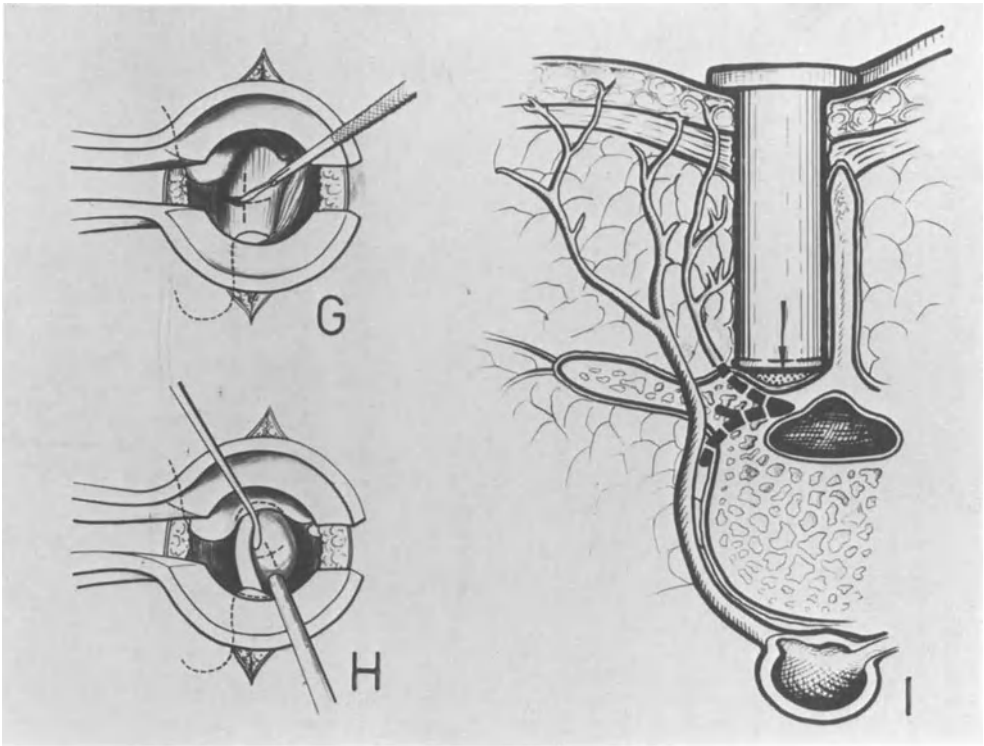


Fig. 2. G: Spreading in a longitudinal direction. The end of the branches must come to lie directly above the vertebral arch, so that one can see the whole interlaminar space. After cross incision of the ligamentum flavum, fenestration with various punches. If visibility is poor, the microscope is introduced at this phase
 H: Outlining of root and herniation under the microscope. Clearing
 I: Transverse section of the operation site with introduced retractor. The vascular and nerve supply of the back musculature is not impaired. The smooth-walled round profile of the instrument does not cause any noteworthy pressure damage to the musculature. The arrow points to the ligamentum flavum (dotted)

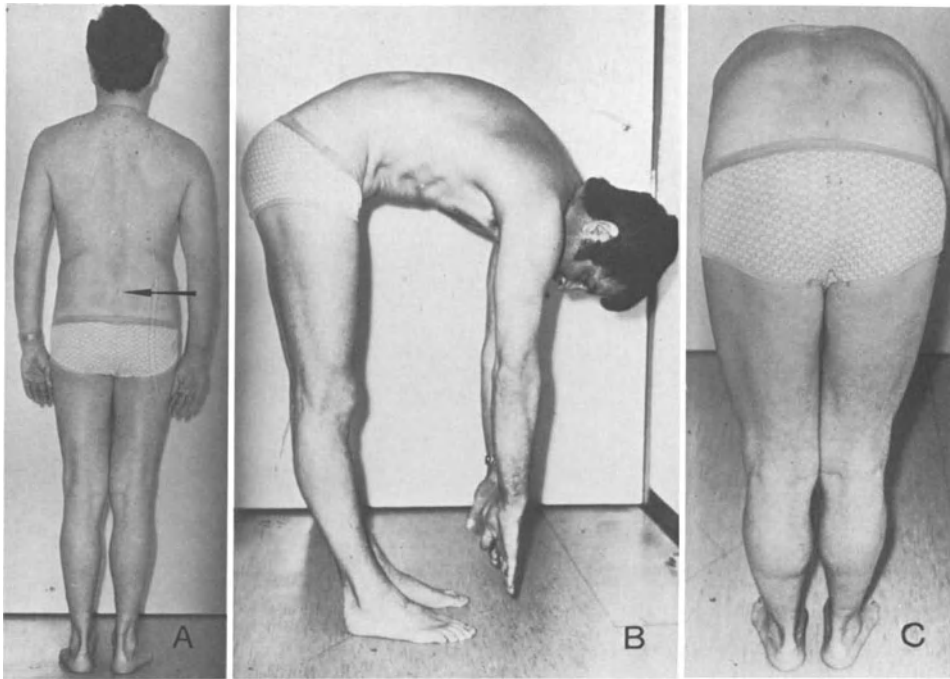


Fig. 3. A 34-year-old patient three weeks following surgery (herniation L4/5). The arrow points to the 2.5 cm long surgical scar. Before surgery there was severe misposture of the spine and loss of function (finger-flow distance more than 50 cm). The corresponding pictures could not be published due to lack of space

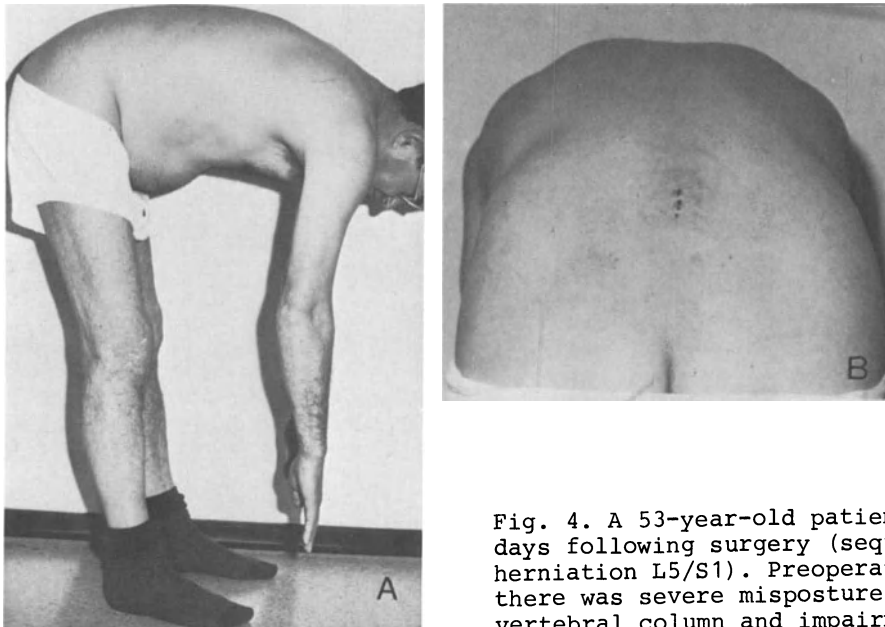


Fig. 4. A 53-year-old patient ten days following surgery (sequestered herniation L5/S1). Preoperatively there was severe misposture of the vertebral column and impairment of function

Microsurgical Operation of Herniated Lumbar Disc

M. G. YASARGIL

Since 1967, 105 cases of herniated lumbar disc have undergone operation utilizing the operating microscope and microsurgical technique. Advantages of performing the procedure under the operating microscope include improved vision and lighting, precise identification of structures in a deep field, and safe control of bleeding by bipolar coagulation.

A midline incision is made between the spinous processes over the involved disc space, generally a length of 2 1/2 to 3 cm. Paraspinous muscles are freed from the spinous processes and lamina in the subperiosteal plane and retracted with a selfretaining retractor. The deep narrow blades of the retractor provide enough mobility that the disc space above and below can be also inspected if this should prove necessary. If one centimeter space exists between the adjacent lamina the procedure is entirely interlaminar. If osteophytes are present on the lamina or the lamina overrode, a small laminectomy is made using a high-speed electric drill to avoid injury to the articular facets. A U-shaped incision is made in the ligamentum flavum and this flap is sutured laterally.

Identification of the dural sac, nerve root, radicular artery and epidural veins is facilitated by use of the operating microscope. Epidural veins may be controlled with bipolar coagulation and are discernable from radicular arteries. The dural sac and nerve root may be retracted with an adjustable self-retaining retractor attached to the operating table although frequently adequate retraction is proved simply by the sucker.

If the annulus is ruptured, free disc fragments are located and removed. If the annulus remains intact, a U-shaped incision is made. Through this opening disc contents are evacuated with curettes and rongeurs. Osteophytes from the rims of the vertebral bodies may block access to the disc space; these are removed with the electric drill. Following a reasonably complete removal of nucleus pulposus, the annulus is resutured with 7.0 suture. This may help prevent adhesions. The small flap of ligamentum flavum is positioned to restore normal anatomical planes and the lumbodorsal fascia and skin closed.

In 105 cases, no recurrences have been observed in postoperative periods of from 1 to 9 years. There was no impairment of neurological symptoms and no postoperative radiculopathy has been noted. One patient developed a wound infection and 8 patients had sterile wound seromas. It is suggested that microsurgical technique allows improved visualization and precision in the operative treatment of herniated lumbar disc.

„Traumatische“ Bandscheibenvorfälle?

R. A. FROWEIN und D. TERHAAG

Die Frage des traumatischen lumbalen Bandscheibenvorfalles (B.V.) ist im deutschen Schrifttum in den 50er Jahren eingehend diskutiert worden, besonders von REISCHAUER 1949, 1951, BÜRKLE de la CAMP 1951, 1967, KUHLENDAHL 1951, 1957 u.a. Diese prinzipiellen Ergebnisse und die zunehmenden Erfahrungen sind in den Handbüchern der Unfallbegutachtung von LOB 1954, 1973, PROBST 1961, GÜNTZ 1958, ferner von GLONING und KLAUSBERGER (1957) und von LOEW, JOCHHEIM, KIRELITZ im Handbuch Neurochirurgie, Bd. VII/1, 1969 sowie von BRAUN 1969 in einer souveränen Gesamtschau der Ursachen des lumbalen Bandscheibenvorfalles verwertet worden.

Sie kommen ebenso in den damaligen sozialgerichtlichen Entscheidungen über den Zusammenhang zwischen Unfall und Erkrankung - gesammelt von LOB, ASANGER und PROBST 1958 und weiter von GERCKE, BÖCHEL und LEMME (Medizin im Sozialrecht) - zum Ausdruck.

So heißt es im Urteil des Bayr. LVA vom 1.2.1951 (nach LOB und M. S. 24):

"Der Senat ist der Auffassung, daß nur ein *schweres* Trauma, das röntgenologisch nachweisbare *Spätveränderungen* setzt, bei einer *gesunden* Wirbelsäule mit intaktem elastischem System und Bandapparat, als wesentliche Ursache für eine Pulposushernie durch Unfall anerkannt werden kann."

Demgegenüber hat KUHLENDAHL mit Recht die Formulierung "*gesunde*" Bandscheibe durch den Begriff der "*normalen*" Bandscheibe ersetzt. Denn von Anfang an ist die besonders schwierige Begutachtung von Unfallfolgen an der - schicksalhaft degenerativ - *vorgeschädigten* Wirbelsäule berücksichtigt worden, zusammenfassend von JUNGHANNS 1959, 1966 und LOB 1954. Besonders aber seit den 70er Jahren beschäftigen sich zunehmend Arbeiten mit der Beurteilung der Verschlimmerung von degenerativen *Vorschäden*, und zwar nicht nur bei der Wirbelsäule - ERDMANN 1971, 1975 - sondern auch beim Kniegelenksmeniskus und der Achillessehne: - TURBAN und HANCK 1975 -, sowie von berufsgenossenschaftlicher und sozialrichterlicher Seite ERLENKÄMPFER 1975 und HYMMEN 1975.

Die folgende Darstellung kann diese Problematik nicht lösen, sondern nur zur *Diskussion stellen*.

Trauma-Häufigkeit 10%?

Zunächst ist auffallend, daß direkte, schwere Gewalteinwirkungen als anerkannte Ursachen eines lumbalen B.V. in dem von BRAUN zusammengestellten Schrifttum in einer Häufigkeit von durchschnittlich 10% gefunden wurden: JOCHHEIM, LOEW, RÜTT 9%, BRAUN 6%. Auch PENZHOLZ nennt 1974 noch 10%. In unserem Krankengut 1969 - 1976 waren es nur 5 unter 1000 Operationen. Für die weitere Analyse muß daher, wenigstens prinzipiell, unterschieden werden in Traumen *ohne* bzw. *mit* Vorschädigung der Wirbelsäule.

Diese Individualität trifft sowohl für den einzelnen Patienten wie für die jeweilige Versicherungsart zu.

Schweres Trauma ohne Vorschädigung

Schon seit REISCHAUER 1951, BÜRKLE de la CAMP 1951, GÜNTZ 1958, 1966, JUNGHANNS 1959, 1966, LOB 1954, 1958, 1973 und D. TÖNNIS 1971 u.a. wird übereinstimmend festgestellt, daß ein einmaliges schweres Trauma bei einer *normalen* lumbalen Bandscheibe *nur äußerst selten* einen isolierten dorsalen Vorfall hervorruft. Dies ist in Abb. 1a in Anlehnung an ERDMANN 1971 schematisch dargestellt. Dies gilt auch für Jugendliche (DASCHNER u.M. 1971, AMBRUS und PAPTAEODOROU 1973).

Schicksalmäßige Vorschädigung häufig

Demgegenüber ist davon auszugehen, daß die altersbedingten Verschleißerscheinungen der Lendenbandscheiben in der Erwachsenenbevölkerung sehr weit verbreitet sind, also eine individuelle schicksalmäßige *Vorschädigung* verschiedener Stärke vorliegt. Diese spondylitischen und osteochondrotischen, summarisch "degenerativ" genannten Veränderungen wurden bekanntlich nicht nur bei Menschen im Jahre 3000 v. Chr., sondern ebenso bei fossilen quartären Vertebraten, z.B. beim eiszeitlichen Murmeltier MARMOTTA marmotta L gefunden, wie LIECHTI (1948) und MIFKA (1963) eindrucksvoll beschrieben haben.

Bagatelltrauma: keine wesentliche Beziehung.

Bei vorgeschädigter Wirbelsäule genügt bekanntlich oft ein *geringer Zusatzimpuls*, eine Gelegenheitsursache, eine alltägliches Bagatelltrauma, um eine akute Verschlimmerung und das aktuelle klinische Syndrom auszulösen (REISCHAUER 1951, BISCHOF und NITTNER 1969) (Abb. 1b). Die Verschlimmerung ist somit nur bei *Gelegenheit* gerade dieser Tätigkeit hervorgetreten. Es muß dabei aufgrund der Anamnese und des Röntgenbefundes wahrscheinlich gemacht werden können, daß das vorher bestehende Wirbelsäulen-Syndrom, die ruhende Leistungsschwäche oder latente Insufficiencia intervertebralis (JUNGHANNS 1959) nach klinischer Erfahrung auch außerhalb dieser Tätigkeit bei jedem anderen nicht zu vermeidenden alltäglichen oder betriebsüblichen Anlaß zum Ausbruch gekommen wäre. In diesem Fall hat der Zusatzimpuls, die Gelegenheitsursache, der Bagatellunfall zum Erfolgseintritt, zur Verschlimmerung *keine wesentliche*, daher keine rechtserhebliche *Beziehung*.

Diese Feststellung gilt sowohl für die private wie auch für die soziale Unfall-Versicherung.

Schweres Trauma bei Vorschädigung.

Anders liegen die Verhältnisse bei einmaligen schweren Traumen. Für den Bereich der *gesetzlichen*, also berufsgenossenschaftlichen *Unfallversicherung* ist der Rechtsgrundsatz gültig, daß *jeder so versichert ist, wie er ist* (REICHENBACH, 1963, S. 62, ERLenkÄMPFER 1972). Das heißt, daß bei Zusammentreffen von einer besonderen Veranlagung - hier vorerkrankte Wirbelsäule - und echtem Unfallereignis letzteres als *Teilursache* anzusehen ist. ERDMANN 1971 formuliert: "Ausgangslage ist eben derjenige gesundheitliche Zustand, in dem sich der Unfallversicherte zum Zeitpunkt des Unfalles befunden hat. Selbst dann, wenn dieser Vorzustand für den Betreffenden eine erhöhte Verletzungsgefährdung bedeutet haben sollte, selbst dann wird von diesem Rechtsgrundsatz nicht abgewichen."

Der Vorschaden wird mit der Zeit und mit zunehmendem Alter größer werden: auch dieses Risiko trägt die RVO mit.

Wenn daher eine äußere erhebliche Einwirkung weder eine planmäßige alltägliche Verrichtung noch eine betriebsübliche Tätigkeit war, sondern einen plötzlichen unvorhergesehenen Vorgang, einen Unfall, dar-

stellte, der nicht jedem anderen nicht zu vermeidenden Anlaß außerhalb der Tätigkeit gleichgesetzt werden kann, so ist er als wesentliches Glied in der Erfolgskette anzusehen. Ein *einmaliges schweres Trauma* ist dann als Ursache der Verschlimmerung, als *Teilursache des Gesamtsyndroms* wahrscheinlich (Abb. 1c) (vgl. dazu auch LSG Baden-Württbg. 1965 bei TURAN u. HANEK, 1975).

Wahrscheinlichkeit

Die Feststellung eines ursächlichen Zusammenhanges wird im Regelfalle nicht mit einer jeden Zweifel ausschließenden vollkommenen Sicherheit möglich sein. Die *Rechtssprechung* in der Sozialgerichtsbarkeit *fordert* deshalb für die Annahme des ursächlichen Zusammenhanges auch *keine* solche, angesichts der menschlichen Unzulänglichkeit selten zu erbringende *Sicherheit*. Sie *fordert* vielmehr das Vorliegen einer *Wahrscheinlichkeit*, d.h. bei vernünftiger Abwägung aller für und gegen den Zusammenhang sprechenden Umstände müssen die für den Zusammenhang sprechenden Erwägungen so stark überwiegen, daß die dagegen sprechenden für die Bildung und Rechtfertigung der Überzeugung außer Betracht bleiben können. Die bloße *Möglichkeit* reicht zur Annahme des Zusammenhanges bekanntlich *nicht* aus.

(Brief BG.-Chemische-Industrie v. 18.9.1975 im Fall Dr. K. Sch.).

Forderung für Anerkennung

Für die Anerkennung eines ursächlichen Zusammenhanges zwischen Unfall und Bandscheibenschaden (gemeint ist: Verschlimmerung) fordern BÜRKLE und BETZEL 1967:

1. den Nachweis eines echten und geeigneten Unfallereignisses,
2. zeitliche und örtliche Übereinstimmung zwischen Gewalteinwirkung und Bandscheibenschädigung.

REISCHAUER, 1951, verlangte bei *gesunder* Bandscheibe maximale Soforterscheinungen, etwa dieselben wie bei einem Wirbelbruch; bei Bandscheibenkrankheit müßten grobe Symptome nicht sofort, wohl aber im allgemeinen in den nächsten Stunden bis 8 Tagen einsetzen; auch diese Frist könne bei besonderer Begründung mit eindeutigen klinischen Argumenten gelegentlich noch etwas überschritten werden. Einerseits hat es also schon bei REISCHAUER eine Anerkennung der Verschlimmerung von Vorschäden gegeben, nur wurde sie damals nicht herausgestellt.

Andererseits zeigen neue berufsgenossenschaftliche und Sozialgerichtsgutachten, daß unter Neurochirurgen *keine* Übereinstimmung darin besteht, was als einmaliges, schweres Trauma, also als *geeignetes Unfallereignis* beurteilt werden kann und muß.

Kasuistik

Deshalb muß die klinische Kasuistik weiterhelfen. Aus den von LOEW, JOCHHEIM und KIRELITZ sowie BRAUN zitierten seltenen traumatischen, operativ bestätigten Bandscheibenvorfällen der Literatur, den Sozialgerichtssentscheidungen und aus eigenen Beobachtungen ist die Abbildung 2 skizziert.

In allen Fällen kam es akut - sofort - oder innerhalb von 6 Stunden zu einer heftigen Lumbago, daran anschließend, spätestens innerhalb der folgenden 3 Wochen, zu radikulären Kompressions-Syndromen bis zu beidseitigen Cauda-Syndromen. Von den vielfältig möglichen von außen kommenden, unerwarteten erheblichen Gewalteinwirkungen, welche die Vorschädigung der Bandscheibe in den schmerzhaften Zustand des akuten

BV umwandeln, wurden vor allem *Sprünge aus 10 m Höhe* und *Stürze* als Teilursache anerkannt: Sturz durch Luke bei Brand; Kölner Serie: Sturz bei Glatteis, auf Holz- oder Betontreppe, von Leiter bei Sturmschaden, durch Hufschlag; JUNGHANNS 1959, S. 33: Sturz vom Fahrrad. Sturz mit Kind auf dem Arm als Privatunfall wurde abgelehnt.

Sowohl REISCHAUER 1951 und JUNGHANNS 1959, wie LOEW und JOCHHEIM 1969 haben auf die eminente Bedeutung der *genauen Analyse aller Umstände* und Abläufe hingewiesen; das gilt besonders für *Auffahr-Unfälle*: Das Verdrehen des Körpers durch Herumschleudern, die Zusammenstauchung bei dem Aufprall, dürften in ihrer tatsächlichen Schwere von der Geschwindigkeit und dem Bremsweg abhängig sein, die also zu eruieren sind.

Sprünge aus geringen Höhen sowie *Heben* und *Tragen* wurden meistens als betriebsüblich *abgelehnt*.

Man darf wünschen, daß weitere kasuistische Mitteilungen eindeutiger Zusammenhänge den *Beobachtungsrahmen ausfüllen*, dadurch spätere Vergleiche erleichtert werden und doch der Unfallursachen-Begriff so straff wie möglich gehalten wird.

Dabei wird die *Entwicklung der Sozialgerichtsentscheidungen* in der EWG aufmerksam zu verfolgen sein: KAHN 1973 berichtet aus Lyon von folgender Entscheidung eines französischen Berufungsgerichtes: das plötzliche Auftreten einer körperlichen Störung, die sich zum Zeitpunkt und an der Stelle der Arbeit durch einen plötzlichen Schmerz kundtut, stellt schon für sich allein einen Arbeitsunfall dar, sofern der Versicherungsträger keine andere Ursache, die ganz außerhalb der Arbeit liegt, nachweisen kann.

Für die hiesigen Verhältnisse bleibt es wohl vorerst bei der sorgfältigen Abwägung von Unfall und Vorschädigung.

Verschlimmerung nur vorübergehend - nicht richtunggebend -

Aus dem vorausgehend über die Vorschädigung gesagten ergibt sich im allgemeinen, daß der als unfallbedingt anzuerkennende Syndrom-Anteil nur eine vorübergehende Verschlimmerung sein kann. Früher hatte ich die Ausführungen von JUNGHANNS 1959 dahin verstanden, daß das Notwendigwerden einer *Operation* an sich schon eine *richtunggebende* Verschlimmerung bedeute. Dies scheint mir heute aber nur noch für die seltenen Fälle richtig, bei denen klinisch und röntgenologisch *gar keine* Vorschädigung nachweisbar ist. Für den schon *bestehenden* degenerativen Prozeß ist die Verschlimmerung dagegen nicht richtunggebend. LOEW u.M. nehmen nach einer Bandscheiben-Operation bei unkompliziertem Verlauf eine abklingende Beeinträchtigung noch für 1 Jahr an. Dabei schreitet der degenerative Prozeß nach seiner eigenen Gesetzmäßigkeit fort.

Unter den zitierten Beispielen traumatisch verschlimmelter Abläufe traten aber in mehreren Fällen ein *perforierter* Bandscheibenvorfall und ein entsprechend schweres neurologisches Syndrom, Beschwerden und Lähmungen über ein Jahr hinaus, also eine Heilung mit Defekt auf. REISCHAUER hat schon 1951 gerügt, daß besonders Neurochirurgen daraus auf die Schwere des Unfalles zurückschließen; daß sei unberechtigt, weil auch zahlreiche *spontane* Massenprolapse zu bleibenden Caudasyndrom führen (LINDEMANN und ROSSACK). Der Sozialrichter ERLENKÄMPFER, 1975, betont nun aber, daß es nicht auf den Regel- sondern nur auf den individuellen Fall ankommt.

Nach dem vorausgehend Gesagten ist der Defekt eigentlich eine Konsequenz der fortgeschrittenen Vorschädigung. Nach REICHENBACH (1963, S. 63) gibt es aber in der sozialen Unfallversicherung keine Möglichkeit, fortschreitende Krankheits- und Alterserscheinungen zu berücksichtigen.

Dazu kommentiert "Die Berufsgenossenschaft" (1963, S. 213 ff.) ein Urteil des BSG vom 26.4.1962 (2 R U 223/59):

"Ist ein Leiden durch die Auswirkungen eines Unfallereignisses im Sinne einer Verschlimmerung beeinflusst worden, so kann der Entschädigungsanspruch nicht von vornherein zeitlich begrenzt werden, ohne daß ausreichende naturwissenschaftliche *Feststellungen* darüber getroffen werden, daß die weiter anhaltende Verschlimmerung nicht mehr ursächlich auf das Unfallereignis zurückgeht."

Hier stellt uns also das alte Problem des "traumatischen Bandscheibenvorfalles" eine weite Forschungsaufgabe, zu der die Ergebnisse gerade dieses Kongresses ein wichtiger Beitrag sein dürfen.

Zusammenfassung

Es wird hervorgehoben, daß in der sozialen Unfallversicherung der schicksalhafte Bandscheiben-Degenerations-Prozeß als Risiko mitgetragen wird (ERDMANN 1971). Daher können nicht Bagatellereignisse oder betriebsübliche Handlungen, in einigen Fällen aber einmalige schwere Traumen die Teilursache einer akuten Verschlimmerung sein. Diese Verschlimmerung einer Vorschädigung ist nicht richtunggebend, sondern fast immer nur vorübergehend für 1 Jahr anzunehmen. Es wird diskutiert, ob darüber hinausgehende Ausfälle als nur durch den Vorschaden bedingt angesehen werden müssen.

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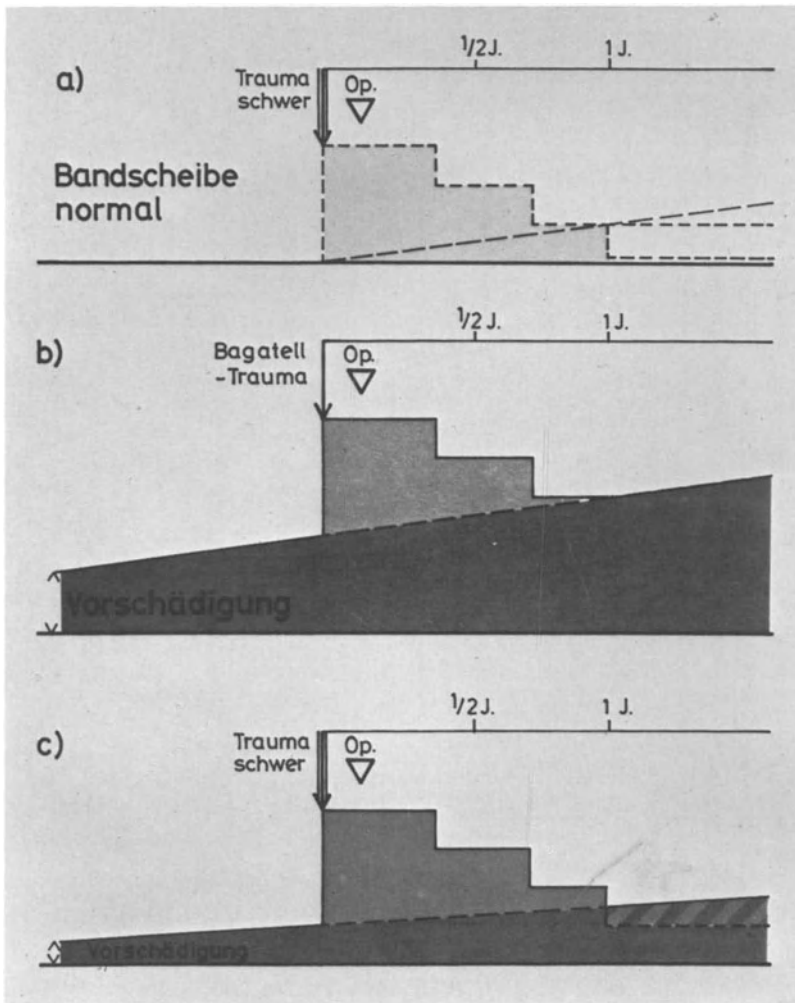


Abb. 1. Traumatische Bandscheibenveränderungen

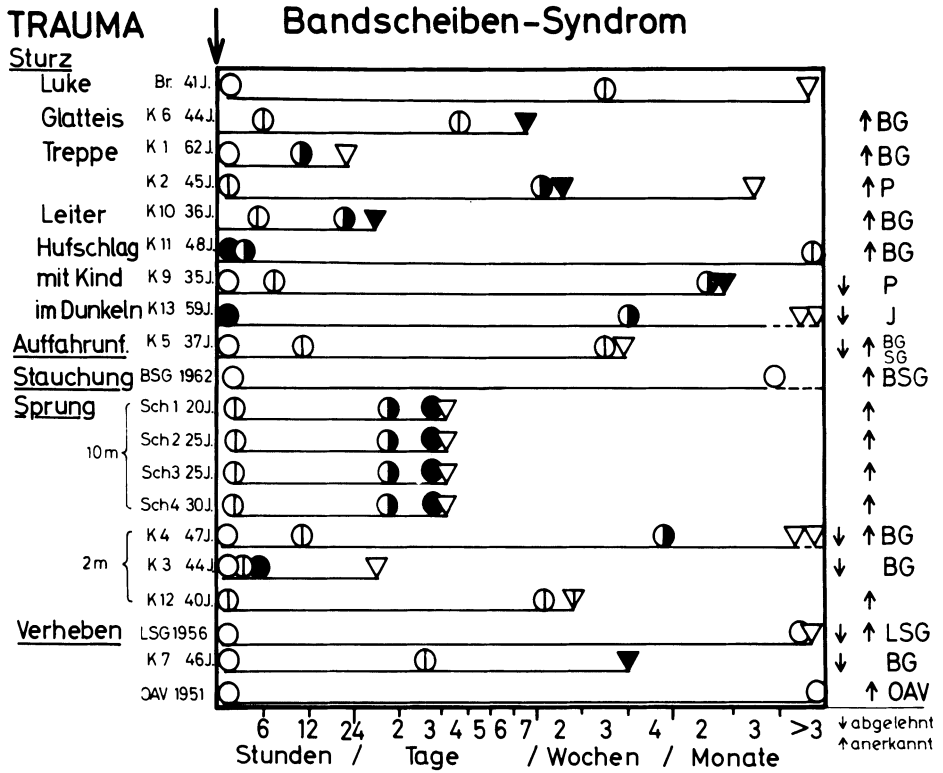


Abb. 2. ○ Lumbalgie ○ radikulär. Schmerz, sens. Strg. ● rad. Parese
● Cauda-Syndrom
Op.-Befund:
▽ Protrusion ▼ Perforation ▽ Sequester

Adult Hydrocephalus

Clinical and Morphological Studies on the Development of Hydrocephalus in Adults

H.-E. CLAR, H.-E. NAU, V. REINHARDT, and L. GERHARD

Fluid dynamics of CSF in adult hydrocephalus is quite different compared to the conditions of hydrocephalus in infants (2). Main reasons for the difference between adult and infantile hydrocephalus are the closed cranial sutures and the physical properties of grey and especially of white matter in adults.

Figures 1 and 2 (1, 4, 6, 12) illustrate the aetiology and the pathological consequences of hydrocephalus in adults. Since the underlying diseases causing hydrocephalus may occur in infants and children but also in adults (Fig. 1), we have limited our investigations to those conditions which occur predominantly in adults (Fig. 2).

An important factor influencing the pathophysiology of adult hydrocephalus is due to the differences in diameter and elasticity of the ventricular wall and the surrounding tissue as well as to the different pressure gradients in the single portions of the ventricular system and the cisternae. The frontal lobes are a special example of this. Here nearly all subarachnoidal space between bone and brain substance is missing. Increasing pressure of the CSF therefore affects the frontal brain substance immediately. The consequences are circulatory disturbances of the frontal cortex manifesting itself especially in the venous system with tortuous dilatations and with a predominant dilatation of the anterior portion of the lateral ventricles in a very early stage (8). Clinically this correlates to psychic disturbances and occasionally to EEG-changes concentrated especially over the frontal lobes (Fig. 3).

The situation of the third ventricle is quite different from that of the anterior horn: Roof and lateral walls are formed by the compact thalamic nuclei, but floor and especially caudal and anterior borders are formed by membrane-like very soft tissue. These are the ventricular portions, which may be fast and easily dilated up to an extreme degree. The ball-like dilatation of the third ventricle is also supported by the neighbourhood of the basal cisternae. Dilatation of the recessus supraopticus, infundibularis and suprapinealis may lead to transparent and paperlike walls (9) with corresponding encephalography (Fig. 4). This morphological change may be accompanied by endocrine and visual disturbances. In one of our patients we observed a Parinaud-syndrome, which we believe to be caused by the pressure of the enormously dilated recessus suprapinealis against the lamina quadrigemina (3).

Aquaeduct and IVth ventricle - which are the physiological narrowings - may compensate even extreme degrees of stenosis for quite a long time. But small and unimportant disturbances are apt to cause the decompensation of this very labile steady state. Figure 4 demonstrates the X-ray picture of a high degree aquaeduct stenosis, which decompensated suddenly after an acute respiratory infection. Figure 5 shows the

Table 1. Causes of hydrocephalus in adults

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1. Inflammation
 2. Post meningitis
 3. Post trauma
 4. Developmental abnormalities
 5. Space occupying processes
 6. Subarachnoidal hemorrhage
 7. Diffuse neoplastic processes in the subarachnoidal space
 8. Demyelinating processes and chronic oedema of the white matter
-

Table 2. Disturbances in cases of hydrocephalus in adults

-
1. Frontal lobe
 - 1.1 Psychosyndroma
 - 1.2 Frontal eeg-disturbances
 - 1.3 Disturbance of venous circulation
 - 1.4 Marked widening of cornua anteriora
 2. Third ventricle
 - 2.1 Blow up of recessus
(supraopticus, infundibularis, suprapinealis)
 - 2.2 In some cases: visual disorders
endocrinological disturbances
 3. Aquaeduct and fourth ventricle
 - 3.1 Paresis of brain nerves (nn. III, IV, VI)
extrapyramidal symptoms
 - 3.2 Forking, stenosis, dilatation of aquaeduct
 - 3.3 Obliteration of foramina of Luschka and Magendie
 - 3.4 Atrophy of cerebellar white matter following
increased intracranial pressure
 4. Disturbances of CSF-resorption
 - 4.1 Common signs of increased intracranial pressure
 - 4.2 Communicating, symmetrical hydrocephalus
 - 4.3 Obliteration of the subarachnoidal space
-

aquaeduct of a sixteen year old patient, who suddenly showed clinical symptoms only after a light head injury. The picture shows a forking of the aquaeduct, which in serial sections had no continuous connections (5, 8). Without such an acute onset and acute disturbances one may observe a variable and changing clinical picture (disturbances of eye muscles, different extrapyramidal symptoms etc.). Closure of the foramina of Luschka and the foramen of Magendie leads to a dilatation of aquaeduct and IVth ventricle causing predominantly damage and atrophy in the cerebellar white matter (Fig. 6).

Pathological processes affecting the subarachnoidal space (10), - an example being the meningeosis carcinomatosa - frequently leads to a symmetrical internal hydrocephalus without any stenosis or blockade of the internal ventricular system. A space occupying lesion does not exist in these cases and only in the Risa-test (7, 11) a disturbance of distribution may be obvious. So the diagnosis frequently is made at autopsy, where an obliteration of the subarachnoidal space can be demonstrated histologically. In these diffuse subarachnoidal processes in which neither an increased pressure of the CSF in the ventricular system exists nor a stop of the CSF drainage can be demonstrated, the hydrocephalus should be attributed to a reduction of the subarachnoidal space responsible for CSF-resorption.

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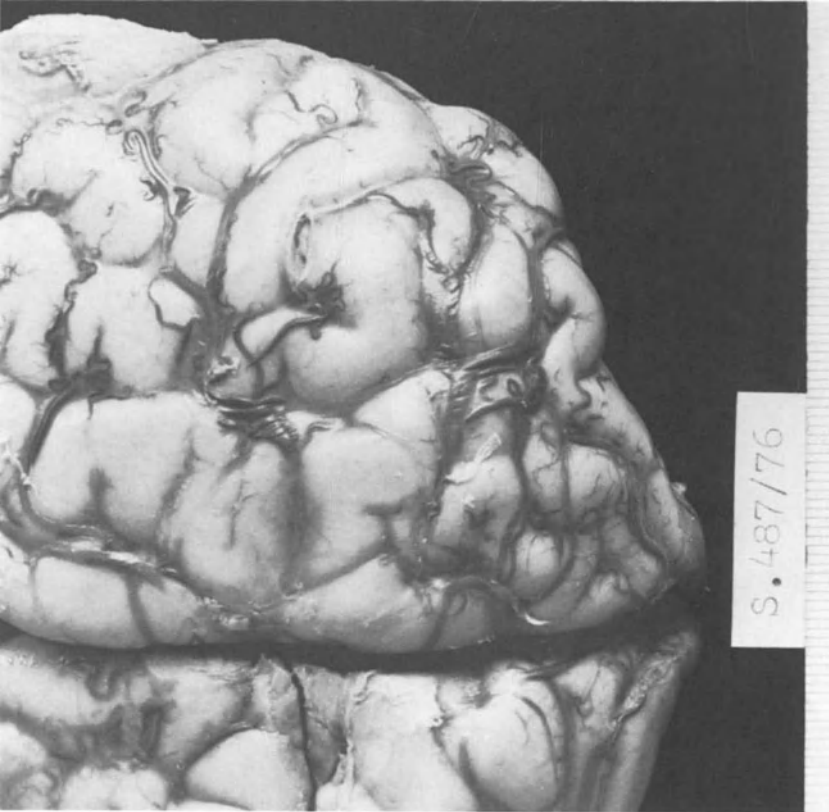
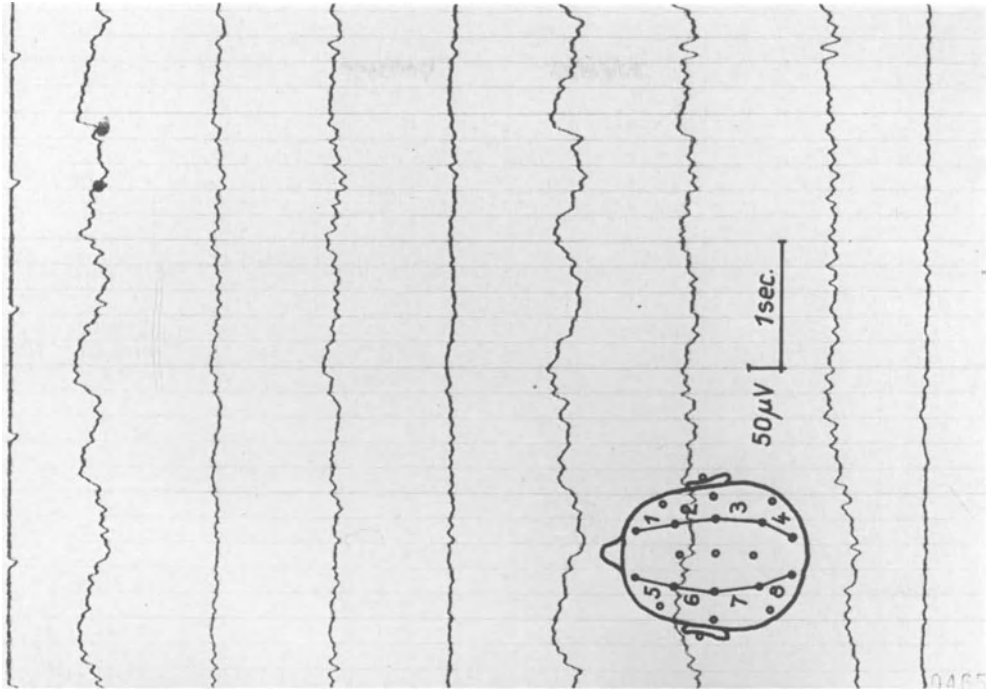


Fig. 1



Fig. 2. Combined ventriculo-encephalotomogram of a 28 year old woman shows a non tumorous obstruction of the aquaeduct. The upper ventricles are dilatated with a remarkable blow up of the recessus supra-pinealis, supraopticus and infundibularis and the upper part of the aquaeduct. The distal aquaeduct and the 4th ventricle are of normal size. Clinically the patient had only a dysaesthesia of the n. maxillaris on both sides and an oedema of the papille as a sign of increased intracranial pressure



Fig. 1. *Left*: Frontal brain of a 20-year-old man who died following incurable status epilepticus with successive development of a brain oedema. Morphologically we found a varicous dilatation of the veins. *Right*: Electroencephalogram of a 54-year-old woman with a hypertensive communicating, symmetrical hydrocephalus. Frontal groups of delta waves which generalized during hyperventilation



Fig. 3. Transverse section of the midbrain shows forking of the aqueduct; 16 year old boy with hydrocephalus occlusus of the lateral and 3rd ventricle



Fig. 4. Transverse section of medulla oblongata and cerebellum of a 46-year-old man with a postmeningitic hydrocephalus. Obliteration of the foramina of Luschka and Magendie. Atrophy of the nucleus dentatus following a dilatation of the fourth ventricle

Dynamics of Cerebrospinal Fluid and Pathophysiology of the Hydrocephalus of the Adult

R. HEMMER

The dynamic of cerebrospinal fluid (CSF) is composed of production, absorption, movement of cerebrospinal fluid and cerebrospinal fluid pressure. The mechanism of *production* of CSF is still in dispute at the present time, but the recent electronmicroscopic studies by COOPER, MILLEN, and ROGERS support the concept that the choroid plexus is a secretory organ. There is no question about the decisive significance of the choroid plexus. However, already 1953 and 56 SWEET's group could demonstrate by means of isotope studies that electrolytes and water can enter the CSF space from every adjacent region by means of diffusion of plasma across the bordering membrane, the protein being dependent in the plexus proper. Under normal circumstances seventy to one hundred ml of CSF are produced per day.

Earlier concepts about the *resorption* of CSF were based on the hypothesis of WEED that absorption occurs mainly through the Pacchionian bodies. However, *historadiographically*, BOWSHER (1960) could not find any passage of marked protein given intraventricularly by means of the arachnoidal villi. The venous side of the Pacchionian granulations always was free of protein. The pial veins and capillaries, the ependyma of the ventricles and, to a small degree, also the choroid plexus showed passage of the marked substance. On the other hand, under pathological conditions, the Pacchionian granulations as well as the arachnoidal villi most likely are significantly involved in the resorption of CSF as shown by the studies of ELLINGTON and MARGOLIS. They found, in subarachnoidal hemorrhage and secondary hydrocephalus, a considerable aggregation of erythrocytes in the arachnoidal villi, later on leading to fibrosis and siderosis. According to clinical findings and to experimental results there is no doubt that the main resorption of CSF takes place within the subarachnoidal space. This especially concerns the proteins while water and electrolytes may be reabsorbed throughout the CSF space.

The most essential studies in *CSF-scanning* have been done following suboccipital injection:

1. Under normal conditions there is no ventricular filling.
2. Activity is detectable all over the subarachnoid space, whatever the site of injection.
3. Activity is detectable in the basal cisterns after 1 - 2 hours, 6 hours later a diffuse activity is noted over the cerebral hemisphere, while at 24 hours it is predominant in the parasagittal region. On antero-posterior view the distribution is symmetrical.
The maximum activity is found between 6 - 12 hours with a progressive decrease (40 to 80% of peak activity at 24 hours, 25 to 40% at 48 hours).

Following intraventricular injection the progressive decrease of activity is 50% within 2 hours, 80% within 4 hours and 90% within 24 hours.

Movement of CSF is initiated by pulsation of the brain and of the choroid plexus. Many factors are involved in maintaining its movement. In addition to production and reabsorption, the posture of the body, pressure in the vessels, cerebral blood flow, arrangement of CSF-space and respiration also play a role. The CSF flows from the lateral ventricles through the foramen of Monro into the third ventricle and from this through the aqueduct of Sylvius into the fourth ventricle. Communication with the basal cistern and the subarachnoid space surrounding the cerebral hemispheres then occurs through the foramina of Luschka. The foramen of Magendie constitutes the communication with the cerebello-medullary cistern which can also be reached through the foramina of Luschka. The CSF then continues to flow over the spinal cord to the caudal cistern. On the basis of studies with radioactive sodium it was suggested that the flow of CSF was from the caudal regions to cranial (RICHLER, LINDER, SCHMEISER). The flow of CSF is maintained not only by the pulsation of the cerebral arteries and the choroid plexus but it is also supported by cerebral venous drainage. The S-shaped jugular bulb, particularly, causes a substantial drop of pressure.

By many authors *normal cerebrospinal fluid pressure* is being evaluated differently. Comparison of results is possible only if the patient is brought into horizontal position. LUNDBERG reported values from 1 - 10 mm Hg (13.5 - 135 mm H₂O) for ventricular pressure, and 5 - 14 mm Hg (70 - 180 mm H₂O) for lumbar CSF-pressure. These results are supported by MERRIT and FREMONT-SMITH. However, more important than a single measurement is continuous pressure recording. This allows to study the course of the pressure-curve and to trace pressure-waves. It must be born in mind that the elastic walls of the cerebro-spinal space cause a damping of the pressure-waves downwards. Therefore, intracranial pressure recording is particularly valuable in the investigation of disturbed CSF dynamics.

Pathophysiology in Normal Pressure Hydrocephalus

The manyfold etiology of normal pressure hydrocephalus (NPH) makes it difficult to give a single pathophysiological explanation of this syndrome. The term "normal pressure hydrocephalus" (HAKIM, ADAMS, SWEET et al.) added difficulties to the discussion. HAKIM et al. (1965) limited themselves to measuring lumbar spinal fluid pressure without continuous recording. The diagnosis of "normal pressure hydrocephalus" has been made widely and exclusively on the basis of isotope studies. It is surprising that CSF-pressure has only recently become a criterion in the diagnosis of hydrocephalus and indication for surgical treatment (SYMON et al., JENNETT et al., ROSSI et al.). Continuous monitoring of the intraventricular pressure has proved an essential diagnostic and prognostic tool. Continuous increase of CSF-pressure during several hours above the physiological levels, or intermittent appearance of pressure waves, prove presence of disturbed CSF-dynamics, if pressure is permanently or intermittently increased. In case of decompensation of hydrocephalus pressure on the ventricular side does not need to be high, provided there is a drop in parenchymal pressure. This may also be observed in partial insufficiency of a shunt. Acute headache may be caused by pressure waves or spikes arising from a normal pressure level. Intermittent extension (HAKIM's "hydraulic press effect") of the wall of the third ventricle is sufficient for the clinical sign. Enlargement of the ventricle mostly takes a longer time. The resorption block is partial or more distal and progressive enlargement of the ventricles may take place over a long time without clinical signs.

Resorption studies show in 37% (PHILIPPON and ANCRI) or (other authors) 70% a filling of the ventricles with ventricular stasis of the activity over 48 or more hours with light or no clearance or associated with pathological distribution of the subarachnoidal activity, which does not reach parasagittal areas. The other main-group of pathological findings concerns the subarachnoidal pathological distribution with a cisternal block or a major asymmetry. The filling of the ventricles is based on a near absence of CSF-flow or at least a flow which is not greater than the protein's diffusion speed associated with a transependymal resorption. Together with these disturbances of CSF-dynamics MATHEW, MEYER, HARTMANN and OTT could find, in patients with normal pressure hydrocephalus, a decrease of the blood flow and blood volume preponderant in the area of the A. cerebri anterior. Disturbances of CSF-resorption furthermore may be detected with intrathecal infusion manometric test (KATZMAN, HUSSEY). The principle of this technique was published in 1947 (SCHALTENBRAND and WOERDEHOFF).

Summary

The CSF dynamics are composed of production - absorption - movement and pressure. It is known that the *production* takes place by active secretion of the choroid plexus. Electrolytes and water can enter the CSF space from every adjacent region by means of diffusion of plasma across the bordering membrane, the protein being dependent on the plexus proper.

As well according to the clinical findings as to the experimental results there is no doubt that the main *resorption of CSF* takes place within the subarachnoidal spaces. This especially concerns the proteins.

Movement of CSF is initiated by pulsation of the brain and of the choroid plexus. In addition and absorption, the posture of the body, pressure in the vessels, cerebral blood flow, arrangement of CSF-space and respiration also play a role.

The *CSF-pressure* in horizontal posture fluctuate intraventricular between 1 - 10 mm Hg and intrathecal (lumbar) between 5 - 14 mm Hg in a wide range. However, more important than a single measurement - a snapshot - is the continuous registration of the pressure during a longer time, the course of the pressure curve and of the pressure waves. In normal pressure hydrocephalus the pressure on the ventricle wall does not need to be high. The acute headache may be caused only by pressure waves or spikes arising from a normal pressure level, especially if this happens in the III. ventricle. The disturbances of resorption are demonstrated in the CSF-scan with filling of the ventricle after suboccipital injection, ventricular stasis of the activity over 48 hours or more, with light or no clearance or associated with pathological distribution of the subarachnoidal activity (asymmetry, no activity in the parasagittal areas, cisternal block). The ventricular stasis of activity is based on a near absence of CSF-flow or at least a flow which is not greater than the protein's diffusion speed associated with a transependymal resorption. Together with these disturbances of CSF-dynamics occurs a decrease of the blood flow and blood volume preponderant in the area of the anterior cerebral artery (postcentral region).

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Subarachnoid Hemorrhage and Hydrocephalus

J. MENZEL

Each subarachnoid hemorrhage (SAH) regardless of its etiology causes a circulus vitiosus of a different degree with releasing of serotonin, catecholamines and other spasmogenic substances on the one hand and an acute form of communicating hydrocephalus on the other (1-8). The aim of the present investigation was to detect the frequency of disturbed cerebrospinal fluid (CSF) circulation, to analyse the different forms of pathological CSF-dynamics and to appraise the indications for CSF-shunting. Therefore we chose isotope cisternographic studies as the most pertinent diagnostic procedure.

In a period of 3 1/2 years 165 patients with SAH were examined. 135 patients underwent qualitative as well as quantitative examinations, and this number is representative for the following explanations. Spontaneous SAH was encountered in 69 patients while 66 patients showed traumatic SAH. In the first group, 51 patients suffered from aneurysms and 18 from arterio-venous malformations. 23 patients or 33.0% presented pathological CSF-dynamics. In 7 cases or 30.4% of the group with disturbed CSF-dynamics we found the following criteria which require CSF-shunting: ventricular reflux, delayed clearance or stasis, no activity over the surface and blood activity under 20% of the applied dosage (Table 1). In clinical aspects all these patients suffered from dementia in different degrees, gait ataxia and/or incontinence. In a second group 66 patients with traumatic SAH were examined. 45 patients or 68.1% showed pathological CSF-dynamics. In 4 cases we found all qualitative and quantitative scintigraphic criteria which require CSF-shunting (Table 2). In clinical aspects dementia was predominating.

Table 1. Distribution of pathological CSF-dynamics in 69 patients with spontaneous SAH

	CSF-dynamics	Patients	Shunt-indication
A.	1. Ventricular reflux	7	+
	2. Insufficient ventricular clearance or stasis		
	3. No activity over the surface		
	4. Blood activity under 20%		
B.	1. Ventricular reflux	12	-
	2. Sufficient ventricular clearance		
	3. Activity over the surface		
	4. Blood activity over 20%		
C.	Others	4	-

Table 2. Distribution of pathological CSF-dynamics in 66 patients with traumatic SAH

CSF-dynamics	Patients	Shunt-indication
A. 1. Ventricular reflux	4	+
2. Insufficient ventricular clearance or stasis		
3. No activity over the surface		
4. Blood activity under 20%		
B. 1. Ventricular reflux	11	-
2. Sufficient ventricular clearance		
3. Activity over the surface		
4. Blood activity over 20%		
C. Others	27	-

Table 3. Results of CSF-shunting in 7 patients with spontaneous SAH

Preoperative clinical findings	Patients	Postoperative clinical findings		
		Better	Unchanged	Worse
Dementia	4	4	-	-
Dementia motor disturbances	2	1	1	-
Dementia motor disturbances incontinence	1	-	1	-

Table 4. Results of CSF-shunting in 4 patients with traumatic SAH

Preoperative clinical findings	Patients	Postoperative clinical findings		
		Better	Unchanged	Worse
Dementia	2	1	1	-
Dementia motor disturbances	0	-	-	-
Dementia motor disturbances incontinence	2	1	1	-

Operation was performed in 11 patients of which 7 had spontaneous and 4 traumatic SAH. In all cases a medium-pressure valve was implanted. Time between SAH and the shunting-procedure varied from 4 weeks to 6 months. All patients had a postoperative follow-up period between 8 months and 2 years.

The results of the operation in 7 patients with spontaneous SAH are summarized in table 3 (Table 3). 4 patients with dementia as predominating symptom improved significantly. Improvement means partial or total resumption of earlier professional or domestic activity (3 cases), or familiar reintegration (2 cases). In 2 patients the clinical picture remained unchanged postoperatively. In no case a postoperative deterioration was observed.

Table 4 (Table 4) presents the results of CSF-shunting in 4 patients with traumatic SAH. Improvement with partial resumption of the pro-

essional activity was registered in 2 cases. In the other 2 patients the clinical picture remained unchanged postoperatively.

To sum up:

1. Taking as a basis qualitative and quantitative isotope cisternography, shunt-requiring criteria of disturbed CSF-circulation occur in 10.1% after spontaneous SAH and in 8.8% after traumatic SAH.
2. Significant improvement was found postoperatively in about 70% after spontaneous and in about 50% after traumatic SAH. Improvement was permanent and confirmed by follow-up investigations up to 2 years.

Summary

165 patients with spontaneous and traumatic SAH were examined by means of isotope cisternography. The frequency of a disturbed CSF-circulation is described. Above all the shunt-requiring criteria of pathological CSF-dynamics are worked out. The postoperative results and follow-up investigations up to 2 years are presented.

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Normal Pressure Hydrocephalus - Idiopathic Type Selection of Patients for Shunt Procedures

P. M. BLACK and W. H. SWEET¹

Patients in whom enlarged cerebral ventricles are associated with normal intracranial pressure, (i.e. below 180 mm of cerebrospinal fluid, csf.) include a group who benefit by operative shunting of that fluid out of the head. The patients who may be helped are readily divisible into two groups: I. those with an identifiable focal disease likely to interfere with absorption of the fluid and, II. those in whom such a process is less clear - a more or less idiopathic group. Common causes of the obstruction to flow include tumors, trauma, spontaneous subarachnoid hemorrhage, meningitis, and ventricular or aqueductal obstruction by cysts, tumors, congenital stenosis, etc. Since attention was first drawn to these patients FOLTZ and WARD (2), HAKIM (3) and my colleagues and me (1), the syndrome has become widely recognized. In general the patients in Group 1 tend to be more readily identifiable, so that relatively few fruitless shunting procedures are done. Contrariwise in the idiopathic group the differentiation between those with enlarged ventricles who will benefit from shunts from those who will not, has yet to be achieved. The problem has been highlighted by STEIN and LANGFITT (6). They classified their patients into 5 grades:

- 0 - working with no neurological deficit.
- I - home, with deficit but functioning independently.
- II - home, requiring supervision.
- III - requiring custodial care.
- IV - no independent function.

After a shunt in their 33 patients with idiopathic hydrocephalus only 6 improved by a single grade to level II or III, and only 2 improved 2 grades to level I. Apparently neither of these 2 was able to work outside the home. Comparisons between the 8 showed after operation some modest improvement and the 25 who did not was carried out vis-à-vis 13 clinical factors, 8 features of the pneumoencephalogram (PEG), 4 of the RISA cisternograms and the effect on CSF pressure of intrathecal infusions. Not one of these 26 factors proved to have any significant correlation with the success or failure of the operations. This disconcerting publication from such a distinguished neurosurgical service and our own numerous poor results have led us to review our entire series of 43 cases in the idiopathic group. They were subjected to shunts between 1959 and April 1976 - a rather small series when one considers its long duration.

We have classified our cases as shown in Table 1. None of the cases in the STEIN-LANGFITT (6) series attained to our "excellent" or "good" category, and only 2 of theirs were, we think, in our "fair" class. We considered the operation of dubious value if the patient still required supervision in a home or institution. To try to distinguish

¹ We gratefully acknowledge the assistance of Dr. Paul F. New and the use of his illustrations 4a, b, c, d and 5b, c, d.

Table 1. Idiopathic hydrocephalus. Results in 43 cases treated by shunts

8 cases	Excellent-recovered to resume pre-illness activity - circa normal
5 cases	Good -recovered to resume pre-illness activity - modest residua
3 cases	Fair -much improved but no return to previous activity
2 cases	Temporary major improvement - then worsening
19 cases	Poor -never reached criteria for Fair
6 cases	Dead from this disease and/or complication of shunt surgery - within 2 months, 1 at 12 months

those who would do well from those who would do poorly after operation we have compared selected criteria only between the 13 cases in our excellent or good group, and the 19 in the poor group. By eliminating from consideration the other 3 groups we hoped to learn which are the significant differential diagnostic points.

A detailed analysis of the clinical data in the excellent and good groups revealed at least 4 different general patterns of presenting symptoms and signs:

1. Defective mentation appeared first and was the dominant disability with motor signs either of lesser degree or coming on later.
2. The converse, gait disturbance was the first and remained the most prominent symptom with reduced mentation and incontinence of bladder and/or bowel later.
3. Slowness both of motor activity and thought process often leading to a diagnosis of Parkinsonism, often with rigidity and tremor, and at times profound lethargy.
4. A single patient with marked ataxia of all 4 limbs and trunk, severe horizontal and vertical nystagmus, normal tonus in the limbs, and only a modest deficit in mentation until shortly before hospital entry.

The protean possibilities in the clinical picture of the good group will be described in detail elsewhere. The only clinical feature we could ascertain as being favorable was a predominance of the gait disturbance. This was seen in 6 of the 13 patients in the good-excellent group and in only 2 of the 19 in the poor group. There were 3 features of the PEG, and a 4th feature, the clinical reaction to PEG, which we found of some value. The maximal width of the frontal horns as measured on PEG or computerized tomographic (CT) scan proved to be less than 59 mm in 12 of 18 of the poor group but in only 2 of 11 of the good group (Table 2). Apparently when intrinsic cerebral atrophy is more significant than obstruction the lateral ventricles tend not to become so large. Conversely, little or no air appeared at PEG in any cerebral sulci in 6 of the 9 patients in the good group, and in only 2 of the 16 in the poor group (Table 2). However, no air was seen over the supero-lateral convexity in 10 of the poor group - one of the factors leading to fruitless operation in them.

The so-called callosal angle is formed by the superior surfaces of the anterior parts of the lateral ventricles as seen in a brow-up sagittal projection. A recent publication in Clinical Radiology by HAWKINS et al., Figure 1, compares this finding in 2 groups of patients after severe head injury. They diagnosed: 1. extra-ventricular obstruction in those 20 patients in whom no air passed over the cerebral convexities, and 2. no such obstruction in 73 patients in whom air

Table 2. Parameters from pneumoencephalogram (PEG)

Clinical Result	Total number of cases in parenthesis
A. WIDTH OF FRONTAL HORNS	
Poor (18)	Good (11)
46 - > 100 mm	55 - 82 mm
12 of 18 < 59 mm	2 of 11 < 59 mm
B. AIR IN CEREBRAL SULCI	
Poor (16)	Good (9)
2 very little or 0	6
10 below supero-lateral convexity	2
4 in supero-lateral convexity	1
C. CALLOSAL ANGLE	
Poor (12)	Good (6)
6 $\leq 130^\circ$	0
2 $120^\circ - 129^\circ$	2
3 $100^\circ - 119^\circ$	2
1 < 100°	

was seen in these loci. Their frequency distribution of the callosal angles in the 2 groups confirmed the conclusion of my colleagues LEMAY and NEW (5) that such a measure was helpful in separating the 2 groups from each other. As we sought to correlate the callosal angle with the response of the patient to operation we were dismayed to see that a hitherto undescribed factor, namely the angle of projection of the X-rays, could be of major importance. Thus in one patient in our poor group when the postero-superior border of the petrous pyramid was projected above the supraorbital rim, the callosal angle was 115° (Fig. 2a). At the same study this changed to 132° (Fig. 2b) when the petrous border was seen below that rim, and to 155° (Fig. 2c) when it was entirely below the orbit. Similarly in another patient in the poor group that same view revealed an angle of 165° (Fig. 3a). On this patient a projection with the petrous pyramids in the orbits brought to light another problem, to wit, that on the side in which the anterior part of the ventricular body was air-filled, the half-angle with the vertical of 47° would have placed the patient clearly in the obstructive group. But the half-angle of 70° on the side of filling only of the anterior horn was well into the range of the non-obstructive group (Fig. 3b). Change in the callosal angle with change of projection was not however consistent. Thus in a third patient also in our poor group 5 different projections ranging from superior border of petrous below the lower orbital rim to one with that border above the upper orbital rim all showed the same callosal angle. Moreover in this patient the angle was the same whether or not the anterior part of the body was filled. Using projections with the petrous seen through the orbits we found a disappointing number of patients in an intermediate range between $100^\circ - 129^\circ$.

Modest assistance was derived from the severity of the reaction to the PEG. Of the 10 good-excellent patients in whom the reactions were reported, it was severe in 7 and none were completely free from any reaction. Only 2 of the 15 patients in the poor group had a severe reaction and 8 of them were strikingly undisturbed by the study. The remainder in the 2 groups had an "average" reaction.

Table 3. Isotope cisternogram

Clinical Result		Total number of cases in parentheses
A. VENTRICULAR FILLING		
Poor (11)		Good (7)
4	very little or none	0
0	slight and/or delayed	1
7	moderate to marked	6
B. SURFACE FILLING CEREBRAL HEMISPHERES		
Poor (10)		Good (7)
0	very little or none	3
9	slight and/or delayed	4
1	moderate to marked	0

The isotopic cisternograms were especially disappointing. Ventricular filling was, as hoped for, absent in none of the good group in whom 6 of 7 had moderate or marked filling. Unfortunately this also occurred in 7 of 11 in the poor group (Table 3). Similarly the distribution of isotope over the convexities showed the decisive finding of failure to fill in only 3 of the good group. Most of the cases in both groups had the equivocal finding of slight and/or delayed filling at the main sites of CSF absorption (Table 3). The cisternograms were the greatest single factor responsible for our futile operations. A few words are in order regarding CSF pressure recordings either continuously for hours or during 1 hour of an added infusion of artificial cerebrospinal fluid. The second person in the recorded literature with idiopathic hydrocephalus to benefit from a shunt, our patient Helen H. in 1959, had several pressure readings at greater than 200 mm CSF after her first PEG, and again later after rupture of the inter-valvular tubing of our first shunt (1). This led us to follow CSF pressures continuously for several hours in 4 patients. In 1 of the 4 we had a false positive result. Six periods of pressures at or over 200 mm in a 3 hour period led to performance of a fruitless shunt. In another patient whose pressures were for 3 hours always below 150 mm, we shunted him on other grounds, securing a good result - a false negative result. The prediction was correct in the other 2 patients, but in only 3 of the 6 in whom Katzmans's type of continuous infusion was done. In view of our need for more reliable predictors of an absorption deficit, and the current availability of much better pressure recording systems, we should probably assess this tactic more extensively.

The CT scans have presented us with about as many new problems as they have solved the old ones. Especially the scans with the 160 x 160 matrix reveal atrophic cerebral sulci to a fuller extent than the usual inadequately filled sulci shown on PEG. Figures 4a and b shows an expected sequence of events with gratifying reduction in size of lateral ventricles 16 days postoperatively in a patient who was clearly improving. However, in patient Ann S., who also moved promptly into the excellent group, a succession of scans showed initially no change and even by 7 months after operation only a slight decrease in the ventricular volume (Fig. 4c and d). The converse situation is illustrated in the next 2 patients. The preoperative PEG with huge ventricles in patient Clara S. was followed by a marked reduction in ventricular size as seen on the 10th post-shunt day at which time the patient was clinically worse and she never made a significant recovery. Indeed the indistinct ventricular outlines intimate ventricular com-

pression (Fig. 5a and b). Patient Eduardo P. showed an excellent symmetrical reduction in ventricular size by the second post-shunt day and even more on the 9th post-shunt day (Fig. 5c and d). At this time the patient was clinically much worse; he went steadily downhill to death in 2 months. These cases challenge our automatic assumption that return of ventricular size toward normal is a fundamental objective whose attainment will lead to clinical improvement. The need for further knowledge of the pathophysiology here is obvious.

Summary

Patients with idiopathic normal pressure hydrocephalus in whom gait disturbances initiate and dominate the clinical picture are often relieved by a shunt. Information re ventricular span, ventricular callosal angle, extent of cerebral sulci, and clinical reaction to PEG are also of some help in selection of such patients for shunt procedures. Interpretation of isotopic cisternograms must be improved, and more information is necessary re continuous CSF pressures with or without infusion, if they are to have value here. The differential diagnosis in these patients is in urgent need of improvement.

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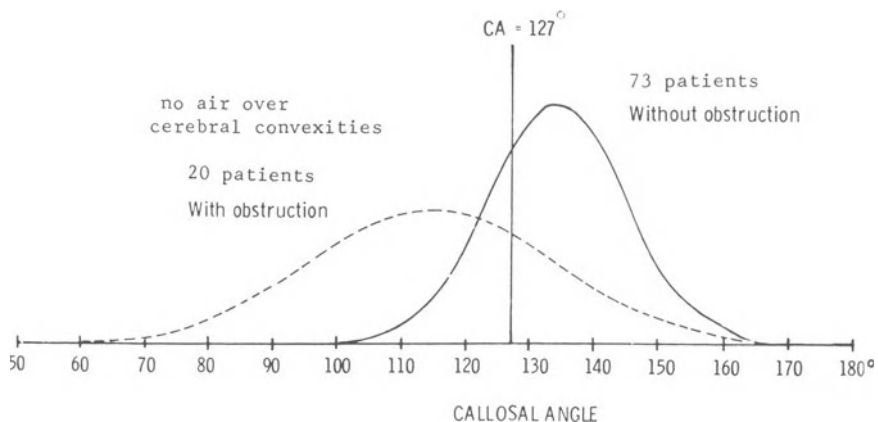


Fig. 1. Frequency distribution of callosal angles in 2 groups of patients with severe head injury. The group "with obstruction" had no air over the cerebral convexities at pneumoencephalogram - the group "without obstruction" did show such air. (HAWKINS et al., Clin. Radiol. July 1976)

Fig. 2 see p.112

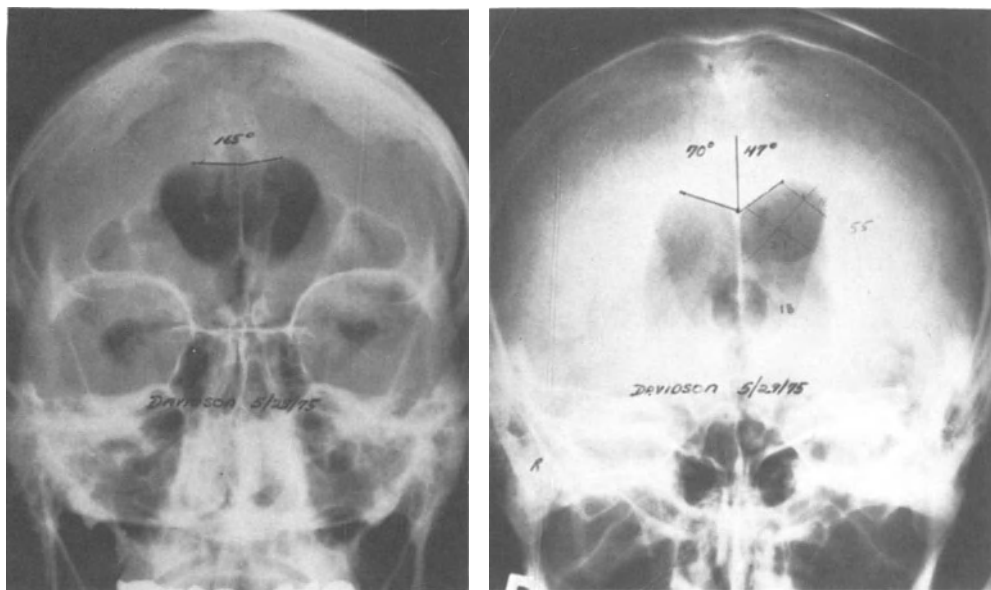
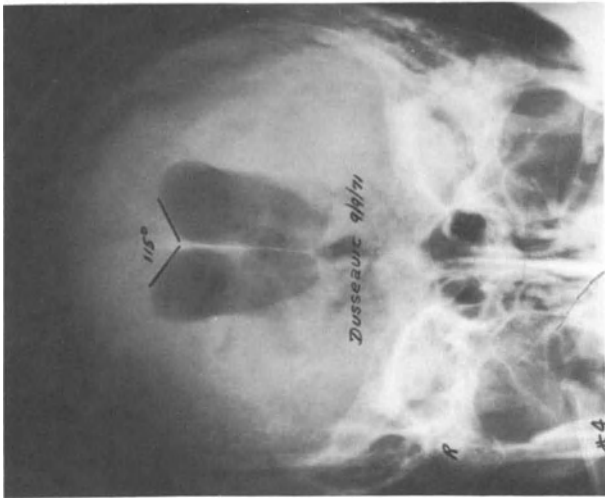
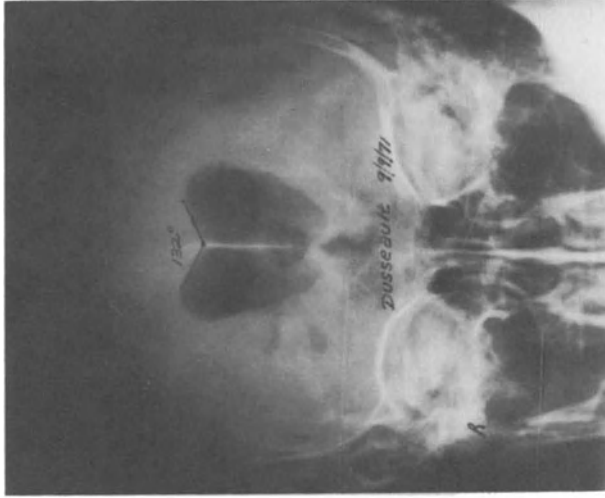


Fig. 3. Variation in callosal angle with variation in angle of projection of photon beam and with amount of filling of anterior parts of lateral ventricle. Superior border of petrous bones projected:

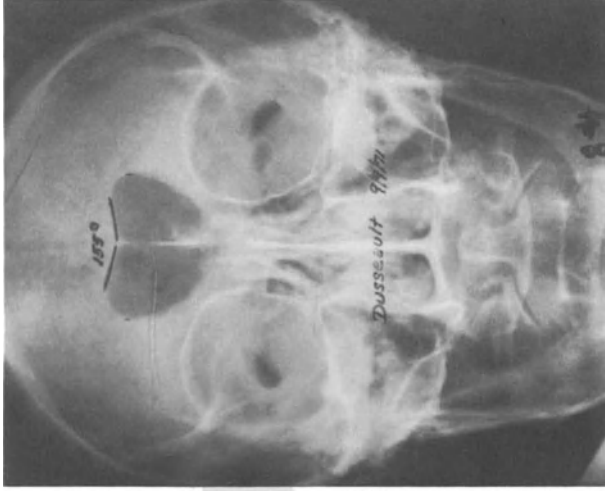
Left: Above upper border of orbits: 1/2 callosal angle on side filling of anterior part of body of ventricle; 1/2 callosal angle 70° on side of filling no filling of anterior part of body of ventricle
 Right: At Lower border of orbits 165°



a) Above upper border of orbits:
angle 115°

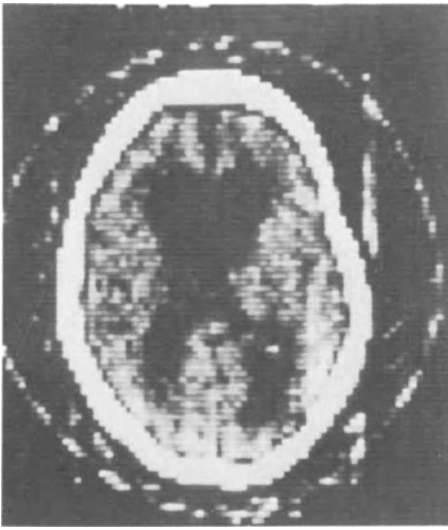


b) Below upper border of orbit:
angle 132°

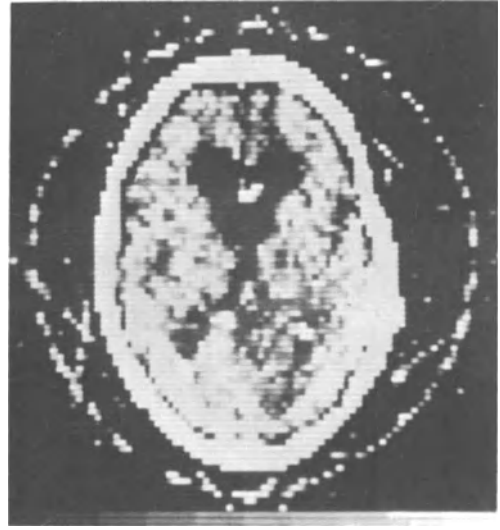


c) At lower border of orbit:
angle 155°

Fig. 2a-c. Variation in collosal angle with variation in angle of projection of photon beam at same study. Superior border of petrous bones projected

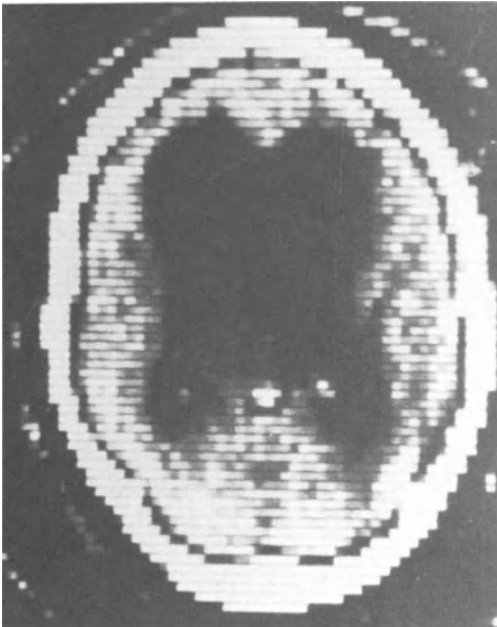


Before ventriculo-venous shunt
Fig. 4a

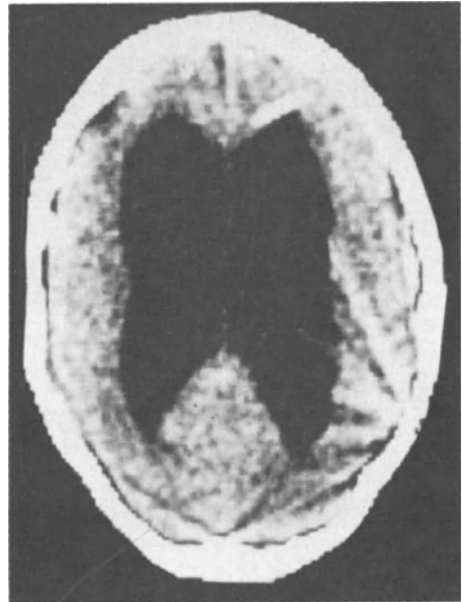


16 days after ventriculo-venous shunt
Fig. 4b

a)-b) Pre- and postoperative views showing dramatic decrease in ventricular size



Before ventriculo-venous shunt
Fig. 4c



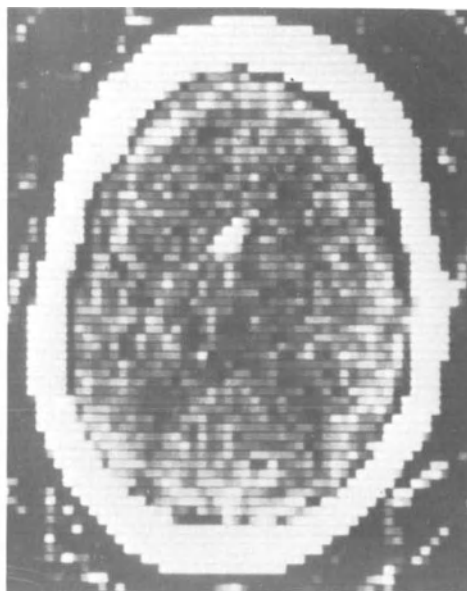
7 months post shunt operation
Fig. 4d

c)-d) Pre- and postoperative views showing minimal decrease in ventricular size

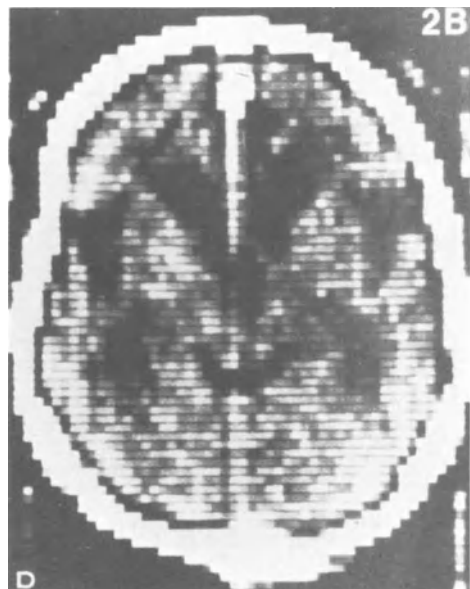
Fig. 4a-d. Variability in response of ventricles in patients in good-excellent group to operative shunt



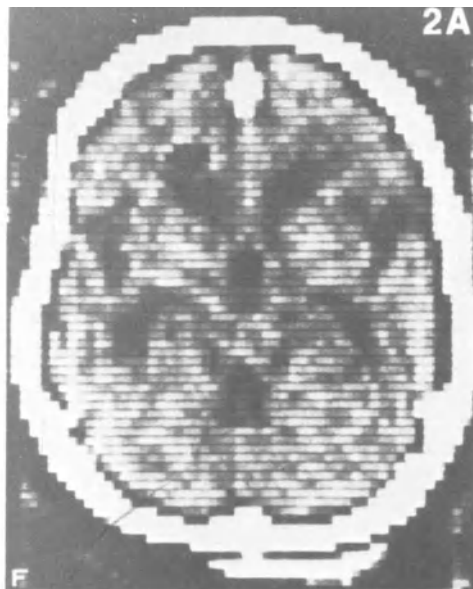
a) Large lateral ventricles before operation



b) Much smaller lateral ventricles 10 days after operation



c) Large lateral ventricles and Sylvian fissures before operation



d) Smaller lateral ventricles and Sylvian fissures 9 days after operation

Fig. 5a-d. Striking decrease in ventricular size in patients with poor clinical response to shunt

Radioisotope Cisternography and Hydrocephalus

R. OBERSON and E. ZANDER

Radioisotope studies of the cerebrospinal fluid pathways are widely used in the screening of potentially hydrocephalic patients and evaluation of all kinds of hydrocephalus (1, 4, 10, 12, 17, 23, 26). In most instances the results of these studies are used to illustrate the anatomical and dynamic conditions of the third circulation (3, 6, 7, 8, 9, 16, 28, 29, 30, 42, 46). Everyday use of these methods during the last 11 years has convinced us that they are very sensitive from both points of view. They are of utmost importance when deciding for or against an operative shunting procedure (11, 12, 17, 23, 27, 31, 40, 45). It should not be forgotten, however, that these methods do not give definite answers in the analysis of intermediate phenomena. Men in general, and neurosurgeons in particular, are constantly searching for absolute and well-defined criteria for decision making in dubious circumstances. They are prepared to trust the most sophisticated and improbable test if this gives them clear cut answers. Sometimes they seem as if they were attempting the impossible. Even if presented as "the only reliable", or, more simply, as "far more trustful than radioisotope studies", physiological tests, carried out with human subjects (and, therefore, mostly uncontrollable) cannot provide valid, clear cut information in an indefinable state. In other words, in dubious cases, a method which does not give dubious data, is, therefore, itself dubious. We must, of course, maintain a high technical standard in the radioisotope studies and base their interpretation on pattern recognition by well-trained personnel (conditions which are not always fulfilled) (3, 8, 13, 16, 18, 20, 21, 28, 29, 30, 31, 32, 33, 34, 36, 39, 40, 42, 46). The "pattern recognition" problem is by far the most important step (25, 35). Our attention will be focused on the main cisternographic pattern in hydrocephalic patients. Technical notes are summarized; details may be found elsewhere (3, 5, 7, 8, 13, 16, 18, 20, 21, 25, 31, 35, 46).

Material and Method

In 11 years (1965-1975), 3130 cerebrospinal fluid scintigraphies were performed in 2140 patients (Table 1). Three kinds of examination were carried out:

1. *The radioisotope ventriculography (RIV)* is generally performed by injecting the radiotracer in the Rickham reservoir cap of the ventriculostomy catheter (36). A catheter is placed in cases of acute or subacute hydrocephalus, i.e. in clinically non-communicating hydrocephalus. Once the intracranial pressure has been reduced, the communication is often partly, at least, restored and the injection of diagnostic (or therapeutic) drugs may be undertaken. The method of RIV becomes easy and innocuous (8, 29, 36).

Table 1. CSF scintigraphies 1965 - 1975

Number of patients		Number of procedures	
RIV	ventriculographies	210	210
RIC	cisternographies	1250	1760
	including	480 MSG	
MSG	myeloscintigraphies	680	1160
	including	510 RIC	
Total		2140	3130

2. *The radioisotope cisternography* (RIC) is mostly performed after suboccipital injection. Only patients with possible problems in the craniocervical area are injected by the lumbar route. An early control (30 min to 90 min after suboccipital injection) may reveal more precise morphological changes and/or ventricular contamination otherwise not seen (31, 34, 35). In about one third of the RIC, the examination includes a study of the vertebral leptomenigeal space (MSG).

3. *The myeloscintigraphy* (MSG) is usually done by lumbar injection (37, 38). In most cases the cranial leptomenigeal space is also inspected. This permeability test of the whole (spinal and cranial) subarachnoid space is called *myelocisternography*.

Radiotracers. Various radioactive agents have been used since 1965: Iodine-131, replaced by Technetium-99m labelled human serum albumin, Ytterbium-169, Indium-111, subsequently replaced by Technetium-99m complexed DTPA. None is ideal (35). Now Tc-99m DTPA seems to give better pictures and its handling is easier.

Imaging. Scintiphotos or scintifilms are taken with a gamma-camera (Searle Radiographics models HP and IV). The controls a, 6, 24 hours after injection include 5 cranial views: anterior, posterior, vertex, left and right lateral views. The spinal canal is examined routinely by 5 successive posterior views followed by 5 lateral views.

The Cisternographic Problem

In our material, numerous cases of the various types of hydrocephalus may be found. The criteria for evaluation have been worked out in two dimensions: space and time. Both aspects have always to be considered (31, 32, 33, 34). There are *anatomical* and *physiological* criteria of normality (Table 2). Looking at different cisterns one can follow the development of their experience, regularity, symmetry and size. All cisterns must be clearly recognized, on CT tomograms, as a whole and at different angles. Successive controls do not demonstrate primarily a flow, but the resultant of forces and factors influencing the radio-tracer dispersal. The progressive contamination of the pericerebral fluid and the apparent absence of ventricular contamination are consistent with a centrifugal flow. Circulation time can be calculated as the time elapsed between the contamination of the sylvian fissures and the hemispheric convexities. The disappearance of the radioactive molecules reflects in some way the pressure-dependent absorption phenomenon. Computerized data processing can be used for stocking the information and correcting the data for physical decay. The leptomenigeal biological half-life of DTPA is normally less than 12 hours in adults, and even shorter in children (Fig. 1).

Table 2. Criteria of normality in radioisotope cisternography

A. SPACE	: morphology - anatomy
	cisternal imaging
	- successive appearance
	- regularity
	- symmetry
B. TIME	: dynamic state - physiology
	- progressive pericerebral (centrifugal) contamination (ventricular contamination not seen)
	- transit time: time elapsed between contamination of sylvian fissures and parasagittal area
	- absorption: curves of the biological period normally less than 12 hours for DTPA

Table 3. Abnormalities in cerebrospinal fluid scintigraphy

Morphological abnormalities
- ventricular dilatation
- abnormal cisterns: irregular and/or asymmetrical
- dilatation
- narrowing
Dynamic abnormalities
- ventricular (centrifugal) contamination
- transitory
- permanent
- prolonged pericerebral transit time
- biological halftime greater than 12 h
- transependymal flux

Space and time are useful landmarks for considering pathological results. Abnormalities are essentially morphological and/or dynamic. Although they are never separate, it is helpful to consider them separately.

Morphological Abnormalities (Table 3)

The ventricular system becomes apparent only if it is dilated and if the pericerebral dispersion is impaired. If the centrifugal bulk flow is preserved, the phenomenon of ventricular contamination is reversible. The pericerebral cisterns are contaminated as the wash out of the ventricles proceeds. Ventricular contamination, erroneously called "ventricular reflux", is more often observed after suboccipital injection thus confirming its transitory character and convincing us once again that cisternal injection is the better suited for the observation of the whole bed of the third circulation (ventricles and subarachnoid space). Asymmetrical hydrocephalus is more likely to represent atrophy. Ventricular contamination is above all a pathological dynamic phenomenon (19, 28, 29, 35).

Morphological changes of the pericerebral cisterns are characterized by asymmetry or irregular shape, with localized widening or narrowing. Cisternal widening may represent cerebral atrophy, porencephaly, malformation (meningocele), or a CSF pouch connected to a leak. Stenosis is non-specific. It may result from leptomenigeal impermeability after hemorrhage, contusion, infection or degeneration. It may also be due

to compression, by internal hydrocephalus under pressure or be related to cerebral or extracerebral tumor (Fig. 2, 7). Pictures are often characteristic. Cerebral tumors compress the leptomeningeal pericerebral space towards the periphery. Extracerebral masses distort a cisternal area: if one part is occluded, the foregoing is widened (prestenotic widening as in cerebral pneumography) (14).

Dynamic Abnormalities (Table 3)

The main phenomenon has already been dealt with. It is the apparent centripetal movement of the radioactive fluid, corresponding to a contamination of the ventricular fluid. To speak of a "reversal of the flow" is incorrect. So-called "ventricular reflux" is a handy expression giving us some idea of what happens, and this probably not far from what the radiotracer is actually reflecting. The naivety of our terms are probably no more open to criticism than the ingenuity of the whole present concept of the third circulation. To be more correct we should say that dispersal is centripetal or centrifugal (depending on whether it is occurring in the central vasa (ventricular system) or in the peripheral vasa (pericerebral subarachnoid space). The fact that some authors have found the results of RIC to be inadequate (11, 45, 47), may be due to their not having solved pattern recognition and/or technical problems. In the first picture, ventricular contamination for example may be difficult to assess because of high levels of radioactivity present in the interhemispheric fissure (anterior view) or the volume and extension of the cisternal system of the *fissura transversa-cerebri* (posterior and vertex views). In the same way, transitory ventricular contamination must not be given any physiopathological importance (Fig. 4). Such a phenomenon becomes pathological only if it progresses between the 1 and 6 hour control periods (Fig. 2) and is still observable 24 h p.i. We may then speak of a "ventricular stasis". In this case other signs are present corroborating the diagnosis of decompensation: biological halflife greater than 12 hours, transependymal flow.

Neurosurgical Conception of Hydrocephalus

From a neurosurgical point of view hydrocephalus can be classified into various groups. RIC is a useful aid in establishing clear pictures and precise criteria for each group. The main question is: how and when is there a need to place a shunting device? Is there a mechanical problem of communication between the ependymal (ventricular system) and leptomeningeal spaces? In this case, should an intracranial shunting procedure be undertaken (Torkildsen or Scarff)? If there is an imbalance between production and absorption, most frequently caused by an impaired permeability of a large subarachnoid area of the convexities, hydrocephalus is likely to occur in the poorly compensated or decompensated form. In that case should an extracranial shunting device be installed? The classical distinction between communicating and non-communicating hydrocephalus is often misleading. Normally all the ventricles and cisterns are communicating. Wherever an occlusion occurs, hydrocephalus may develop thus provoking the same therapeutic problem of communication. Of course, the most dramatic situation is when the occlusion is located in the ventricular system. Besides this central occlusion there may be other sites of occlusion in the peripheral vasa, the most significant of them being the *incisural block* and the *convexity block* (24, 39, 40). From a neurosurgical, pathophysiological view-point hydrocephalus developing secondary to these blocks is not essentially different from a non-communicating hydrocephalus. The major problem is not the communication but the

state of compensation of hydrocephalus. RIC gives the best appraisal of this unsteady dynamic state which constitutes a form of hydrocephalus. In most instances its criteria allow a definition of the state of compensation or decompensation of hydrocephalus (Fig. 4, 5, 6, 7) and at the same time show which part of the third circulation bed is occluded and which cisterns are permeable. With RIC one tries to place even doubtful cases in well-defined patterns.

Hydrocephalus: Communicating or Not?

Advocates of an enlarged mechanical concept of hydrocephalus have proposed a new terminology. The neurosurgical concept of non-communicating hydrocephalus (i.e. shunt tributary) has to be applied whenever there is an occlusion, be it in the maze of the central vase or in a cisternal complex. It seems, therefore, more suitable to speak of "*central obstructive hydrocephalus*" (corresponding to the classical "non-communicating hydrocephalus") and "*peripheral obstructive hydrocephalus*" (corresponding to the class of "blocked communicating hydrocephalus").

Central Obstructive Hydrocephalus (Table 4)

Characteristic cisternographic pictures are obtained (Fig. 3). The ventricular system is either not discernable or only indirectly indicated by the stretched sylvian cisterns pressed against the lateral walls of the neurocranium (Fig. 7 J). In the basal cisterns it appears that occlusion or tight narrowing of the foramina of the 4th ventricle are able to stop the movement of the pericerebral fluid. There is stasis of the radioactive fluid in the basal cisterns. Pictures are almost the same 6, 24 and 48 hours p.i. (Fig. 3). If the occlusion is

Table 4. Cisternographic pattern of central occlusive hydrocephalus (non communicating)

-
1. No contamination of the ventricular system
 2. Stasis of the radiotracer in the basal cisterns in the case of non communicating hydrocephalus
 3. Stasis is less marked in the case of aqueduct stenosis
 4. Narrowing of the sylvian fissures (if contaminated)
(indirect sign of ventricular enlargement)
 5. Leptomeningeal biological halflife greater than 24 h
-

Table 5. Cisternographic pattern of peripheral occlusive hydrocephalus (communicating hydrocephalus)

-
1. Ventricular contamination
 - transitory
 - permanent
 2. Cisternal block
 - incisural block
 - chiasmatic angle block
 - fissura transversa block
 - interhemispheric block
 - sylvian fissura block
 - convexity (bilateral or unilateral) block
-

at a higher site (e.g. in the aqueduct) or if the narrowing is less marked, stasis is less pronounced. In all these cases however, the leptomenigeal biological half-life is greater than 24 hours. RIV may confirm ventricular stasis and dilatation. Radioisotope studies have demonstrated that, except in acute cases, non-communicating hydrocephalus most often remains slightly communicating (35).

Peripheral Obstructive Hydrocephalus (Table 5)

The bulk flow of the pericerebral fluid may be blocked or severely impaired at an important cisternal crossroad (Fig. 2, 5). The most exposed one is found at the incisura tentorii (foramen of Pacchioni). Its closure gives rise to the *incisural block* (39, 40). But other sites may be involved: the optochiasmatic cistern, the quadrigeminal cistern, the interhemispheric fissure, both sylvian fissures or large areas on the hemispheric convexities. RIC shows a progressive and permanent contamination of the enlarged ventricular system. No, or only slight, wash out is seen (ventricular stasis) (Fig. 2, 5, 6). Cisterns are widened below the obstruction, and absent above.

Hydrocephalus: Compensated or Not?

Both types of obstructive hydrocephalus (central and peripheral) are generally decompensated or ill compensated (Table 9). Cisternographic signs are clear.

In *decompensated hydrocephalus* (Table 6), provided there is a communication between the injected peripheral vasa and the ventricles, the ventricular contamination is always progressive, i.e. the ventricles can be seen clearer and clearer between the control 1 and 6 hour p.i. periods. The ventricular contamination is massive and the enlarged ventricles are symmetrical. Ventricular contamination persists beyond 24 hours. Transependymal flux may be observed (Fig. 6).

Table 6. Cisternographic pattern of decompensated hydrocephalus

-
1. Ventricular contamination
 - progressive: more marked at 6 h than at 1 h
 - symmetrical and important
 - permanent: still visible at 24 h and 48 h p.i.
 2. Stasis in the basal cisterns
 3. Supratentorial cisterns poorly contaminated (if ever)
 4. Biological half-life greater than 24 h
 5. Blurring of the ventricular contour at 24 h (transependymal flux?)
-

In *poorly compensated or ill compensated hydrocephalus* (Table 7), an unsteady state is present. It would be wrong to use absolute criteria to define such an intermediary state. Clinical, neuropsychological, biological and radiological controls are needed when observing the evolution of such a situation. In a few cases a cisternographic control may also be needed. However most cases can be classified by evaluating the importance of the dynamic abnormalities as well as the morphological changes (Fig. 5).

Table 7. Cisternographic pattern in ill-compensated hydrocephalus

-
- Dynamic abnormalities
 - more or less transient ventriculography
 - prolonged biological halflife (greater than 12 h)
 - Morphological abnormalities
 - cisternal narrowing and/or widening
 - localized
 - unilateral
 - diffuse
- This intermediary state requires
- consideration of other tests and clinical factors
 - control cisternography in 1 or 2 weeks
-

Hydrocephalus Ex Vacuo (Table 8)

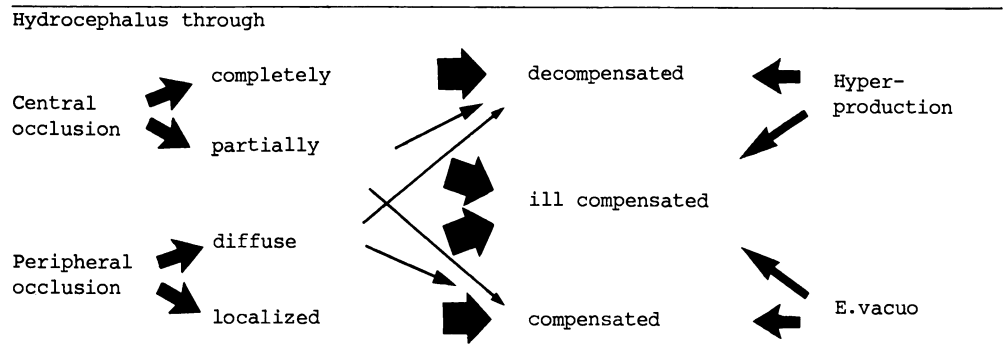
This type of hydrocephalus is generally *non obstructive* and *well compensated* (Fig. 8). This is a case of non-active cerebral atrophy. In some instances, however, hydrocephalus may become unbalanced. Peripher- al occlusion of a large area may occur or the balance between pro- duction and absorption of the CSF may be destroyed. As in other cases the origin remains largely unknown. Hydrocephalus ex vacuo does not represent a final equilibrium state.

Table 8. Cisternographic pattern in hydrocephalus ex vacuo

-
- Widened pericerebral leptomenigeal space
 - diffuse
 - localized
 - Biological halflife about 24 h
 - No ventricular contamination: H. ex vacuo is generally well compensated
-

It is still subjected to slow changes. This dynamic point of view is supported by the fact that some patients with hydrocephalus ex vacuo have been improved after shunting (Fig. 2, 41, 43, 44). RIC may reveal a slight or moderate, early contamination of the ventricles, but this is always transitory. Ventricular wash out is seen to be progressive. The pericerebral cisterns are diffusely and symmetrically widened. The absorption is moderately impaired so that the biological halflife is about 24 hours (Fig. 1).

Table 9



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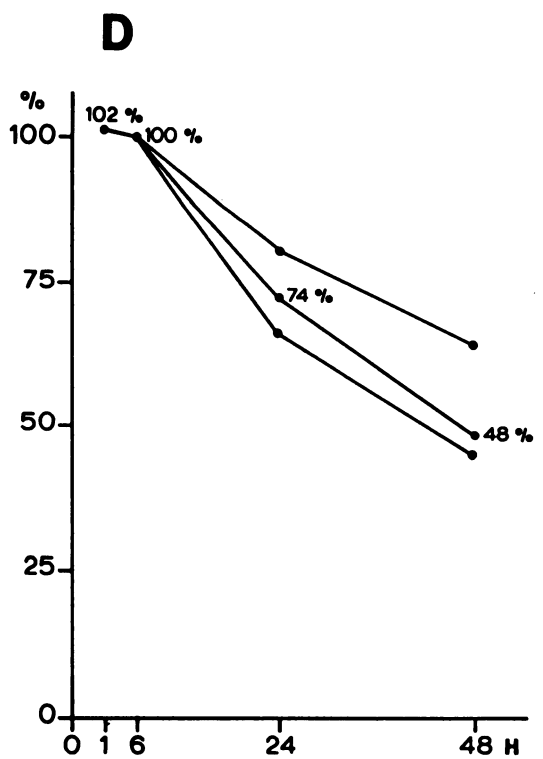
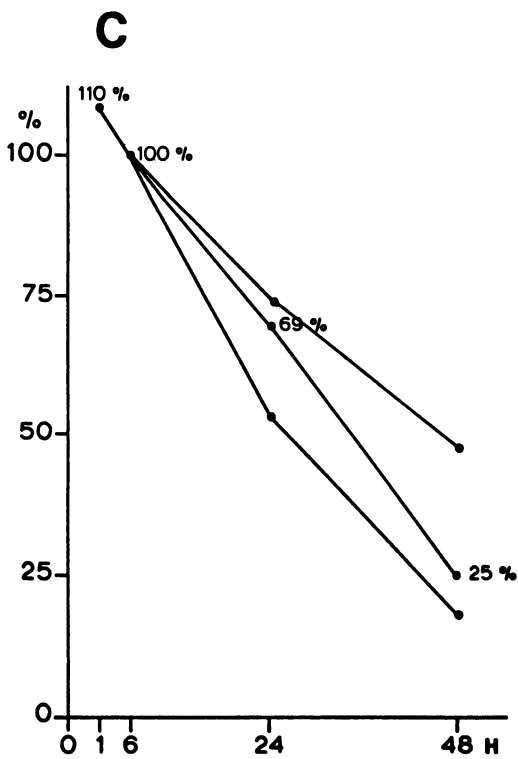
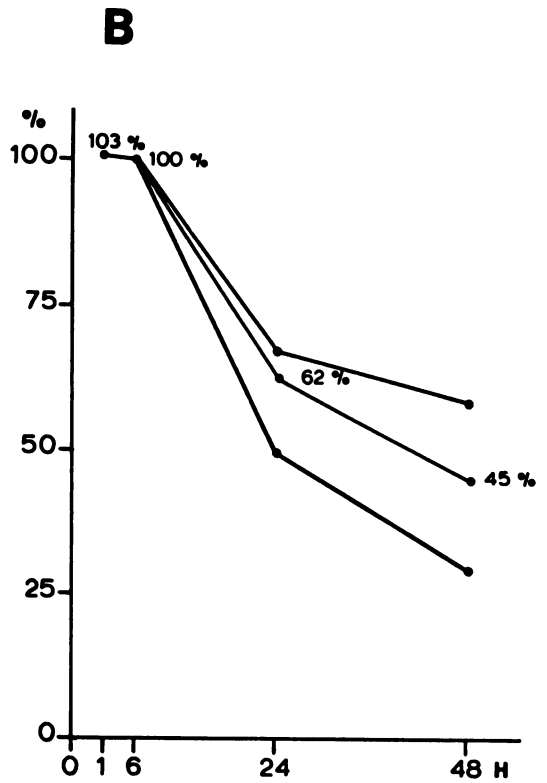
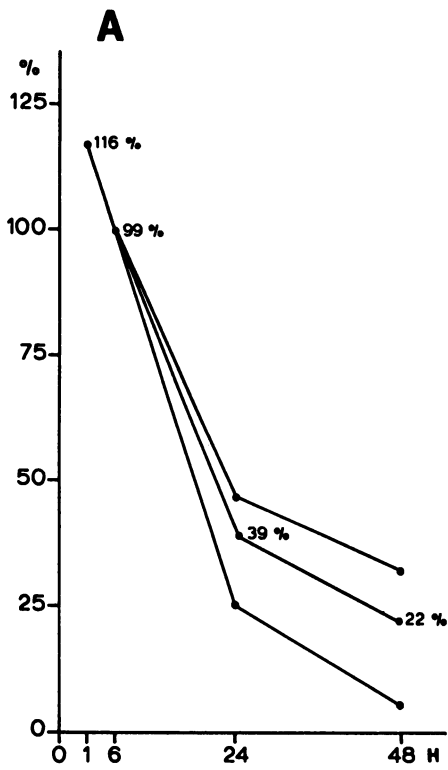
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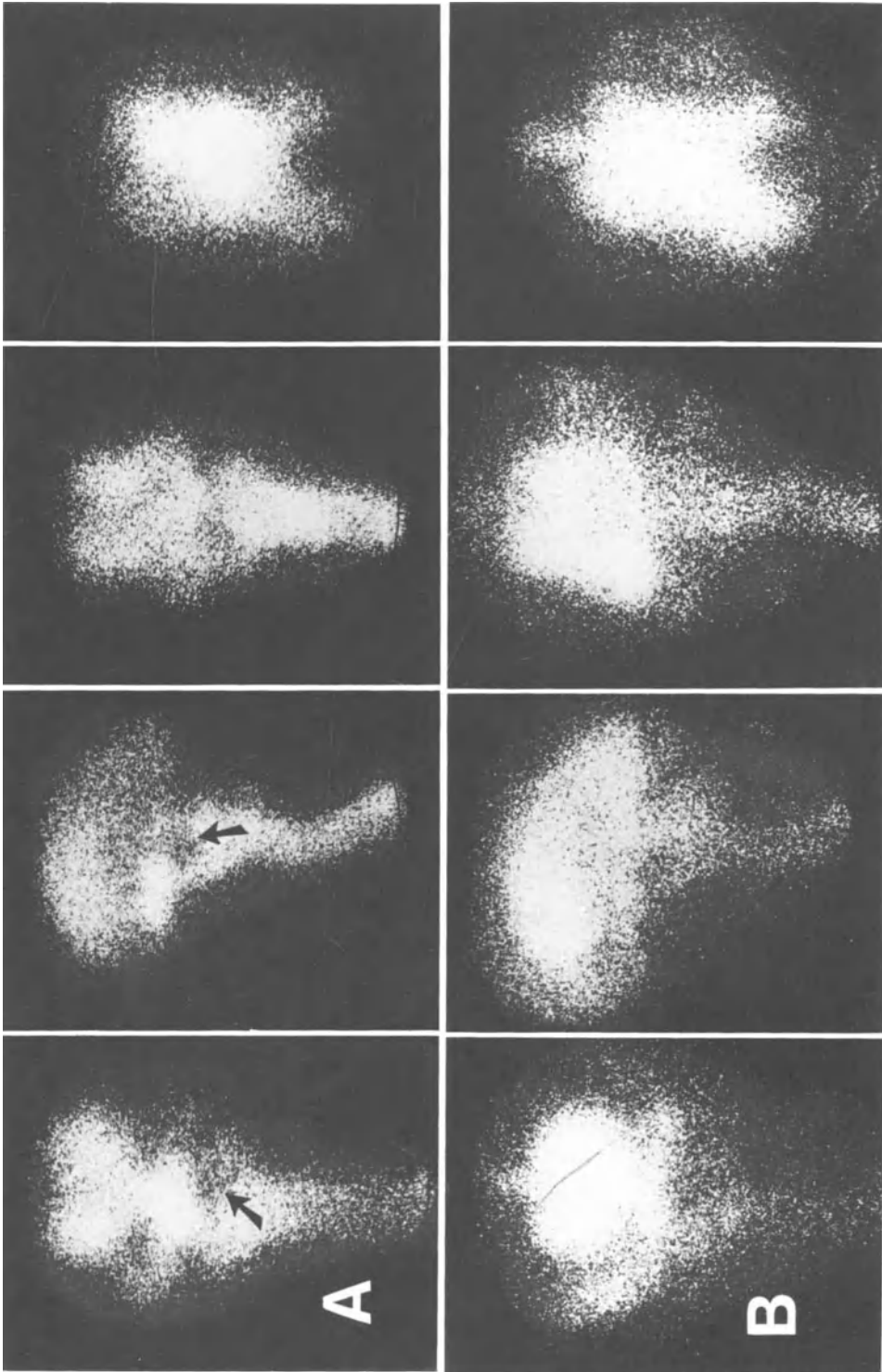
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Fig. 1. Resorption curves of ^{169}Yb DTPA after suboccipital injection. MED II data processing of the radioactivity of the head calculated from 5 usual views 1, 6, 24 and 48 hours after injection. The values are corrected for decay.

- A. Average normal curve from 15 patients between 20 and 30 years old. Biological halftime is about 10 h
- B. Average resorption curve in 10 patients with hydrocephalus ex vacuo
- C. Dispersion of curves obtained in 22 hydrocephalic patients presenting unsteady state of compensation
- D. Dispersion of curves obtained in 18 patients presenting signs of decompensated hydrocephalus





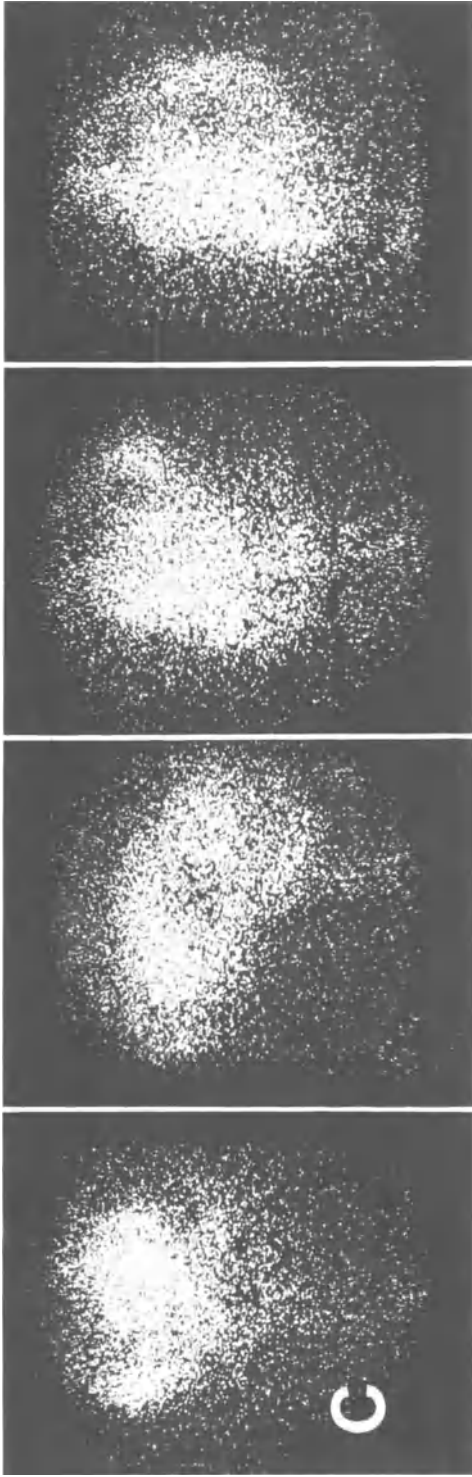


Fig. 2. RIC in a 45-years-old woman with meningioma of the inner and posterior part of the middle cerebral fossa. From left to right anterior, left lateral, posterior and vertex views taken A. 1 h, B. 6 h and C. 24 h after suboccipital injection of ^{99m}Tc DTPA. Decompensated hydrocephalus in relation with a cisternal block around the left hemisphere and the space occupying meningioma (arrow)

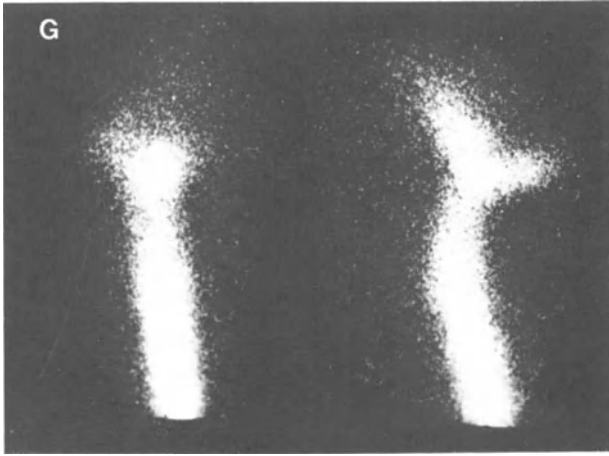
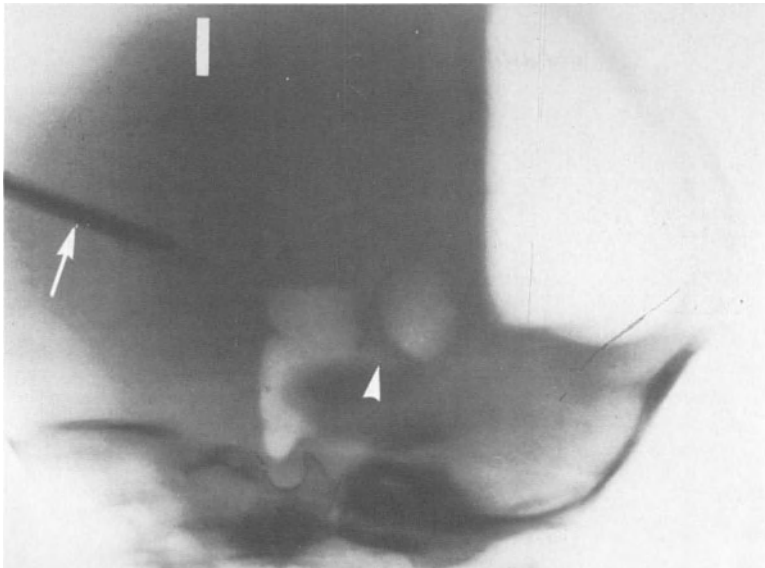
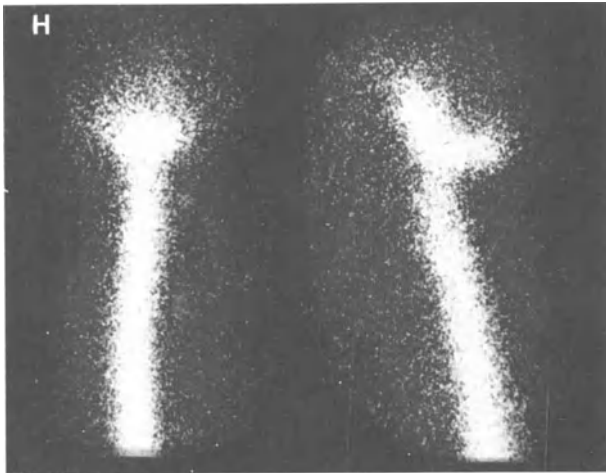


Fig 3. RIC in a 4-months-old girl. ^{99m}Tc -DTPA was injected by lumbar route. Posterior and left lateral views taken G. 30 min and H. 5 h after injection. Stasis of the radiotracer in the basal cisterns. I. Midline tomogram of the gas ventriculography through the ventricular catheter (arrow). See the aqueduct occlusion (head of arrow)



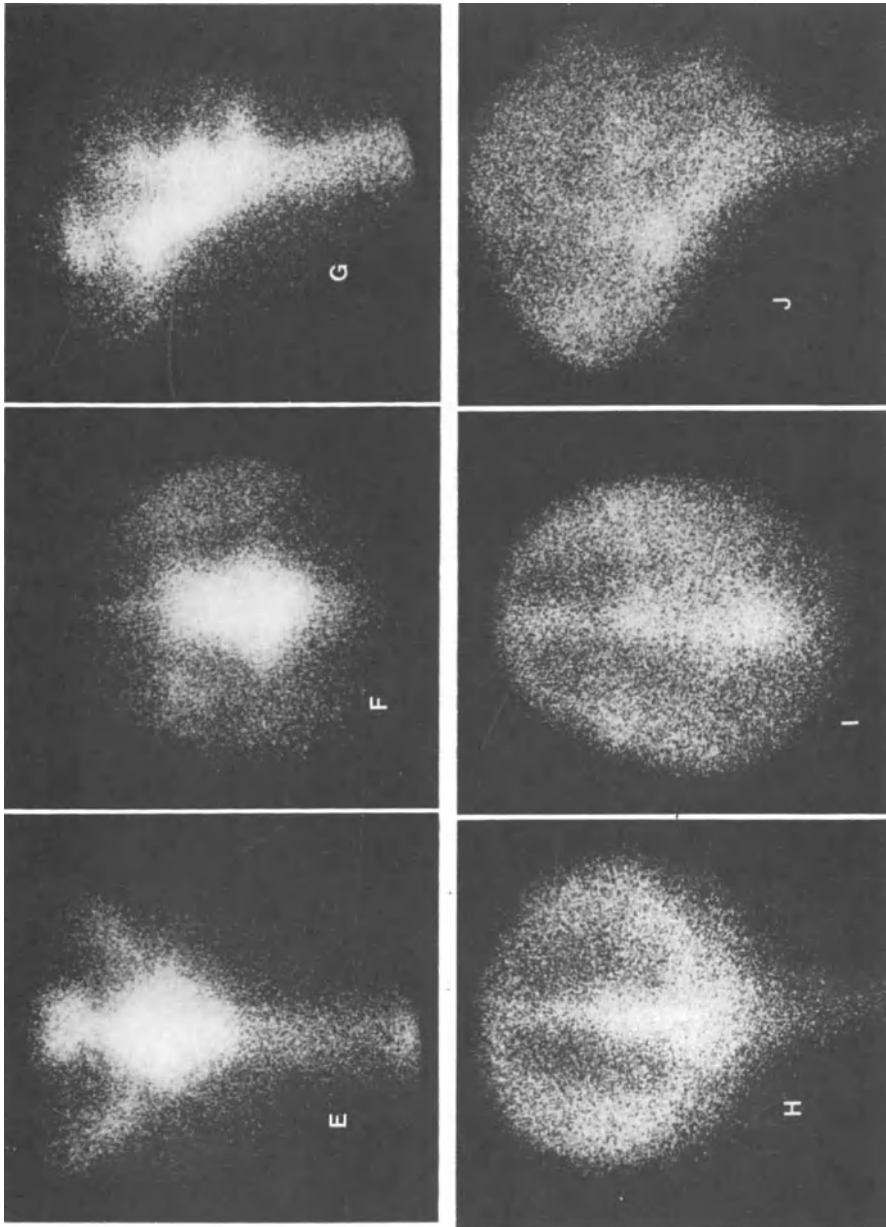
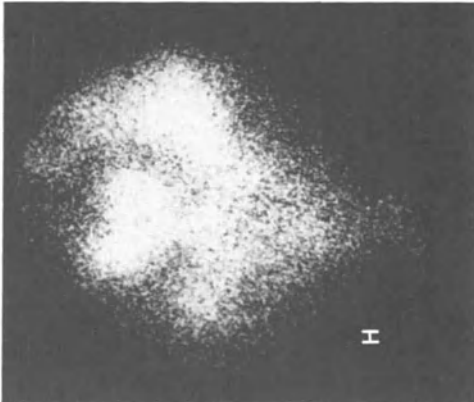
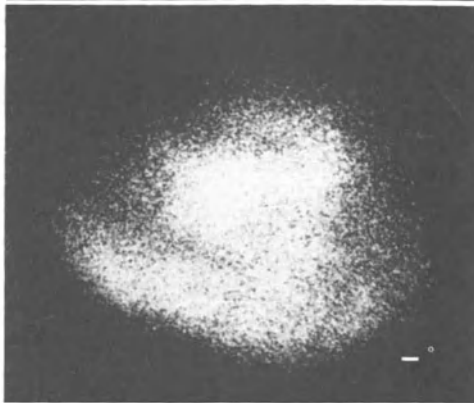
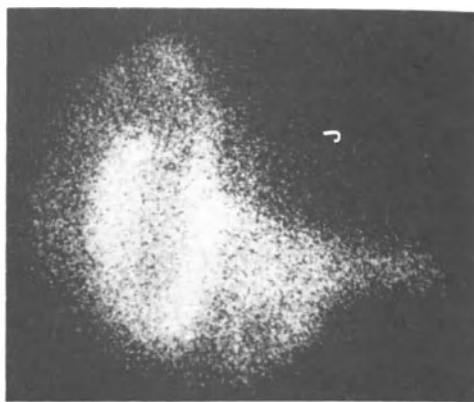
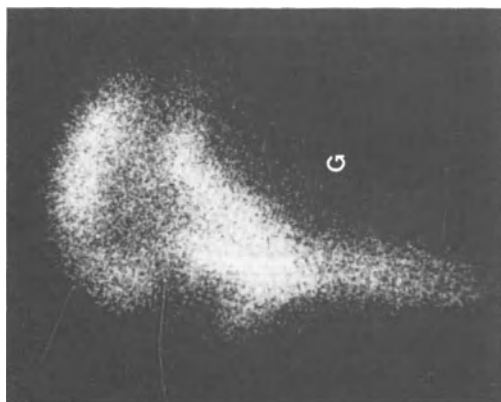


Fig. 4. RIC in a 23-years-old man by suboccipital route. Posttraumatic hydrocephalus of the well compensated type. Anterior, vertex and left lateral views taken E, F and G 1 h p.i. and H, I, J, 6 h p.i. See progressive wash out of the radioactive ventricular fluid and progressive pericerebral (centrifugal) contamination



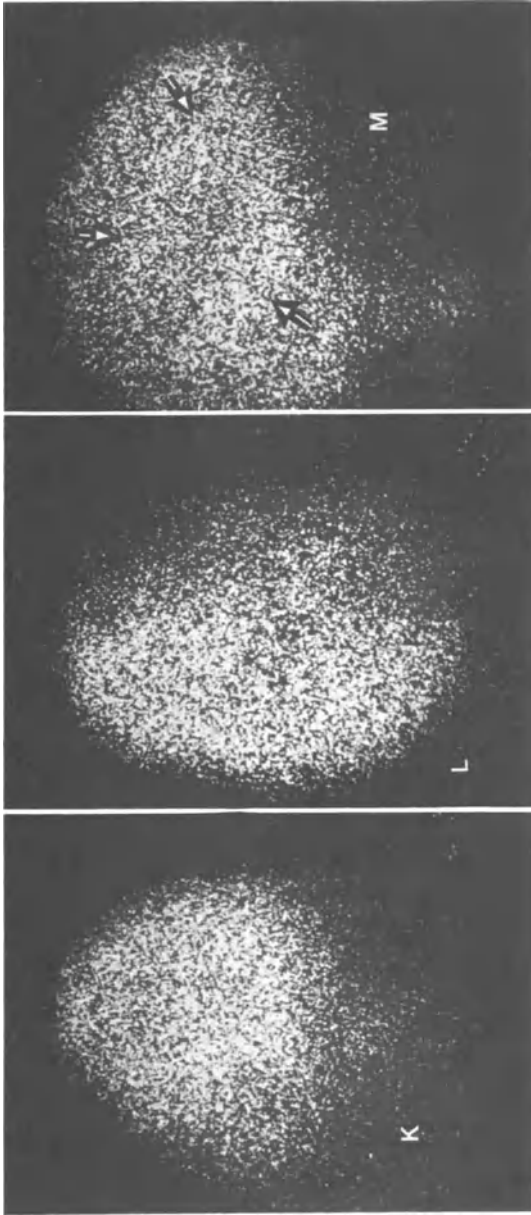
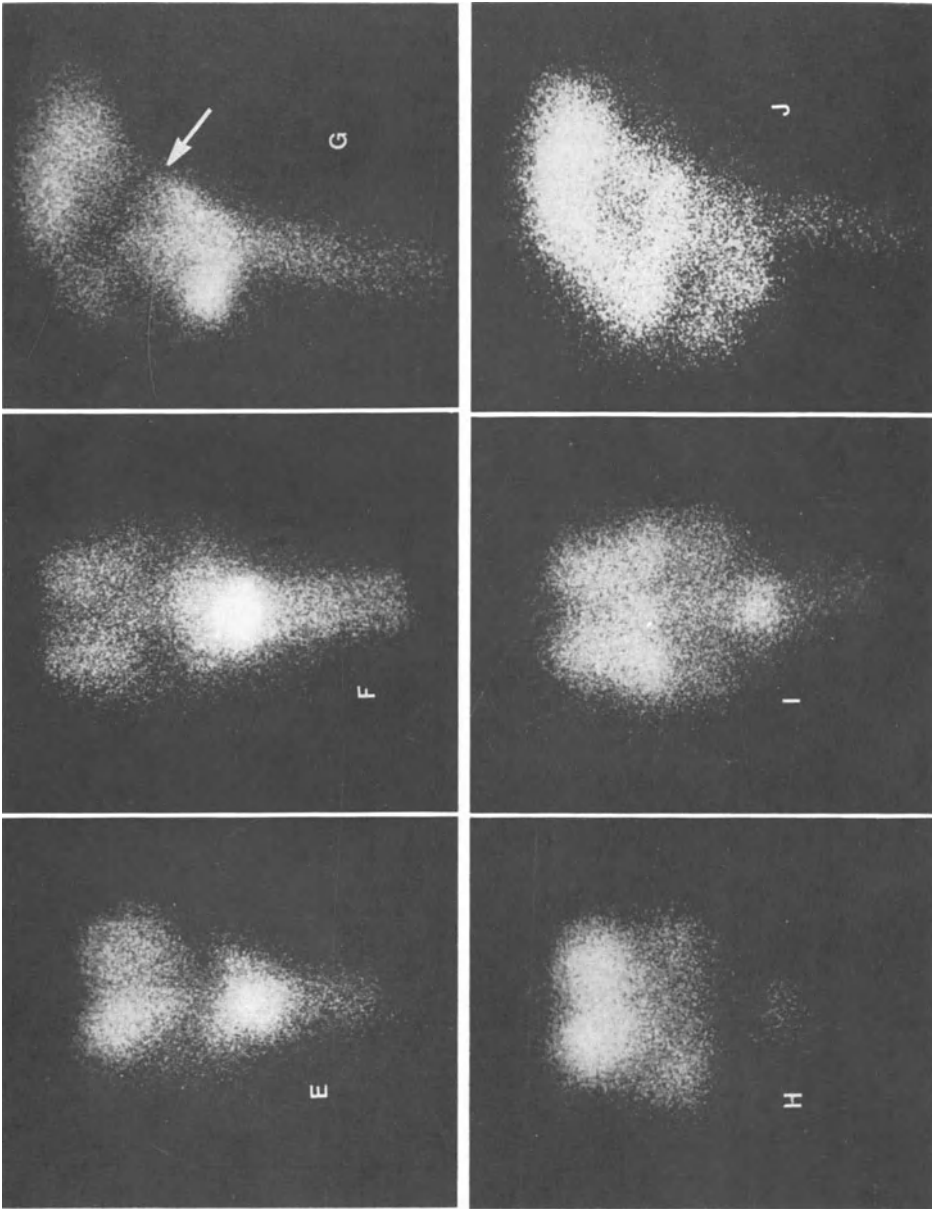


Fig. 5. RIC in a 20-years-old man by suboccipital route. Posttraumatic hydrocephalus. Anterior, verte and right lateral views taken E, F and G 1 h, H, I, J 6 h and K, L, M 24 h p.i. See the poor wash out of the radioactive ventricular fluid, the ventricular stasis 24 h p.i. (arrows), and the occlusion of the whole leptomeningeal space over the right hemisphere. This pattern suggests ill compensated hydrocephalus. The patient was shunted and subsequently improved



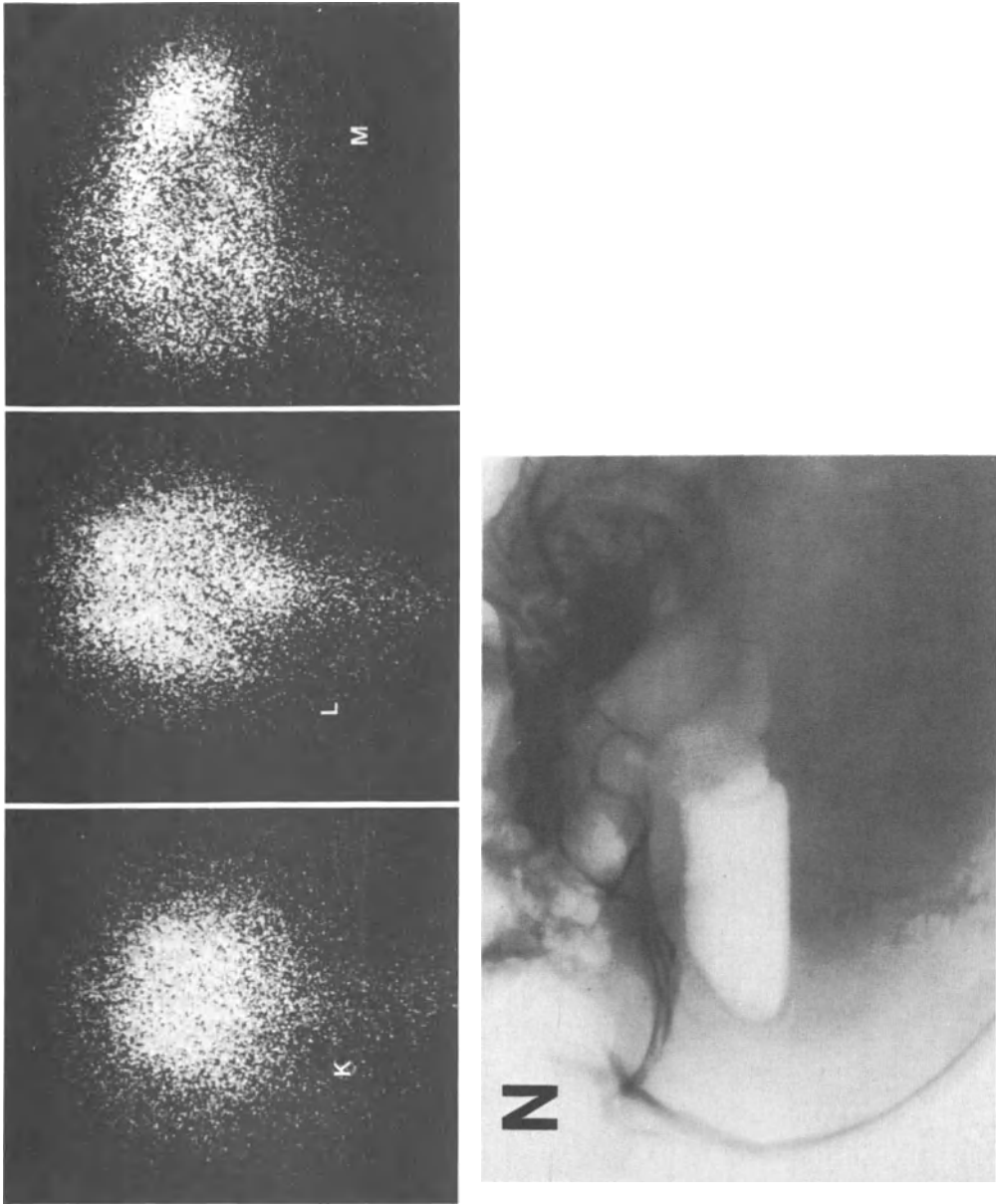
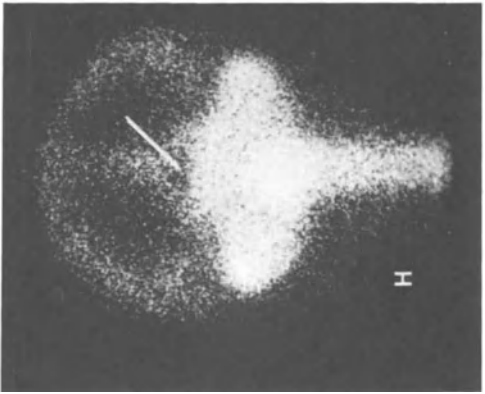
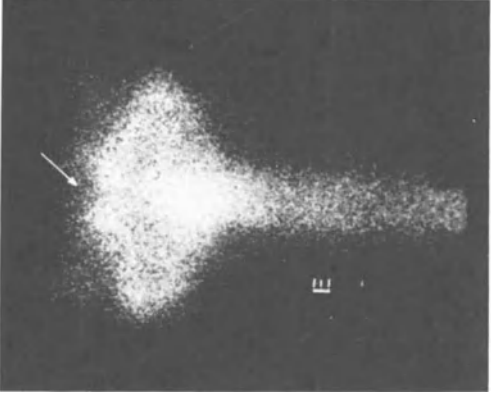
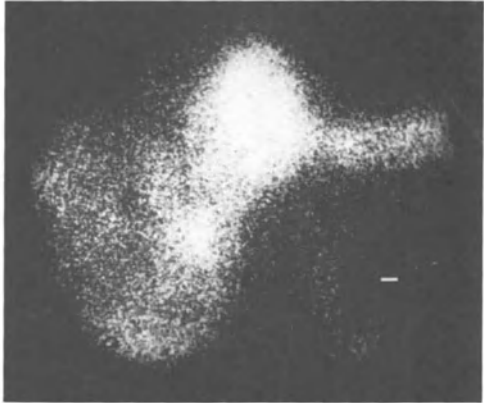
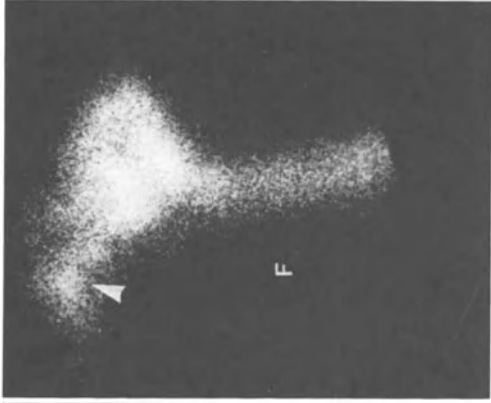
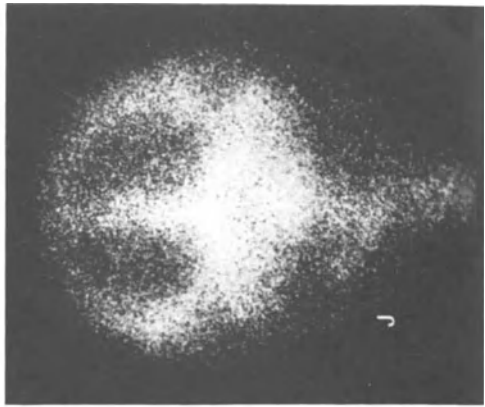
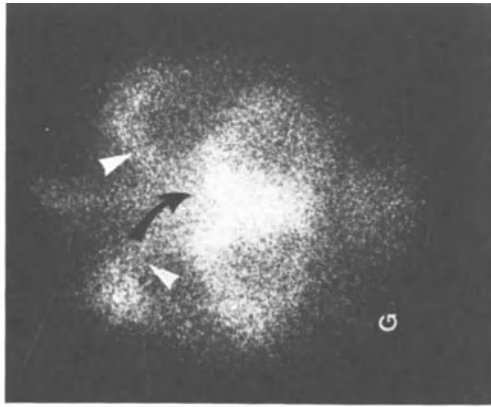


Fig. 6. RIC in a 20-years-old man. Decompensated postmeningitic hydrocephalus. Anterior, posterior and right lateral views E, F, G 1 h, H, I, J 6 h, K, L, M 24 h p.i. by suboccipital route. See the progressive (centripetal) contamination of the ventricular fluid between 1 and 6 h, the incisural block (arrow), the ventricular stasis on the 24 h picture, the lack of pericerebral contamination and the blurred margin of the ventricular system 24 h p.i. (transependymal flow). N. Gas encephalography. Head down lateral view showing the dilated frontal horns and the floor of the third ventricle pointing into the sella



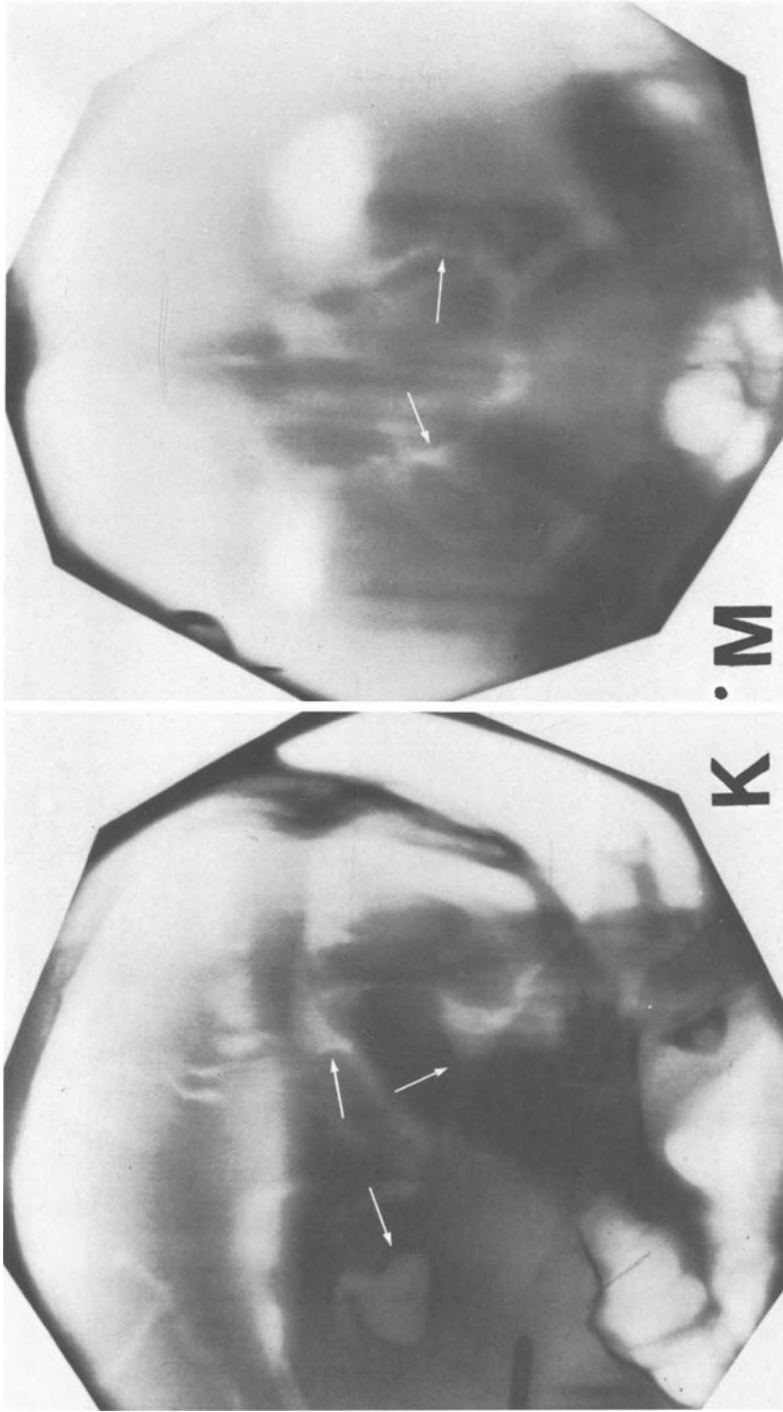


Fig 7. RIC in a 74-years-old woman. Meningioma of the upper anterior margin of the tentorium cerebelli. E, F, G posterior, left lateral and vertex views 1 h p.i. by suboccipital route. H, I posterior and left lateral views 6 h p.i. J anterior view 6 h p.i. See the superior incisural block (arrow), the pericerebral (centrifugal) contamination through the anterior basal cisterns (arrow head), in spite of the important (communicating) hydrocephalus. See the indirect sign of hydrocephalus in J. Gas encephalography. K midline tomogram. M frontal tomogram through the space-occupying meningioma (arrows) of the free margin of the tentorium

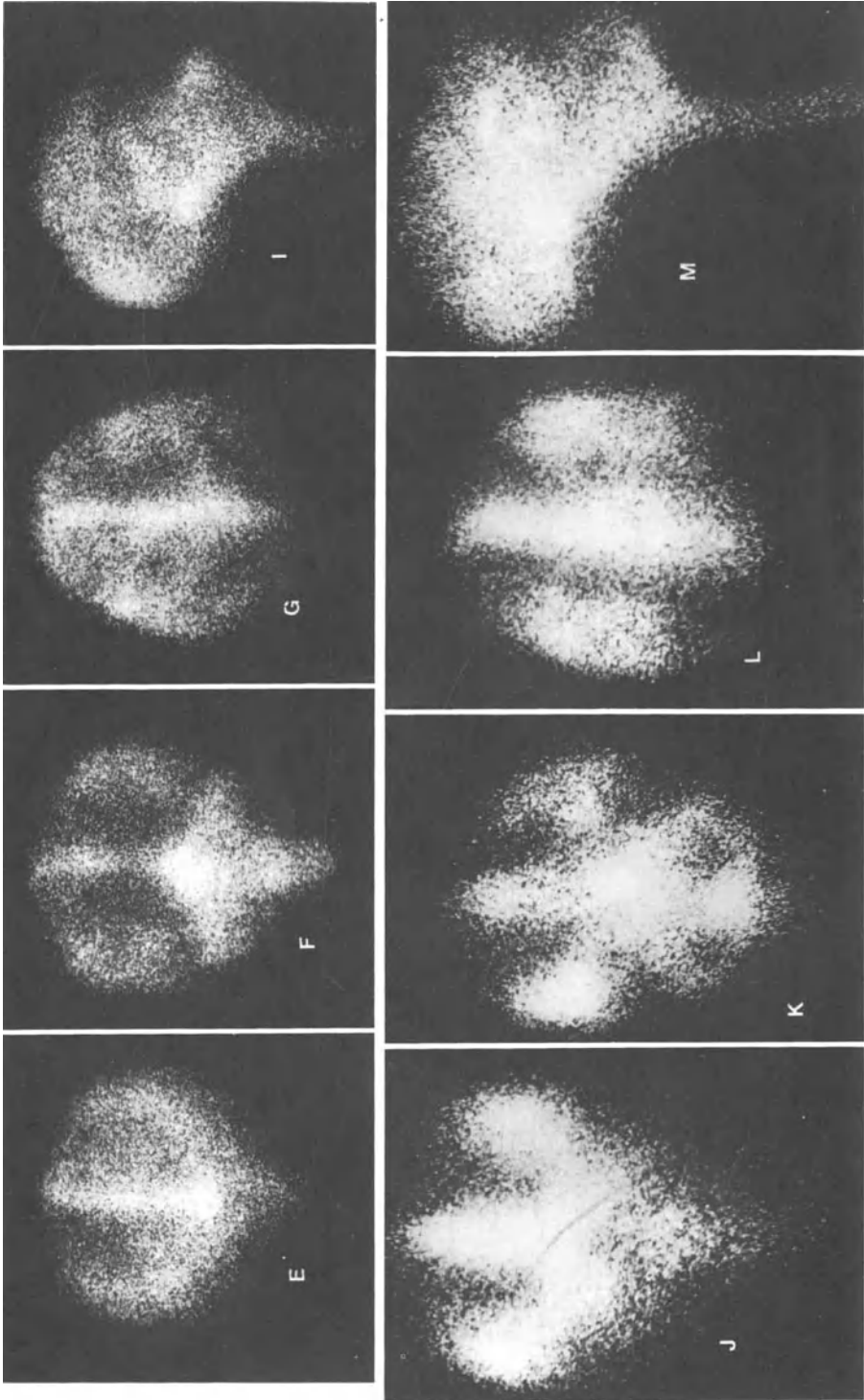


Fig. 8. RIC. Anterior, posterior, vertex and left lateral views 5 h p.i. by suboccipital route. E, F, G, I in a 54-years-old woman: normal patterns. Compare with J, K, L, M in a 68-years-old man: hydrocephalus ex vacuo

Considerations About the Pathophysiology of the So-Called Cisterno-Ventricular Reflux

Preliminary Report

A. PALMA, T. KOLBERG, W. ENTZIAN, and A. PALMA

The cisterno-ventricular reflux or flow inversion is discussed in recent literature as a particular feature of normal pressure hydrocephalus. Descriptive classifications such as persistent, transitory, partial, early and late reflux or reflux, with or without stasis, are used (1, 2, 3, 4, 5, 6, 7, 9). Its significance with regard to therapeutic consequences still is a source of controversy. Therefore, a numeric method for description of cerebrospinal fluid (CSF) movements between compartments was pursued in order to be in a better position to discuss the pathophysiological basis of this problem. The iterative balance calculations of concentration courses, was derived from the following hydrodynamic model (Fig. 1) and compared with the results of measurements in 22 patients which were submitted to dynamic gamma-cisternography with I^{131} -human serum albumine.

Model

Two chambers, the volume A representing the lateral ventricles and the volume B representing the functional unity of the basal cisterns and upper cervical canal (distribution pool - DP) are communicating. B is open for loss of tracer towards the convexity and the spinal canal. A permits ependymal resorption under certain conditions. In normal situations fluid moves unidirectionally from A to B, corresponding to the CSF pathway from the ventricles through the basal cisterns on its way to the distal places of resorption. Tracers, when applied in B, will then never appear in A. If there is a "reflux" besides this main current, that necessarily implicated presence of *turbulences*, the tracer is partially carried back to A. This phenomenon is well known and described in chemical technology, where it is usually called *backmixing*. According to the physical properties of backmixing, the amount of reflux is less important than the main current, so the tracer's concentration in A will never attain that in B, when the tracer was applied in B. Applied to the CSF spaces, backmixing will be recognizable from the fact that the tracer's concentration in the lateral ventricles will remain below that in the basal cisterns after suboccipital injection. In case of "maximal reflux", which is to be differentiated from backmixing and flow inversion, the tracer moves with equal ratios from B to A and inversely. This phenomenon will be called *total permixing*. It produces equal tracer concentrations in the CSF of the basal cisterns and the ventricles a certain time after suboccipital injection. The time delay between injection and maximum concentration in A ventricles may be short or long depending upon the velocity of intercompartmental transport and upon the volumes of the compartments. The patient's actual tracer concentration in his ventricles and basal cisterns is calculated from the approximately determined volumes of the two interacting chambers and their counter-rates during the time as measured externally with the scintillation camera. A detailed description of that method, which yields reproducible results when

compared with paralleled measurements of concentrations in CSF specimen with the gamma-counter, needs more space and will be presented in the near future.

The values of the tracer concentration in the ventricles and the basal cisterns are plotted as a function of time, and compared with the results of numeric variants put into the model. Using the known approximations for the volumes, suitable values for the flow components are selected and applied in the model. The result is an identical relationship between the model's curves and the patient's curve obtained from the dynamic gammacisternography before.

Results

In 18 of our 22 patients the features of backmixing were found: the curve of the tracer concentration in the ventricles did not reach that of the basal cisterns after suboccipital application (Fig. 2). From the model, we know that one can read the degree of backmixing in per cent of the genuine ventriculo-cisternal flow from the relation between the value of ventricular maximum and the value of the cisternal concentration at the moment of that maximum.

Patients with the feature of backmixing have a normal or enlarged ventricular system, partially compromised convexity ascension of radiotracer (8) and accelerated spinal descent of it (11).

In 4 of the 22 patients the features of total permixing were found: the curves joined each other and remained together (Fig. 3). The meaning of this observation in terms of hydrodynamic rules is, that the amount of CSF moving from the ventricles to the cisterns is equalized by the amount that is brought back into the ventricles. These patients always had an enlarged ventricular system and neat periventricular emigration of radiotracer, this in combination with absence of ascension to the convexity and deceleration of the spinal descent.

Under the presupposition of known volumes, the above mentioned iterative calculations are used to find suitable flow values resulting in comparable model curves (Figs. 2 and 3). In the patients of fig. 3, showing the patterns of total permixing, their volume and flow values can, for example, be used to predict the curves of the same patients in the case of *intraventricular application* of tracer. This might be considered as a cross test for the accuracy of the method, as was done with the results shown in Figure 4 (bottom). The model's curves prove to be quite similar to the patient's curves (Fig. 4 upper) obtained from dynamic *ventriculography* afterwards. From these results the validity of such a numeric model seems to be basically conceivable.

We don't know if real *inversion* of flow exists. An inversion, i.e. a predominant or even unidirectional flow from the cisterns into the ventricles must be discernible by concentration values in the ventricular CSF, exceeding those in the cisterns some time after suboccipital application of the tracer, in combination with at least transependymal emigration. Such patterns have not been observed yet.

Summary

From the quantitative evaluation of dynamic gamma-cisterno-ventriculography using radioiodinated human serum albumin as a tracer, it is possible to derive with good approximation the volumes of cerebral ventricles and of the functional unity of the basal cisterns, as well as to observe the behaviour of the tracer's concentration in those two compartments through a time change. The respective values were applied in a hydrodynamic model by iterative balance calculations, that allows qualitative and quantitative conclusions about the so-called ventricular reflux. Two very different types of this phenomenon were found.

1st: in case of *backmixing*, turbulence carries tracer from the basal cisterns into the ventricles against the genuine ventricular outflow, establishing there lower concentrations than in the basal cisterns. Such cases have partially compromised tracer ascension to the convexity and accelerated spinal descent.

2nd: in case of *total permixing*, however, equal concentrations in the ventricular and cisternal CSF are found a certain time after suboccipital injection; then the backflow is equal to the ventricular outflow, and periventricular tracer emigration is well demonstrable. Such patients have no ascension of tracer to the convexity, and show a decelerated spinal descent. A real inversion of flow into the ventricles, defined by predominant or unidirectional cisterno-ventricular CSF movement, was not observed till now. We don't know yet if this exists.

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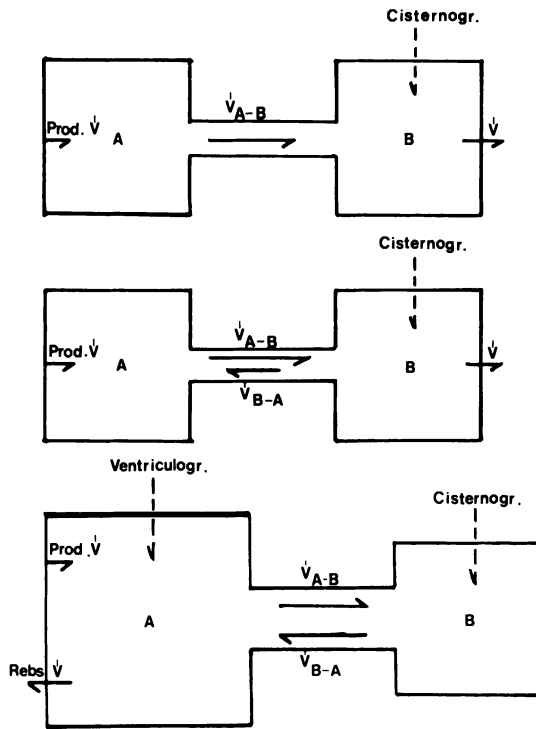


Fig. 1. The model as simplified system. A = ventricular volume, B = cisternal volume. \dot{V} = production resp. elimination flow (ml/5'). \dot{V}_{A-B} = ventriculo-cisternal flow (ml/5'). Flow from B to A and through the ventricular wall can be put in as additional variables

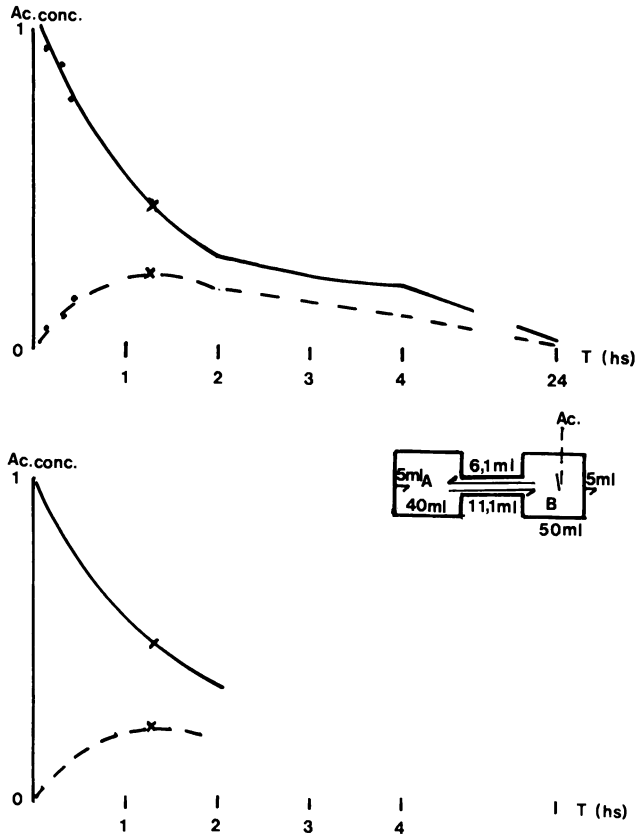


Fig. 2. Typical backmixing. Upper: patient's curves of cisternal — and ventricular ---- concentration course after dynamic gammacisternography. Initial cisternal maximum standardized to 1. Relation between ventricular maximum and simultaneous cisternal concentration = 55%. Volume and flow values (ml and ml/5') as shown gives similar correlation between patients (upper) and theoretical (lower) curves. 6.1 ml/5' is 55% of 11.1 ml/5' and production-elimination of 5 ml/5' is their difference

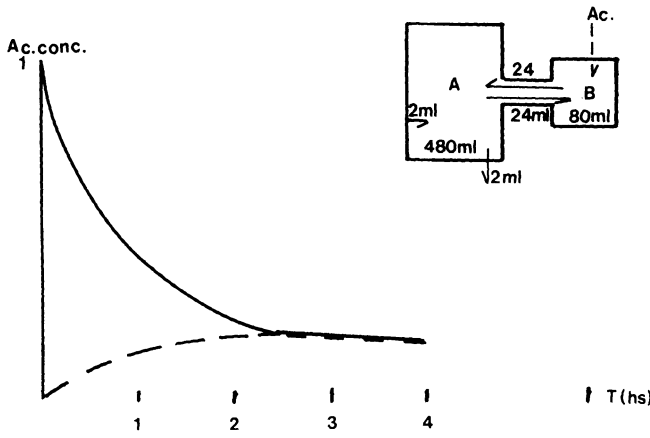
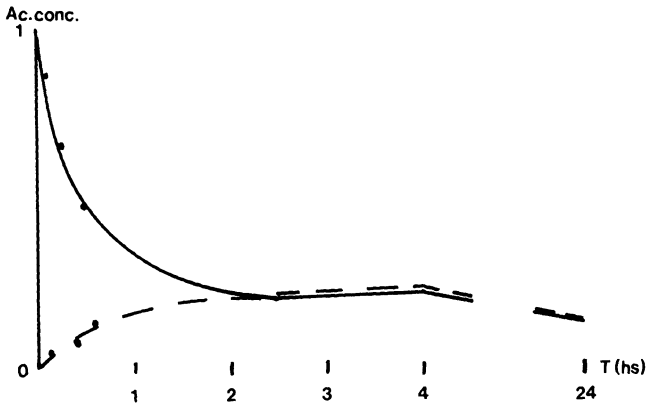


Fig. 3. Typical total permixing, cisternal application, — cist. concentration, ---- ventr. concentration course. Patient's curve (upper) shows joining concentrations; only possible if intercompartmental flow ratios are equal in both directions. Standardization as in Figure 2. Values shown in model produce similar curves. 24 ml/5' as interchange ratios only can produce identical ventricular maximum (4 hrs after injection). Production and transepndymal resorption of 2 ml/5' gives then similar height of maximum at the ventricular volume (distribution) of 480 ml

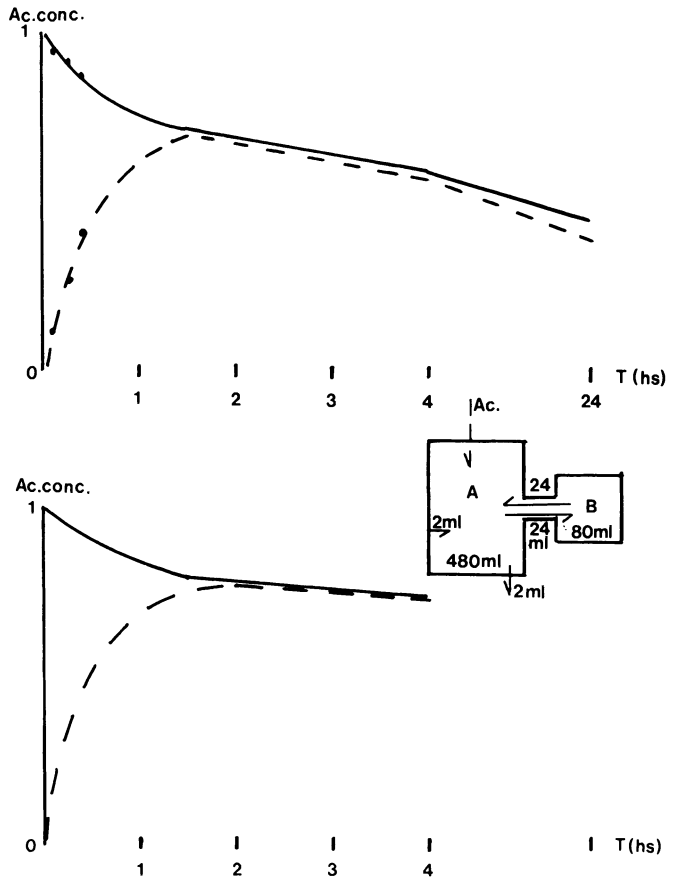


Fig. 4. Cross test in the patient of Figure 3. First the theoretical curves (below) were established with the same data as in Figure 3, but as hypothetical ventricular (!) application. Note joining curves indicating total permixing. Upper curves are those of the patient's ventriculography performed thereafter. Note similarity. Note also inversed significance: A-concentration —, B-concentration ----. Maximum in B is higher and sooner than in cisternography because of the inversed volume relation of the compartments

Cerebral Blood Flow and Cerebrospinal Fluid Pressure in Patients with Communicating Hydrocephalus

A. HARTMANN and E. ALBERTI

The hypothesis of HAKIM states that in chronic condition of communicating hydrocephalus (CH) the ventricular system remains enlarged inspite of the normal cerebrospinal fluid pressure (CSFP) because the effective CSF force - which is the product of CSFP and the ventricular area - is increased due to ventricular dilatation (7). According to this author, the ventricular system continues to be enlarged even when the original obstruction in the intracranial subarachnoid space is removed.

SYMON and his group observed patients with chronic CH paroxysmal plateau waves (22). He believes that the increased CSFP is a sign of permanent or temporarily disturbed equilibrium between CSF production in the ventricles and absorption in the arachnoid villi.

GREITZ et al. measured regional cerebral blood flow in patients with CH. Because blood flow went up after CSF drainage by a ventriculoatrial shunt, and because symptoms of their patients improved, they believe that the major pathological factor in chronic CH is reduction of tissue perfusion (6).

The clinical symptoms of CH such as progressive dementia, disorders of gait, incontinence of urine, and sometimes other features like parkinsonian signs (1, 3, 16), are often misleading in differentiating CH from other types of dementia. Pneumoencephalography offers the opportunity to study the dilatation of the ventricles. Due to technical problems it does not always give accurate information regarding the subarachnoid space over the convexity (14).

In our experience CSF scintigraphy using Ytterbium 169 DTPA or Indium 111 HSA is capable of indicating an obstruction in the subarachnoid space. However, if only delayed clearance occurs due to impaired function of the arachnoid villi for draining CSF into the dural sinus, the differentiation between CH and other dementias becomes difficult.

Pneumoencephalography and CSF scintigraphy might prove the clinical diagnosis of CH. They do not give enough information about the dynamic condition of brain function in CH. They are often insufficient in selecting patients for shunt surgery. Since the surgical results in individual patients are unpredictable, and since shunt operations improve clinical condition in only 40-60% of all operated cases, other diagnostic procedures have been developed.

This communication presents our observation in 14 cases with chronic CH (CH-group), 10 patients with Alzheimer's disease (group II) and 5 patients with dementia due to cerebral arteriosclerosis (group III).

Patients and Method

All patients suffered from progressive dementia. The 14 patients with CH have had in their medical history one or more episodes of subarachnoid hemorrhage (8 cases), head trauma (2 cases), exstirpation of cerebral tumors (2 cases), meningitis (1 case), or radiation (1 case) to the brain in case of cerebral tumor.

All patients of the CH-group, group II and III underwent the following workup: electroencephalogram, brain scanning, cerebral angiography, pneumoencephalogram, and CSF-scintigraphy. Using the results of these studies, the cases were classified according to the above mentioned groups.

Thereafter the following tests were performed:

1. Continuous monitoring of CSFP by a polyethylene catheter which was placed through a bent puncture needle into the lumbar subarachnoid space. If the transducer is located in height of the ventricular system, and if there is free communication between the ventricles and the lumbar subarachnoid space, CSFP equals intraventricular pressure. Further methodological items are discussed elsewhere (8, 9).
2. Lumbar intrathecal infusion test using normal saline, which was infused by an infusion pump through the same polyethylene catheter. Two infusion rates were evaluated: 0.74 and 1.47 ml/min.
3. Regional cerebral blood flow (rCBF) and regional cerebral blood volume (rCBV) using the injection of Xenon 133 and Technetium 99m respectively into the internal carotid artery. Up to 32 regional areas were measured by a computerized gamma camera. The methodological particular points are described elsewhere (10).

Results

1. CSF Pressure

In group II and III CSFP was during the 24-hours-study always within normal range. During sleep CSFP rose slightly, but never exceeded 15 mm Hg.

In one case with Alzheimer's disease we observed respiration-dependent B-waves (according to Lundberg's classification, 15). Their maximal height was 4 mm Hg above the base line pressure.

In the CH-group CSFP was in 4 out of 14 patients always higher than 15 mm Hg, and in 8 out of 14 cases occasionally higher than 15 mm Hg (Table 1). Pressure elevations above 15 mm Hg occurred predominantly during sleep.

In addition to this base line CSFP we recorded in 9 out of 14 patients plateau waves. In 3 patients there were A- and B-waves and in 6 other patients only B-waves. In all these cases except case 12 we observed, in addition to A- or B-waves, small plateau waves (Fig. 1). They have had a maximal height of 9 mm Hg and lasted for 1 to 8 minutes. A-waves were 11 to 29 mm Hg above the base line pressure, and lasted for 3 to 18 minutes. Respiration dependent B-waves have had a maximal height of 19 mm Hg and a maximal length of 2 minutes and 15 seconds. They increased slowly and decreased rapidly during the hyperpnoeic phase of the respiratory cycle.

After shunt surgery CSFP recording was repeated in 6 cases (Table 1). In 4 cases we observed a normalisation of CSFP, in 2 other patients a reduction of the pressure (Fig. 2). Plateau waves disappeared or were considerably reduced in height and length (Fig. 3). A-waves did not occur.

Table 1. Cerebrospinal fluid pressure and plateau waves in CH

Patient	CSFP pre-Op.	CSFP post-Op.	Plateau waves
1	22/32	22/23	A/B
2	14/17		-
3	16/19		-
4	20/26 ^a 14/15		B
5	22/39	11/22	A/B
6	8/12		-
7	19/26	9/16	B
8	7/14		-
9	10/12	9/10	B
10	8/16		B
11	9/14	4/11	B
12	15/20		A/B
13	10/13		-
14	10/26	6/12	B

CSFP = mean CSF pressure range during 24-hours-study

Plateau waves = Lundberg's A- or B-waves are indicated

^a Case 4 (CH after subarachnoid hemorrhage) was monitored twice: 2 and 4 months after his bleeding.

2. Intrathecal Infusion Study

Using the lower infusion rate the reaction was determined pathological in 7 out of 14 CH-patients. The quotient of the maximal pressure rise under infusion and the time to achieve maximal CSFP ($= \Delta\text{CSFP}/t$) was calculated as being between 0.7 and 2.6 (Table 2). All patients developed headache, which led to discontinuence of the infusion. In all cases CSFP decreased slowly after the end of infusion. In 7 patients CSFP did not rise constantly under intrathecal infusion. The quotient $\Delta\text{CSFP}/t$ was between 0.3 and 1.0. No patient developed headache or nausea under infusion for maximal 60 minutes. CSFP decreased within 2 minutes after discontinuence of infusion. In these 7 cases the test was regarded as being physiological.

In group II and III no patient developed complications under infusion for 60 minutes. CSFP rose very slowly or reached a plateau where CSFP was kept until end of the study. The quotient $\Delta\text{CSFP}/t$ was between 0.2 and 1.5. After discontinuence of the infusion CSFP decreased within 2 minutes.

Using the higher infusion rate in 6 patients with CH, 5 patients developed headache. 4 out of these 5 cases had a normal response to the lower infusion rate. The sixth case had a normal response to both the lower and the higher infusion rate for 60 minutes. CSFP went down after halting the infusion within 2 minutes. In the 5 cases with pathological reaction of CSFP under infusion at the higher rate the quotient $\Delta\text{CSFP}/t$ increased by 3- to 7-fold. The quotient was between 1.6 and 3.0. In the control groups II and III the quotient $\Delta\text{CSFP}/t$ rose by maximal 3-fold. The absolute value was between 0.3 and 1.0. In one case the quotient decreased.

Table 2. Infusion quotient in CH and controls. The quotient is calculated by the difference between the steady state CSFP and the maximal CSFP under infusion divided by the time to achieve the maximal CSFP

Infusion quotient CSFP/t	Communicating Hydrocephalus		Group II and III		Group II/III
	Infusion rate 0.74 ml/min	Infusion rate 1.47 ml/min	Infusion rate 0.74 ml/min	Infusion rate 1.47 ml/min	
1	0.85	2.4	0.3		III
2	1.0		0.2	0.4	III
3	0.3	1.6	0.9		II
4	2.3		0.4	0.7	II
5	0.82		1.5	1.0	II
6	0.45	2.99	1.2		II
7	2.67		1.0	0.4	II
8	0.4	2.5	0.6	1.0	II
9	1.1		0.3		II
10	0.68	3.0	0.4	1.1	II
11	0.3	0.4	0.4	0.8	II
12	0.7		0.6		II
13	0.7		0.2	0.3	III
14	2.6		0.5		III
			0.3		III
			0.4		III
Mean	1.06	2.1	0.6	0.7	

3. *rCBF* and *rCBV*

Hemispheric CSF was in the CH-group between 27.9 and 58.6 ml/100 g.min. In the 10 patients with presenile dementia it was between 29.7 and 49.2 ml/100 g.min and in the 5 patients with arteriosclerotic dementia between 27.3 and 48.7 ml/100 g.min. It was not possible to differentiate between the groups on the basis of this data, which was calculated for PaCO₂ of 40 mm Hg using hyperventilation or hypercapnia as activation tests prior to the second rCBF-measurement.

The regional distribution of rCBF showed the following pattern: in the CH-group rCBF-valleys with a flow of less than 15% below the hemispheric CSF-value are located predominantly in the frontal, central and parietal area (Fig. 4). The reaction of the vascular system to alteration of blood gases in these areas was reduced, indicated by a reactivity factor ($\frac{\Delta CBF}{PaCO_2}$) of lower than 0.9.

In group II rCBF-valleys appeared over the whole hemisphere, sparing the central areas and the most occipital part of the hemisphere. The reactivity to altered blood gases was reduced but less than in the control group.

In group III rCBF-valleys were located in the frontal area. We did not observe any significant reduction of the blood gas reactivity factor.

The hemispheric CBV is shown in Figure 5. Compared to a control group of 4 normal patients, hCBV is decreased in CH mildly and more in arteriosclerotic dementia. In presenile dementia of type of Alzheimer's disease there is no significant difference compared to the normal individuals.

In 6 patients with CH shunt surgery was performed. The postoperative CBF study in 4 cases showed an increase of hemispheric blood flow in 3 patients (10.5% to 24.4%) with improvement regarding mental condition and gait, and a reduction of CBF in case 14 by 40% 3 weeks after surgery. This patient was at that time only slightly improved in his gait performance. However, at present time (3 months after operation) the family reports a moderate reduced dementia and regained control over the bladder.

The regional distribution of rCBF after shunt surgery is shown in Figure 6 for those 3 patients who presented after surgery an increase of CBF. rCBF improved predominantly in areas with flow-valleys prior to operation.

Cerebral blood volume increased after surgery by 14.5 to 28.6% in 3 cases. In patient 14 postoperative reduction of CBF the blood volume was unchanged.

Discussion

In most of cases, with typical history of subarachnoid hemorrhage, meningitis, trauma or intracranial surgery, the diagnosis of CH is easy to make. The classical clinical symptomatology with progressive or fluctuate dementia, gait disorders, and incontinence of urine is combined with hydrocephalus internus sine externus in the pneumoencephalogram and a pathological CSF scintigram with prolonged ventricular reflux, subarachnoid block and delayed clearance of the tracer. So-called idiopathic CH is sometimes difficult to differentiate on pure clinical grounds from other dementias. In this group, pneumoencephalography and CSF scintigraphy are the most valuable diagnostic tools in establishing the diagnosis (3). Still there remain cases with idiopathic and secondary CH, in which the differentiation from cerebral atrophy is doubtful even using these tests (21).

Furthermore, the improvement of patients with CH by shunt operation reported in the literature, which ranges from about 40% to 60% (3, 14, 17, 2, 20, 21), indicates that selection of patients for shunt therapy needs more tests.

The monitoring of CSFP with CH showed in the majority of our cases a normal pressure while awake. During sleep CSFP rose above 15 mm Hg in some patients. This does not occur in cerebral atrophy or arteriosclerotic dementia. Together with the observation of plateau waves this elevated base line pressure can sustain the diagnosis of CH. However, in case 6, 8, and 13 neither CSFP elevations nor plateau waves occurred. It might be that prolonged recording of CSFP for up to several days, or even a week, is useful in detecting plateau waves. We believe that continuous recording of intracranial pressure in patients with CH is an important diagnostic procedure.

The increased CSFP in some patients and the plateau waves in the majority point to the important role of intracranial pressure for development and preservation of symptomatology of CH.

If CSFP is monitored repeatedly, as in patient 4, it can be noted that an initially increased pressure (acute CH with increased ICP) will disappear or lead to a reduced pressure with occasional plateau waves.

We, therefore, agree with SYMON (22) that elevated ICP in chronic condition of CH plays a dominant role. The intraventricular force which is increased due to enlargement of ventricular area might sustain the clinical picture and prevent reduction of ventricular size even when the pressure is normal (7). The plateau waves might be responsible for progression of the clinical picture. Reduction of ICP by a shunt drainage noted in our patients (Fig. 2) and by others (4, 5) leads to clinical improvement even in some patients without postoperative reduction of ventricular size.

The shunt does equalize the disequilibrium between constant CSF production and impaired absorption in the arachnoid villi. The absorption capacity can be tested by the intrathecal infusion test as proposed by KATZMAN and HUSSEY and HUSSEY et al. (11, 13). Since the use of a needle might lead to extraarachnoidal infusion we perform this test only by infusion through the above mentioned polyethylene catheter. All patients of group II and III tolerated the procedure well at the lower infusion rate, whereas 7 out of 14 cases with CH showed an abnormal reaction. With the doubled rate we observed only one out of six cases which tolerated the procedure. The infusion quotient in this patient was lower than 1.0. In the control group only one out of 8 patients has had an infusion quotient which was higher than 1.0 (Table 2). Still, some of the control patients developed headache and nausea after some time. We suppose that in our controls the absorption capacity at this rate is exhausted after this period, and that in CH usually the capacity is more diminished. We do not know for how long healthy individuals can tolerate this infusion rate, but KATZMAN reported that some of his normal patients did not develop complications at an infusion rate 6 to 8-fold higher than the physiological CSF production rate (0.3 to 0.6 ml/min).

Since the mean infusion quotient of both groups at the lower and at the higher rate are quite different we believe that reduction of absorption capacity is important for the development of chronic CH. With the infusion test - if properly performed - the majority of patients with CH can be differentiated from other dementias. Since some patients with CH present a normal reaction to the infusion at both rates, (case 11) and since some patients with cerebral atrophy show a deficient absorption to doubled infusion rate, both continuous monitoring and observation of CSFP under infusion have to be performed. They do not replace each other.

We agree with WOLINSKY et al. that selection for shunt surgery should be done only after having performed several tests (23). We would not recommend surgery in patients who have clinical symptoms of CH but do present a normal CSFP, no plateau waves and a normal response to intrathecal infusion at both rates. For this reason, shunt surgery in patients only with Alzheimer disease is not indicated. It has to be clarified in this group whether there is in medical history any disease leading to CH of secondary type. If the idiopathic type of CH is combined with the presenile atrophy in this special individuum this have to be proven by monitoring of intracranial pressure and the intrathecal infusion test. From the theoretical point of view a reduced capacity of the villi to transfer CSF into the blood is imaginable in cases with neuronal atrophy of unknown cause (malabsorption hydrocephalus).

rCBF and rCBV studies probably are not helpful in establishing the diagnosis of CH or presenile dementia. However, they provide some useful insight into the pathophysiological formation of the complex. The principle of shunting patients with CH is to increase CBF by reducing ICP (16, 19). Particularly, the brain with inhibited autoregu-

lation is susceptible to alteration of ICP even in low ranges. Since CBF in our patients was decreased prior to surgery in some areas, and since CSFP increased occasionally, these regions might suffer from further relative ischemia. In some patients the reduction of rCBF by increased CSFP (which is identical to a reduced perfusion pressure if autoregulation is damaged) might lead to irreversible tissue damage. However, we observed in 3 out of 4 shunted and remeasured patients an increase of CBF after shunt procedure. This was accompanied by a clinical improvement. Like INGVAR et al. (12) we recorded the preoperative reduction of CBF in particular areas which might correlate well with clinical symptoms. CH might be due to relative ischemia in areas supported by branches of stretched cerebral vessels. The distortion is due to dilated ventricles and/or increased ICP. Postoperatively the vessels can dilate again indicated by increase of CBF and CBV, thus restoring neuronal function (18).

Summary

Continuous monitoring of cerebrospinal fluid pressure, control of cerebrospinal fluid pressure during intrathecal infusion of normal saline, regional cerebral blood flow and regional cerebral blood volume have been measured in patients with chronic communicating hydrocephalus, Alzheimer's disease and arteriosclerotic dementia. Pressure elevations, plateau waves, and abnormal response to intrathecal infusion occurred more in patients with communicating hydrocephalus than in others. Cerebral blood flow and -volume was prior to shunt surgery reduced and increased in some patients after operation. It is believed that temporarily increased intracranial pressure and depression of blood flow are the major factors sustaining the clinical picture of communicating hydrocephalus.

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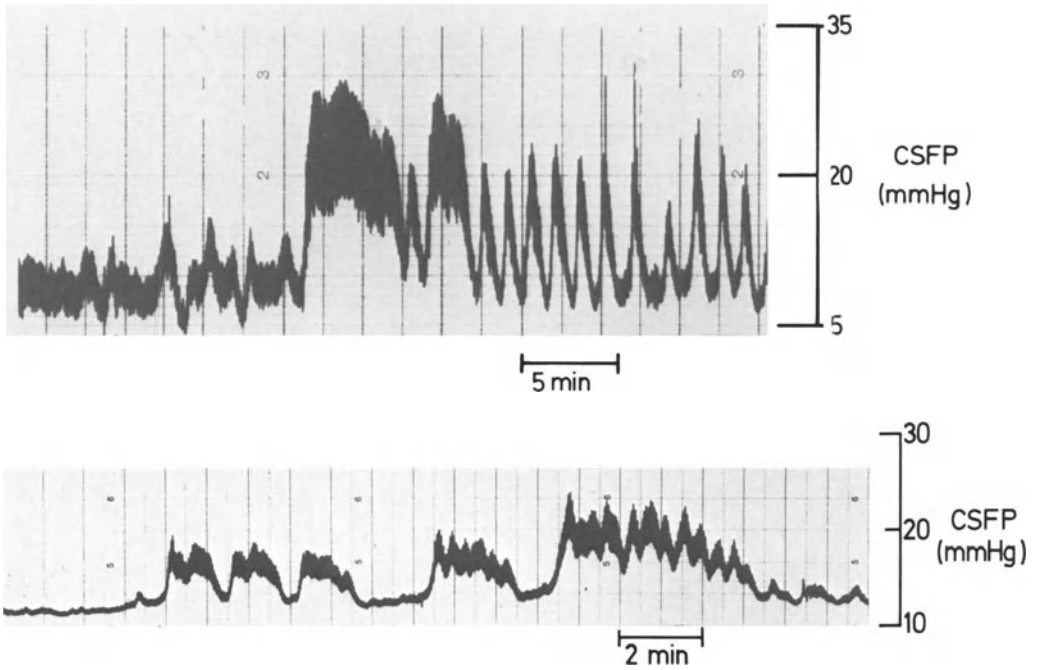


Fig. 1. Plateau waves in CH. The upper figure shows respiration-dependent B-waves, which increase slowly and decrease fast. The A-waves increase fast, keep their level for several minutes and decrease fast. They are not in correlation to the respiration. The lower figure indicates respiration-independent small plateau waves which were more often observed than A- or B-waves

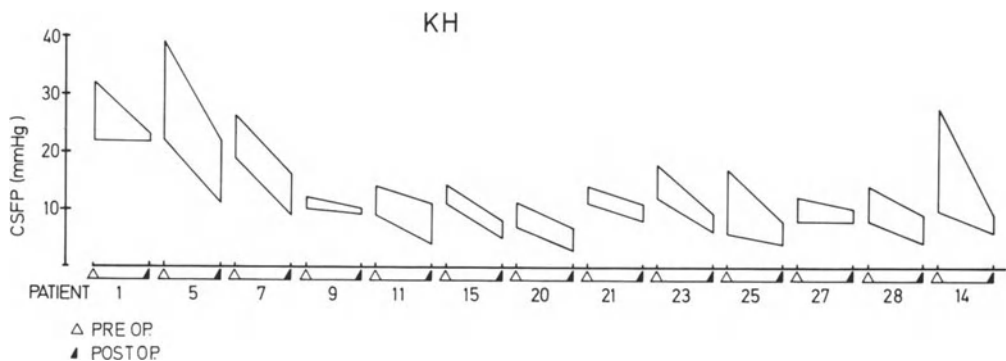


Fig. 2. Schematic drawing of pre- and postoperative CSFP in patients with chronic CH, who were shunted during the time of our studies about CH. Patient 1, 5, 7, 9, 11, and 14 are presented in this communication. Empty triangles = CSFP prior to surgery
Black triangles = CSFP after surgery

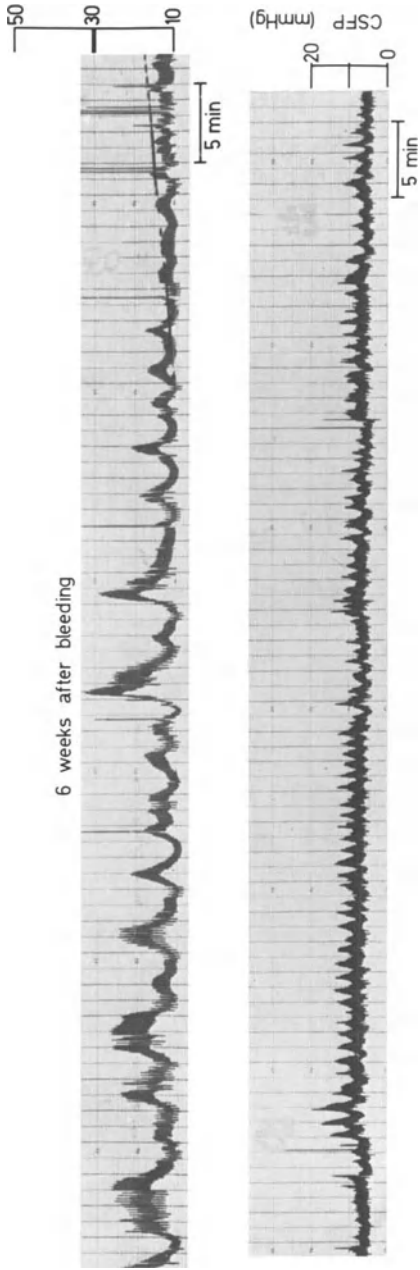


Fig. 3. Pre- and postoperative CSFP monitoring in case 14. Plateau waves disappear after surgery or become considerably smaller and shorter. Above: before shunt surgery; below: after shunt surgery

		41	32	31		
34	32	37	39	37	36	29
38	40	39	40	31	42	30
43	43	36	42	38	44	35
45	46	46	44	43	39	
		42	42	44	46	

Fig. 4. rCBF distribution in patient 5 (tuberculous meningitis). Lowest values (valleys) were recorded in the frontal, parietal and central areas. CBF increased after operation by 24.4%, blood volume by 28.6%. CBF = 39 ml/100 g.min; PaCO₂ = 31.1 mm Hg

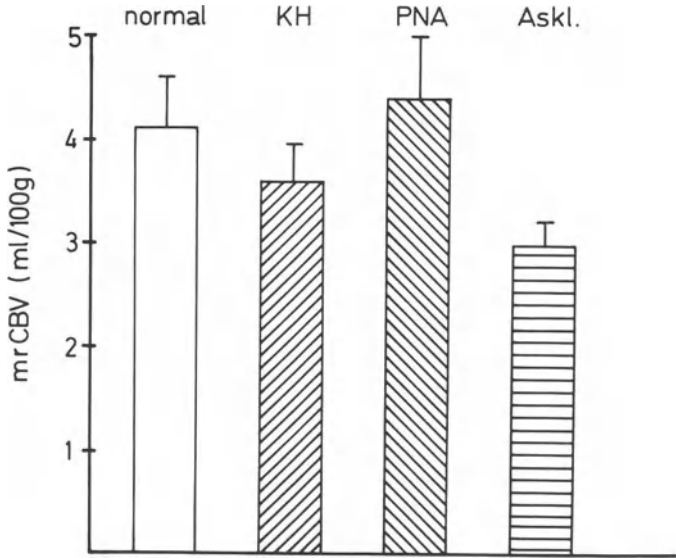


Fig. 5. Hemispheric cerebral blood volume in normal patients (4), communicating hydrocephalus (KH), cerebral atrophy (PNA), and arteriosclerotic dementia (Askl)

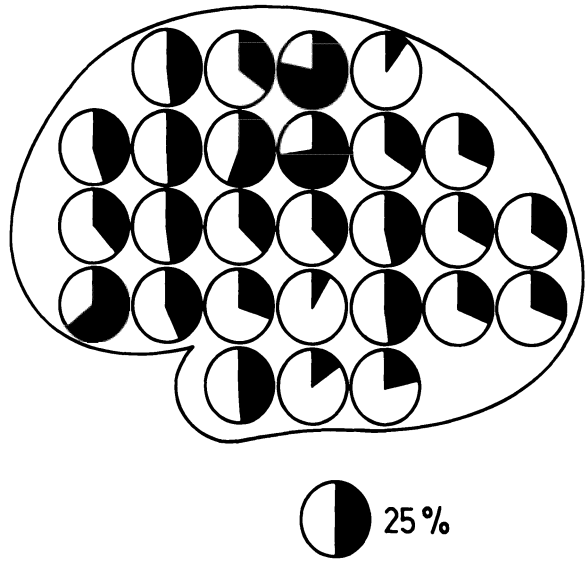


Fig. 6. Regional change of rCBF after shunt-operation. The change is indicated in percentage. This figure includes the data obtained from 3 patients who improved by surgery regarding clinical symptoms and blood flow

Acute Intracranial Volume Fluctuation

E. C. FUCHS

Introduction

Intracranial pressure (ICP) was measured continuously for several days in patients in whom low pressure or normal pressure Hydrocephalus was suspected. Against all expectations, increases of pressure up to 30 or even 40 mm Hg were recorded, especially at night (SYMON). The pressure waves could be recorded for several minutes at a time before they disappeared spontaneously. REM phases concurrent with the pressure increases were recorded for several minutes with electroencephalogram (MAIRA). Measurements of cerebral circulation indicate that circulation does not follow this phased pattern (RISBERG).

Many clinicians, using the method suggested by LUNDBERG, measure (ICP) with an intraventricular catheter. We have modified this procedure to allow drainage of cerebrospinal fluid with simultaneous quantitative measurement of the amount of drained fluid.

Method

An intraventricular catheter is implanted in the usual way through a right frontal burr hole in patients in whom either diagnostic ICP measurement or therapeutic fluid drainage is indicated. The catheter ends in a 4-way valve which allows closed pressure measurement through a Statham element with amplifier as well as simultaneous fluid drainage in a sterile system after CORDIS. We set the maximum measurable pressure equal to pressure in the outlet branch of the drain (Fig. 1). If intracranial pressure exceeds this predetermined pressure in the outlet, then fluid is pressed out through the drain. Pressure in the outlet of the drain is set according to the condition under treatment. For example, a child with a tumor of the posterior fossa and with corresponding symptoms of occlusion would receive an overflow drain set at 42 cm (equivalent to a pressure of 30 mm Hg) or higher, 24 hours preoperatively. The drain would be set at 15 cm (equivalent to 11 mm Hg) or less for a patient in whom low pressure hydrocephalus is suspected. If this pressure is exceeded, the drain fluid is registered electronically by a photo cell and recorded graphically on an apparatus with a paper speed of 6 cm/hour (Fig. 2).

Results

Surprisingly, the volume of drained fluid has shown a distinct day and night rhythm in almost all of the patients that we have examined with this method (n = 14). We had previously recorded almost linear fluid volume measurements by registering volume at one hour or two hour intervals (FUCHS). Recordings at five minute intervals registered fluctuations in the amount of drained fluid which indicate that short

phases of increased drainage, followed by phases without drainage, occur intermittently during the night. Such intermittent courses can be found in patients with low pressure hydrocephalus, and we conclude that fluid reabsorption is disturbed in altered arachnoid villi (Fig. 3). However, the same phenomenon is present in patients in whom fluid circulation is disturbed by midline tumors or tumors of the posterior fossa. Distinct quantitative differences are evident in these two, basically different conditions.

Discussion

There are two possible interpretations for these curves.

1. There could be fluctuations in fluid production, in which phases of high production alternate with periods of little or no production, especially at night. This explanation seems highly improbable to us, since studies have demonstrated that fluid production is relatively constant under normal conditions, though it can be influenced by medication (DAVSON). We define normal conditions as undisturbed autoregulation and a normal blood pressure range between 80 and 140 mm Hg. In any case, blood pressure fluctuation was never observed in our patients during these phases, and the outflow pressure was kept at a constant level.

2. It seems more probable to us that fluctuation in the measured volume of drained fluid is an indirect sign of intracranial volume fluctuation. The arterial and venous blood vessels would be the most likely source of fluctuation. If one assumes that RISBERG's blood flow measurements in fact demonstrate increases in total blood flow at the peaks of the pressure curves - while cerebral circulation remains constant, then one could explain an increase in volume as an enlargement of arterial diameter (LUNDBERG). We have measured fluctuations of 10 to 30 ml. Since the standard value for intracranial blood volume is about 150 ml, this would correspond to fluctuation of up to 20% of total intracranial blood volume.

Patients with low pressure hydrocephalus seem to suffer primarily from a disturbance in the buffer mechanism of the arachnoid villi. Coughing can provoke considerable intracranial pressure fluctuation of several minutes' duration in these patients (Fig. 4). This increase in intracranial pressure is caused by increased pressure in the venous system and is usually compensated within minutes by increased fluid reabsorption in the arachnoid villi (Fig. 5). Under pathological conditions, the CSF of these patients cannot be adequately buffered, and an increase in intracranial pressure can be registered for a period of several minutes. Similar mechanisms could explain the reported volume fluctuations. However, the cause of this sudden cerebral vasodilation remains unknown.

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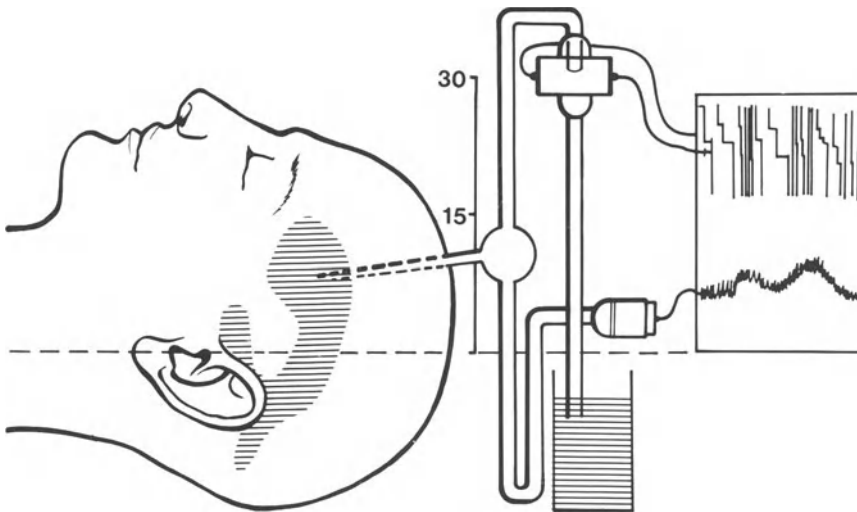


Fig. 1. The illustration demonstrates the basic principle of our method. The overflow drain is set at 30 cm. Lower pressures are registered by a Statham element. Higher pressures are "registered" as drained CSF, which is measured with a photo cell

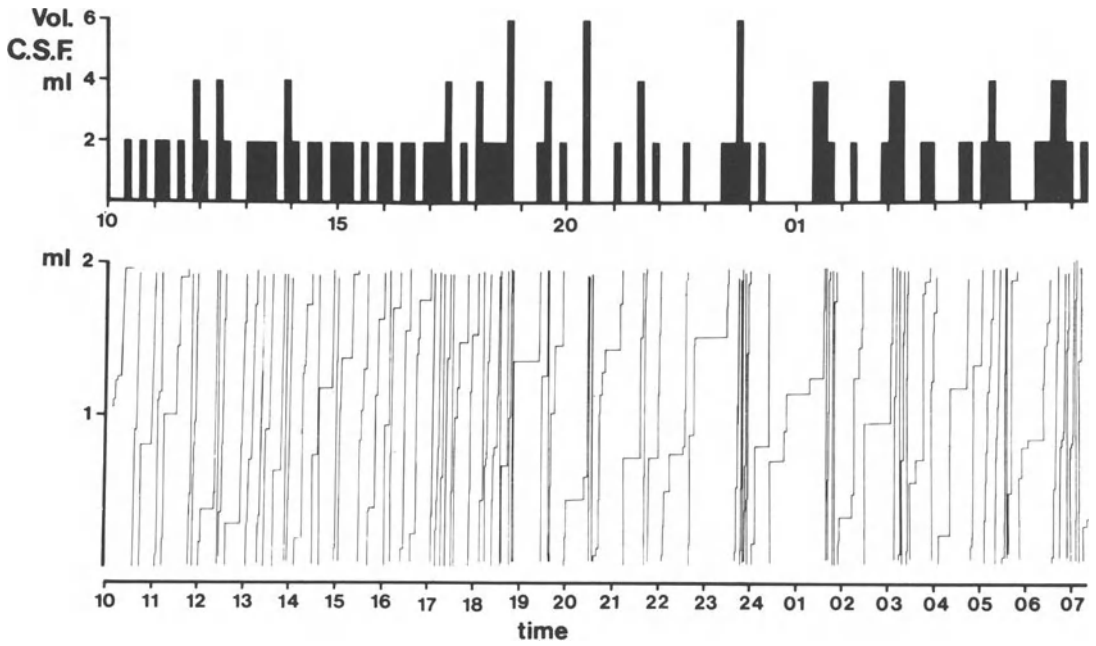


Fig. 2. Original registration of drained CSF as well as quantitative evaluation for 10 minute intervals

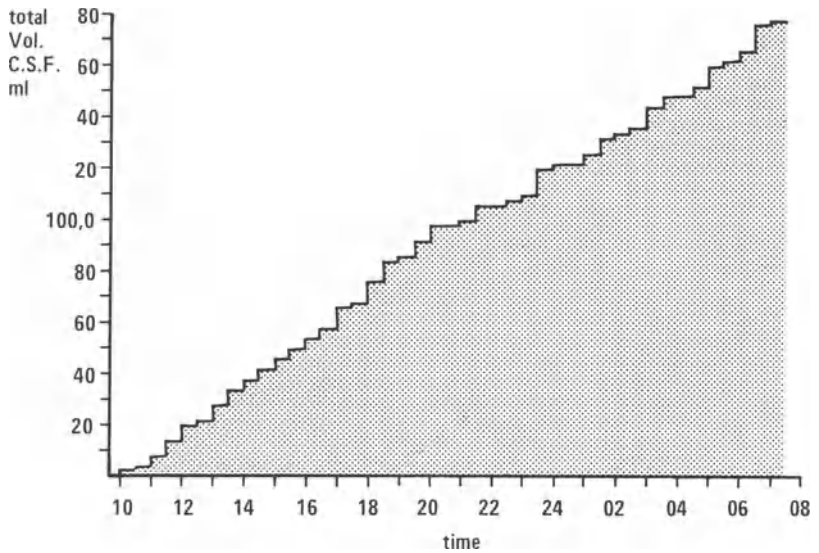


Fig. 3. Quantitative measurement at 15 minute intervals shows a day and night rhythm. A change in the width and height of the individual steps is characteristic of the night rhythm

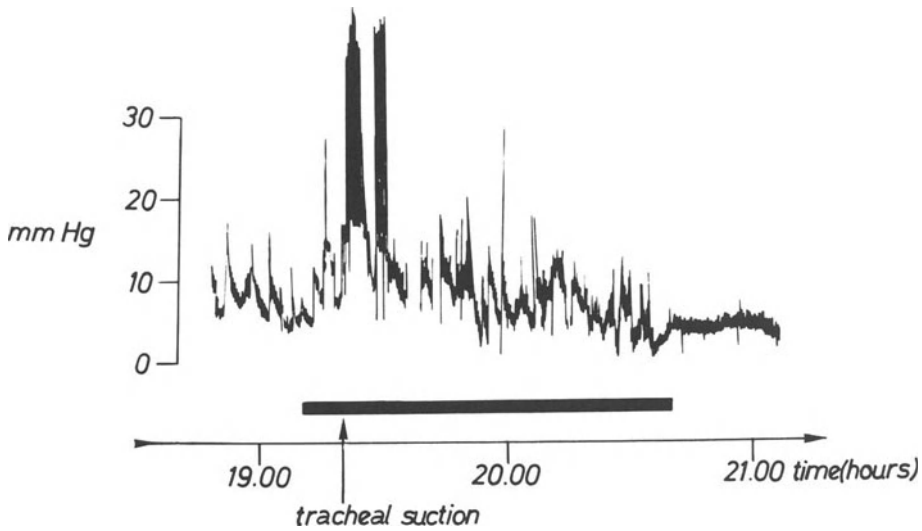


Fig. 4. Registration of intraventricular pressure with the LUNDBERG method in a patient with low pressure hydrocephalus. Simple tracheal suction led to continuous pressure increases significantly above 30 mm Hg in this patient

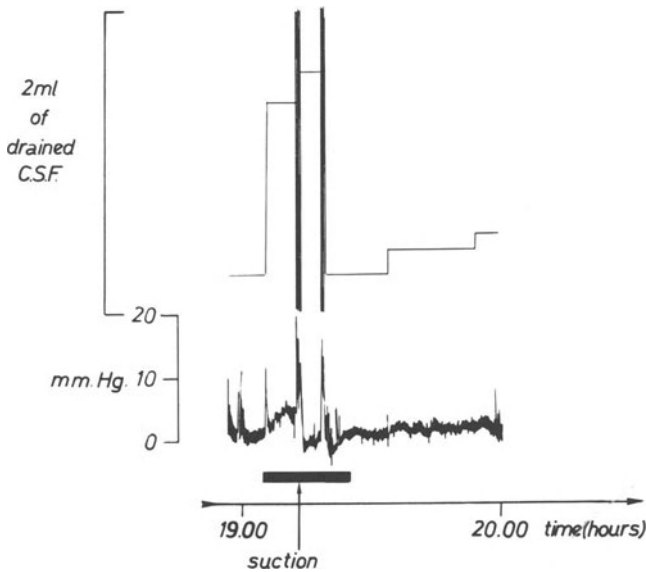


Fig. 5. If the outlet of the CSF drain is set at about 14 cm (≈ 10 mm Hg) in a patient with low pressure hydrocephalus, the pathological increase in cerebral pressure which accompanies tracheal suction is buffered by drainage of 10 ml of CSF. Of course spontaneous increases in cerebral pressure are also prevented through use of this method

Pre-and Postoperative Evaluation of Hydrocephalus Using the Infusion Test

CH. SPRUNG, H. COLLMANN, E. C. FUCHS, S. SUWITO, and R. DUISBERG

We evaluated the validity of the constant-infusion manometric test for the diagnosis of normotensive hydrocephalus. In 1970 KATZMAN and HUSSEY introduced the constant infusion manometric test as a diagnostic criterion. In recent years, however, there have been sceptic reports about the relevance of this test for the diagnosis of NPH and for its surgical prognosis (1, 5). We compared the reliability of the constant infusion manometric test and its value in the prognosis of shunting results to other diagnostic examinations.

Method

We applied the examination technique described by KATZMAN and HUSSEY (3, 4). A standard lumbar puncture is performed using a 18 gauge spinal needle with the sedated patient in lateral position. A 0.9% sodium chloride solution is infused at a constant rate of 0.75 ml/min. The hub of the needle is attached to a three-way stopcock and connected to a pressure transducer in order to obtain a closed sterile system for infusion and constant recording of the pressure-time curves.

The classification of normal and abnormal curves was carried out following the criteria given by KATZMAN and HUSSEY. A slight increase and plateauing of the pressure response below 300 mm H₂O corresponding to 22 mm Hg has been classified as normal (Fig. 1).

A rise in pressure above 22 mm is thought to reflect an impaired CSF absorption capacity and is considered as pathological (Fig. 2).

Results

The subarachnoid infusion test was performed on 55 patients suspected of suffering from normotensive hydrocephalus on the basis of clinical symptoms and pneumoencephalography. Additionally, an isotope cisternography was attempted on 85% of the patients.¹

The evaluation regarding the reliability of our test was based on the long term clinical course of all 53 patients. A comparison of infusion test and isotope cisternography is shown in Table 1. In about 25% of all cases false results, either false positive or false negative, are obtained from both methods. However, the infusion test provides at least as reliable data as the isotope cisternography.

¹ The authors thank Prof. Haubold, Divisions of Nuclear Medicine, Free University, Berlin, Klinikum Charlottenburg, for performing the isotope cisternography.

Table 1. Reliability

Infusion test		Isotope cisternography	
Correct pos.	25%	36%	
Correct neg.	53%	36%	
	78%	72%	
False pos.	15%		27%
False neg.	7%		1%
	22%		28%

Table 2. Value in the prognosis

No.	Name	Inf. Test	Isotope Cistern.	Pneumo enc.	Neurol. status	Shunting Results
1	I.G.	+	+	+	+	+
2	H.T.	+	+	+	+	+
3	H.M.	+	+	+	+	+
4	V.M.	+	+	+	+	+
5	J.R.	+	+	+	+	+
6	W.B.	+	+	+	+	+
7	J.K.	+	+	+	+	+
8	M.E.	+	(+)	+	+	+
9	K.P.	+	+	+	(+)	+
10	E.R.	-	+	+	+	+
11	E.K.	-	-	+	+	+
12	E.S.	-	+	+	-	+
13	F.P.	+	+	(+)	+	(+)
14	M.S.	+	+	-	+	(+)
15	B.P.	+	(+)	+	-	(+)
16	U.B.	-	+	+	(-)	(-)
17	C.S.	+	-	+	-	(-)
18	R.H.	-	+	(+)	-	(-)
19	R.R.	-	-	+	-	(-)
20	H.L.	-	+	+	-	-
21	K.L.	-	+	(-)	-	-
Prediction correct/		17/4	16/5	15/6	17/4	
false						

Taking both tests into consideration, we selected only 21 of the 53 patients provisionally regarded as normotensive hydrocephalus for surgical treatment, i.e. 40%.

The main purpose of this evaluation is to obtain information on the value of the infusion test in the prognosis of the surgical result compared to other examinations (Table 2). The column on the right shows the surgical results following the insertion of a Holter ventriculo-caval shunt. 15 of the 21 patients showed benefit from CSF shunting, i.e. 70%. 12 patients showed excellent improvement, 3 only moderately improved. There was no definite positive effect in four cases, and further downhill course was seen in two patients. In the two groups with positive surgical results the infusion test turned out non-pathological in three cases, i.e. false negative concerning the outcome of the operation. In the group of patients with inferior results one test has to be considered false positive. This means, that in 4 cases

a false prediction was obtained from the infusion test, in 17 patients the prognostic indication was correct. The isotope cisternography showed about the same ratio of correct and false predictions.

Furthermore, we conclude from Table 2, that a reliable surgical prognosis cannot be obtained from a single examination. Only patients, fulfilling the major diagnostic criteria, should be shunted.

In 4 patients, the postoperative improvement was only moderate. To check the doubtful functioning of the shunt, the infusion test was repeated. Contrary to the preoperative state the increase of the CSF pressure remained within normal values. Using the criteria of WOOD-FORD et al. (8), shunt patency could be established.

We were confronted with the following difficulties and disadvantages of the infusion test.

1. The interpretation of the test is very difficult, especially in a borderline abnormal pressure curve, if the patient becomes restless. Therefore, in our opinion, sedation is absolutely necessary.
2. The performance of the test requires a strict aseptic technique.
3. We agree with TROTTER and WOLINSKY (6, 7) that a leakage of CSF from a prior dural puncture is most often the reason for a false negative response of the pressure curve. Therefore, the infusion test should be performed at the first lumbar puncture, or delayed two weeks after a prior puncture.

At present we evaluate the combination of the infusion test with computer assisted tomography of cerebrospinal fluid introduced by GREITZ and collaborators (2). With this method we hope to substitute the isotope cisternography and shorten the diagnostic procedure of the normal pressure hydrocephalus.

We have a second study going on, in which a modified intraventricular infusion test is applied to postoperative children with chronic hydrocephalus and suspected shunt failure. Our method provides valuable information about the shunt patency, but what is more important in these cases is the activity of the hydrocephalus, i.e. its shunt dependency.

This modified test is performed by means of a percutaneous puncture of the Rickham-reservoir. The ventricular fluid pressure (VFP) is then continuously monitored during simultaneous infusion of saline, according to the lumbar test outlines.

Different pressure curves of typical shape have been observed:

- A) Provided an intact shunting system, the infusion causes only a slight increase of VFP followed by a plateau, the level of which depends on the flow rate-pressure relationship of the implanted valve.
- B) In cases of an obstructed cardiac catheter we have observed three different VFP patterns indicating an altered CSF absorption capacity:
 1. A gradual increase of VFP without formation of a plateau or followed by one on a high level, as observed in the already mentioned lumbar test;
 2. a sharp increase of pressure during infusion, without normalisation after infusion stop;
 3. a sharp increase in the VFP during infusion, followed by further critical increase.

Some typical patterns may be illustrated by the pressure curve of a 2-year old girl, operated on for occlusive hydrocephalus at the age of 6 months. The girl was admitted under suspicion of increased intracranial pressure, which, however, could not be confirmed by clinical examination or by computerized tomography. The valve could not be clearly judged either.

The recording of VFP (Fig. 3) showed a moderately elevated resting pressure. The patency of the shunting system seemed to be proved through a prompt response to jugular compression (J) and a slight fall in pressure following manual compression (P) of the valve. The infusion of about 3 ml saline produced a critical increase of VFP. A return to the resting value seemed to be conditioned by squeezing the valve chamber. The repeated test produced a similar response of VFP, which, however, in this second instance returned to the resting level spontaneously.

With respect to the clinical improvement an immediate shunt revision was not believed necessary. However, a few days later, signs of decompensating intracranial pressure forced us to reoperate, and the partial obstruction of the venous catheter was proved. A new postoperative infusion test was found normal.

Our method seems to provide new data on the mechanisms interacting in the so-called "Compensated Hydrocephalus", although further experience is necessary to establish more exact criteria, in order to determine the shunt dependency in cases of childhood hydrocephalus.

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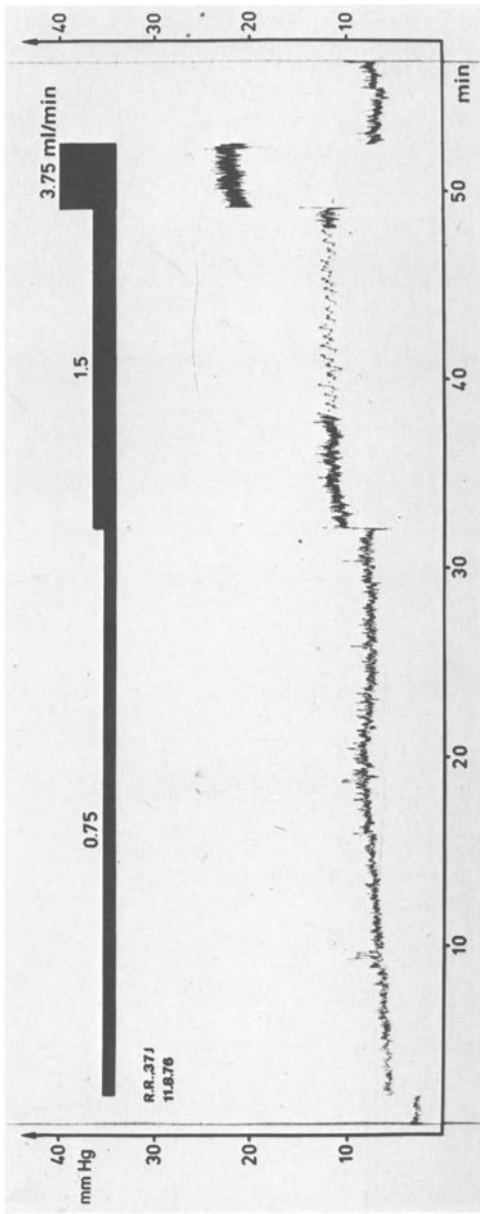


Fig. 1. Example of normal pressure responses (case 19). At 0.75-cc.-per-min infusion rate the pressure-time curve shows a slow steady rise and plateauing after 20 minutes of infusion. At increasing rates of infusion there is no progressive increase in slope. The stepwise rise after onset of the more rapid rates of infusion is caused by the resistance factors in the pump-tubing-needle system

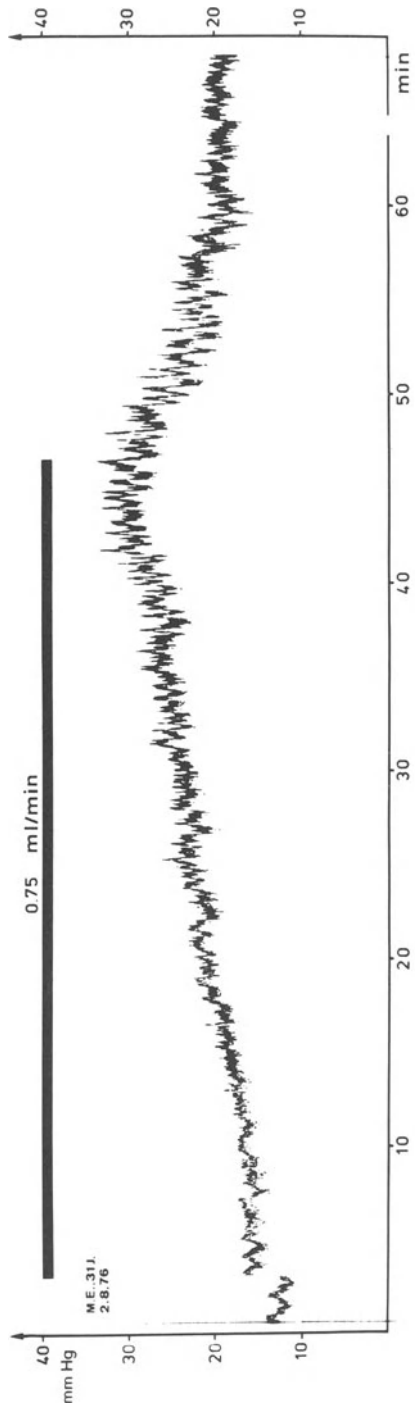


Fig. 2. Typical pathological pressure response (case 8). Continuous increase of pressure above 22 mm Hg without plateauing

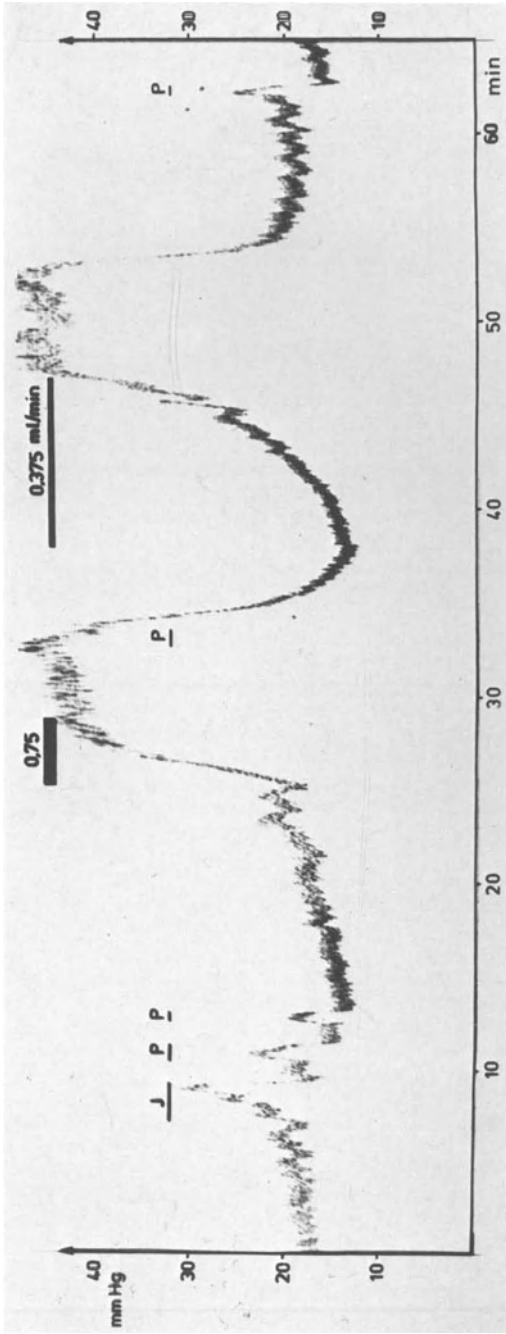


Fig. 3. Child with chronic occlusive hydrocephalus and shunt failure. Note the critical elevation of ventricular fluid pressure caused by intraventricular infusion

Long-Term Measurements of the Intraventricular Pressure in Patients with Normal-Pressure Hydrocephalus

P. GRUSS, A. KROISS, M. GAAB, and U. FUHRMEISTER

Introduction

The syndrome of normal-pressure hydrocephalus, termed "active hydrocephalus" by UMBACH (1971), is characterized by the appearance of certain symptoms, mostly in the very old. Decrease in efficiency with general weakness, signs of forgetfulness, disturbances of memory and concentration, orientation disorders, states of confusion and finally pareses with slight spasticity in the limbs (especially the lower limbs) are most frequent. Urinary incontinence and even syndromes resembling Parkinsonism are also seen (HAKIM 1964 and 1965, ADAMS et al. 1965).

Since such disorders occur frequently in older people (generally due to cerebral vascular damage), the diagnosis of normal-pressure hydrocephalus requires further precise investigations. The condition must be regarded as a disorder of CSF circulation and is by no means inaccessible to therapy. This applies especially since forms of hydrocephalus are frequently seen after inflammatory brain trauma, subarachnoid hemorrhages and more rarely after inflammatory cerebral processes. These likewise show normal CSF pressures when measured, but disturbances of CSF circulation are also present. Air encephalography (recently also computer tomography to an increasing extent) permits an assessment of the size and configuration of the CSF spaces. If the following criteria are observed, then one can speak of a normal-pressure hydrocephalus: widening and rounding of the ventricles, especially in the frontal region, possibly a reduction of the corpus callosum angle, sometimes a weak subarachnoid filling. However, diagnosis of the processes of brain atrophy remains highly uncertain. Thus BEL-LONI et al. 1976 have listed in their cases with normal-pressure hydrocephalus, patients without such a subarachnoid filling and patients with a strong air filling of the subarachnoid spaces.

The question arises as to whether one should resort to treatment measures to alter the CSF circulation, by means of a shunt operation. Methods which only reveal a static picture of the CSF system (air encephalography, maybe computer tomography) are by no means sufficient as information on the disturbed dynamics of the CSF system is required. Besides CSF diagnosis with a radioactive labelled substance the metabolic behavior of which can be studied in the CSF system, continuous measurement of the intraventricular pressure is a highly informative method.

Materials and Methods

The patient must first be given a thorough explanation of the method and rationale of the measurement. A frontal borehole is made, mostly under local anesthesia. The anterior horn of the lateral ventricle is

punctured with a Holter catheter and connected with a Rickham capsule situated in the borehole. After closure of the wound, the Rickham capsule is punctured with a thin disposable cannula. Then a STATHAM element is connected. This is linked with an instrument for registering pressure (Hellige Co., Freiburg). Zero-point calibration of the instrument is carried out before the measurement. The patient is monitored during the measurement. Disturbance factors (eating, defecation, coughing etc.) are recorded to exclude artefacts. The multipen recorder is generally run slowly: speed of writing about 12 cm per hour.

Results

The method described permits long-term observations and recording of the intraventricular pressure (brief fluctuations in pressure are thereby not overlooked). It is possible to measure the pressure under specific conditions (exercise test, resorption test).

Measurements were performed on patients who were awake and orientated. The CSF pressure level was normal or only slightly raised in all patients in whom a single measurement was made. There were forms of hydrocephalus after trauma, after subarachnoid hemorrhages, after inflammatory diseases of the CNS or after operations, as well as active hydrocephalus. In addition, we investigated syringomyelia patients.

Special attention is drawn to the results in patients with active hydrocephalus, which was in fact originally designated as normal-pressure hydrocephalus (HAKIM 1964 and 1965, ADAMS et al. 1965).

Of seven patients investigated, we saw curves of CSF pressure which are to be designated pathological only in six cases; complexes of several short-lived rises in CSF pressure were noticeable, mostly occurring at intervals of a few hours. The pressure rises lasted several minutes and had an amplitude of 10 mm Hg and more (see Figs. 1 and 2, upper pressure curve). Isolated rises in pressure in a course which was overall unsettled were also seen (but more rarely). These were evaluated as pathological (Fig. 2, middle curve).

As a rule, the CSF pressure complexes described lasted about 30 minutes. We observed this phenomenon in all six of our classical normal-pressure hydrocephalus patients exhibiting active hydrocephalus. However, quite similar changes were seen in patients with hydrocephalus after dreams, after operations, after subarachnoid hemorrhages and also in some of the syringomyelia patients we investigated. Figure 3 (upper curve) shows the curve of CSF pressure of a 56-year-old woman patient with a severe syringomyelia syndrome; here we saw two complexes of numerous pressure rises lasting several minutes and with an amplitude from 5 mm Hg to over 10 mm Hg. The duration of a complex of 10 - 15 such pressure rises was once more a 1/2 hour.

Only in one case of severe active hydrocephalus (Fig. 4a shows the ventricular filling of the patient) did we see a normal and smooth pressure curve (Fig. 4b, upper curve) with a strikingly low total pressure level. In this woman patient, a resorption test was carried out. NaCl solution was infused lumbar and intraventricularly. In our opinion, the expected rises in pressure occurred too slowly and were not high enough. This assertion is naturally made with slight reservations, since we lack certain normal pressure curves.

In the Risa investigation, which was also carried out in five of the classic normal pressure hydrocephalus cases, a pathological findings was shown four times. The resorption occurred too slowly and the con-

trast medium dwelled too long in the ventricle in two cases and once only slightly passed the cranio-cervical transition region. We could not discern a relation between certain properties of the CSF pressure curves and the findings in the Risa investigation, especially in view of the low number of cases with classical normal-pressure hydrocephalus.

Discussion

In all patients with appropriate anamnesis and clinical data and who show enlarged ventricles, our findings show that diagnostic procedures should be carried out to gain information on the dynamics of the CSF circulation. Besides isotope diagnostics (Risa), continuous measurement of CSF pressure is certainly an excellent method enabling the indications for shunt operation to be determined. If pressure fluctuations or CSF pressure rises are found, then shunt is indicated since it enables these irregularities to be eliminated in almost all cases. Fig. 2 shows, in the lower curve, the absence of any more pressure rises after shunt operation, just as in the lowest curve in Fig. 3 in the female syringomyelia patient. The pressure rises which we observed most frequently corresponded in their frequency to the "1 per minute waves" designated by LUNDBERG (1960) as B waves, but their amplitude is lower (Fig. 1 and Fig. 2 upper curve); this may be connected with the severity of the disease manifestations, as LUNDBERG primarily studied patients with substantially raised intracranial pressure (see also MERREM 1971).

A clinical improvement occurred in most of our patients, even if sometimes only slight and threatened by relapses. In many corresponding cases, MATHEW et al. 1975 saw an improvement in the cerebral blood flow after shunt operation.

The present results suggest that the term normal-pressure hydrocephalus should be employed as little as possible (see also GRUSS 1973). We saw a "normal CSF pressure curve", i.e. a curve with a low overall pressure level and without pathological pressure rises (Fig. 4b) in only one case with corresponding symptoms (Fig. 4a). However, even in this case a loading test of the CSF system and a resorption test were pathological and the disorder of the CSF circulation obviously proved a disproportion between CSF production and CSF resorption.

Summary

Continuous measurements of the intraventricular CSF pressure in patients with normal-pressure hydrocephalus are reported. The classical normal-pressure hydrocephalus, termed active hydrocephalus by UMBACH and characterized by progressive dementia and various neurological disorders, was the main condition treated. We found pathological CSF pressure curves in all patients investigated apart from one; the overall pressure level was normal, but there were complexes of several short-lived pressure rises with an amplitude of 5 to 10 mm Hg and (in rare cases) also isolated pressure peaks. We saw quite similar changes in the course of CSF pressure in numerous patients investigated with hydrocephalus after trauma, subarachnoid bleeding after operations, more rarely after inflammatory cerebral processes, and also in patients with severe syringomyelia syndrome.

As a rule, the alterations in the pressure curves could be eliminated by a shunt. There was often a slight clinical improvement more rarely a marked improvement. We recommend that the term "normal-pressure

hydrocephalus" should if possible not be used, but the "CSF circulation disorder" should be characterized etiologically.

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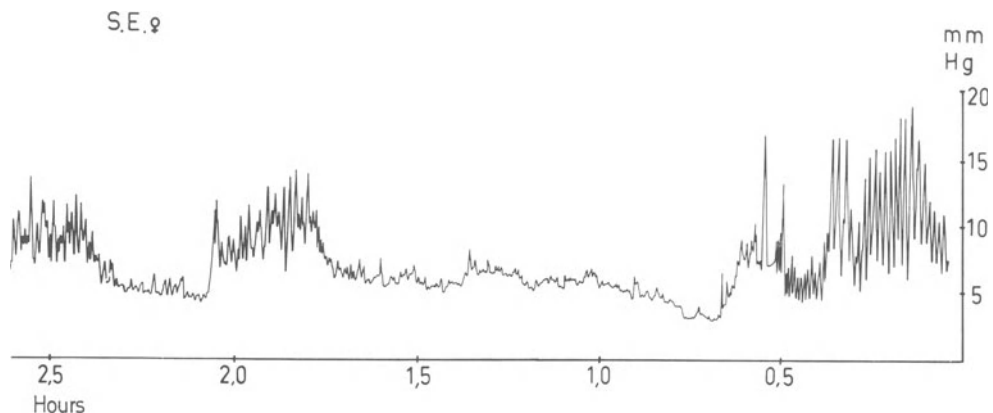


Fig. 1. CSF pressure curve of a 47-year-old woman with normal-pressure hydrocephalus, active hydrocephalus. Two complex short-lived rises in CSF pressure of a good 5 to over 10 mm Hg. A complex exhibiting about 10 pressure rises lasts about 20 - 25 minutes

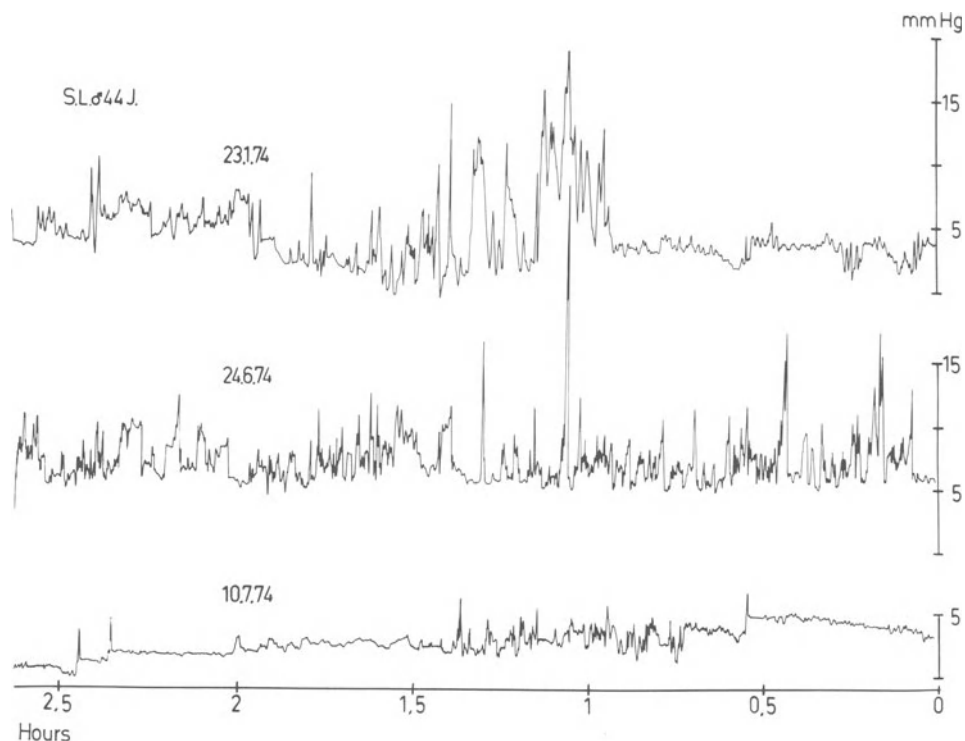


Fig. 2. CSF pressure curve of a 44-year-old man with normal-pressure hydrocephalus, active hydrocephalus. Known misuse of alcohol, otherwise unremarkable anamnesis. In the upper curve, a rather irregularly shaped complex of short and also rather longer lasting pressure fluctuations about 10 mm Hg in height. In the lower curve, which appears irregular as a whole, there are numerous peaks of short duration, amplitude a good 5 mm Hg. The two large peaks in the middle of the curve are artefacts. In the lowest curve, pressure measurement after shunt operation

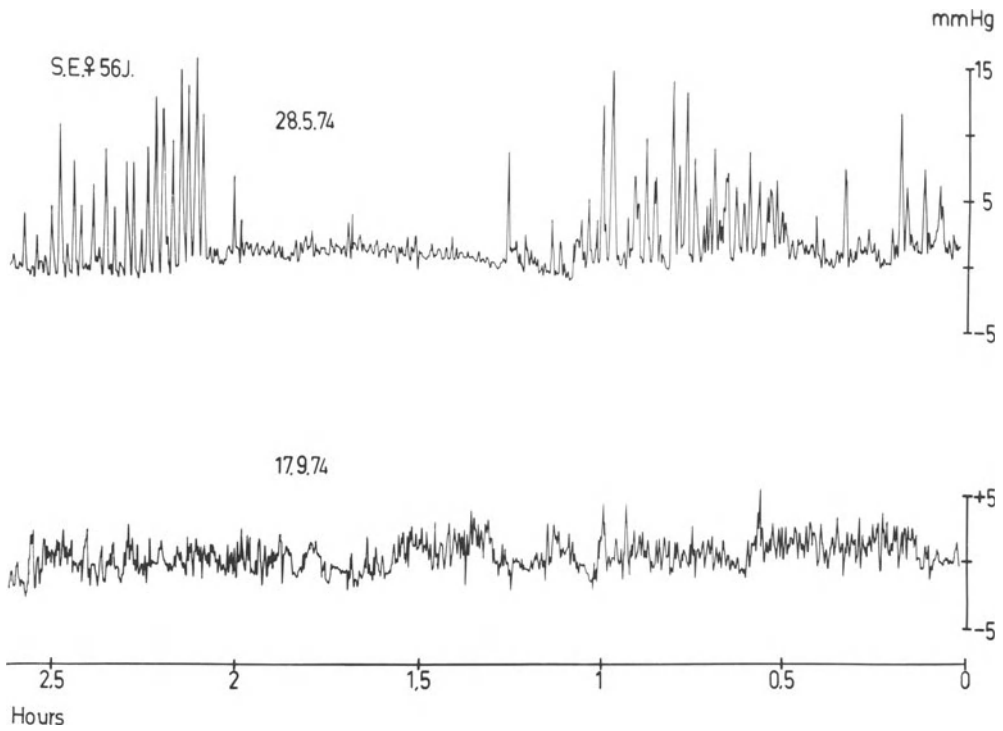


Fig. 3. Woman with severe syringomyelia syndrome, 56 years old, decade-long anamnesis. In the upper curve, two complexes of short-lived pressure fluctuations of a good 5 to over 10 mm Hg, varying amplitude. On the right of the picture, also a few single pressure rises. Lower curve, condition after shunt operation

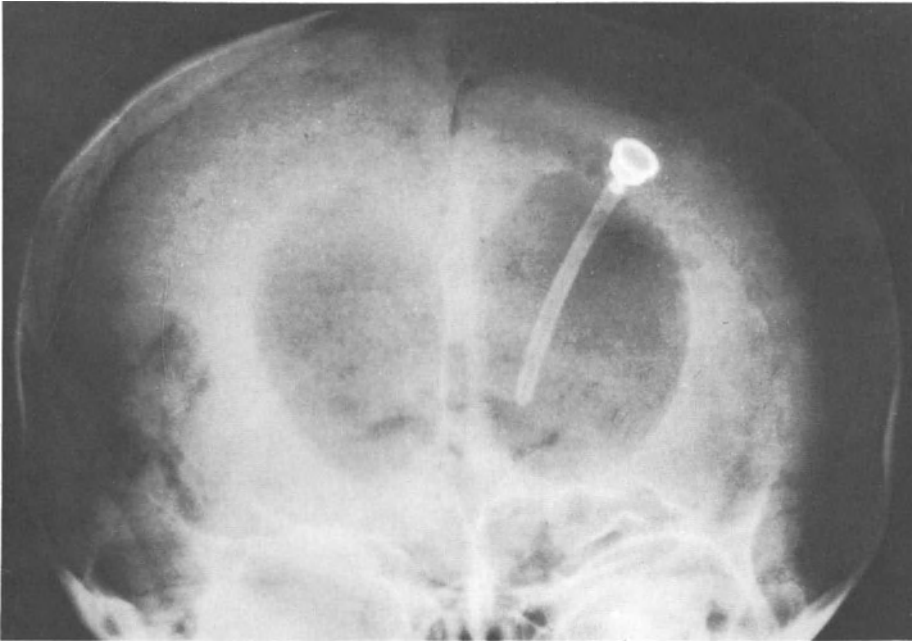


Fig. 4a. 48-year-old female patient with normal-pressure hydrocephalus, active hydrocephalus. Drug abuse known, otherwise unremarkable anamnesis. Substantial widening of the ventricular system is seen, especially in the frontal region. The angle of the corpus callosum is distinctly lowered under 120°

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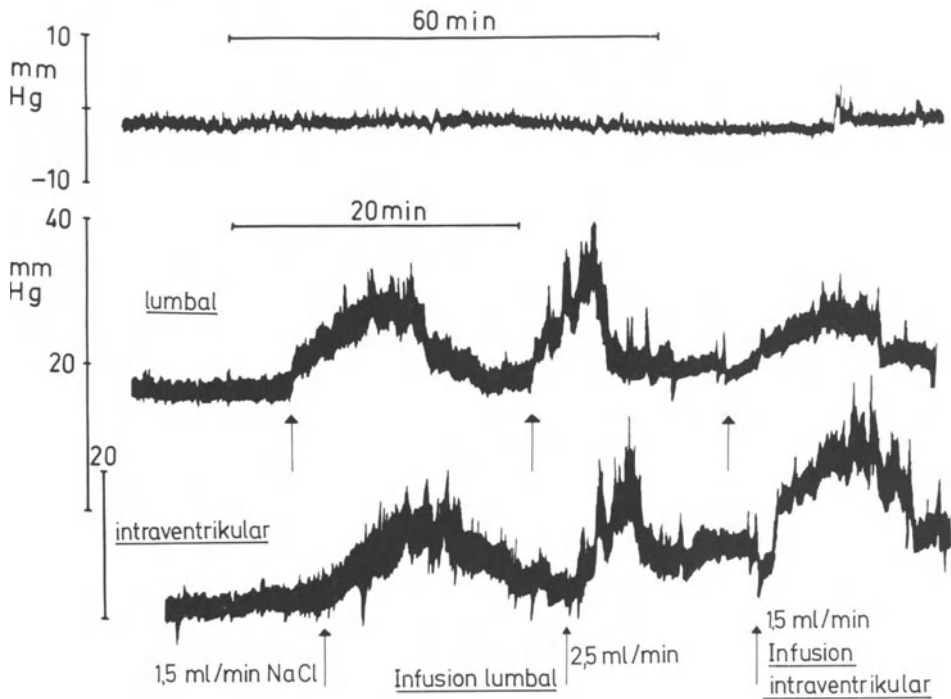


Fig. 4b. The same case as in 4a. Continuous measurement of CSF pressure shows a CSF pressure level about 0 mm Hg. No pathological pressure measurement. Only a stress on the CSF system through infusion of NaCl ventricularly as well as lumbarly (resorption test) showed a delayed and insufficiently high rise in pressure. The resorption disorder is largely verified by this. There was a slight improvement after shunt operation

Diagnosis of Hydrocephalus by Computerized Tomography

TH. GRUMME and S. SUWITO

Computerized tomography of the brain permits a correct visualisation of internal and external CSF spaces. EMI numbers of CSF are between -2 and +9, and are, therefore, significantly lower than those of normal brain with 12 to 18. The computer tomographic image using a gray scale presents CSF spaces as dark zones compared to those of brain.

As in pneumoencephalography or ventriculography the pattern of ventricular enlargement in obstructive hydrocephalus may permit a localization of the pathologic process blocking CSF drainage as in the blockade of Foramen Monroi, stenosis of aqueduct and atresia of Foraminae Luschkae and Magendi. Communicating hydrocephalus may only then be diagnosed, if besides the dilatation of the ventricular system, there is also an enlargement of the basal cisterns and of the interhemispheric cistern. It was, however, proved in 300 children that the IV. ventricle is frequently not dilated, and the basal cisterns are sometimes not enlarged. For the neurosurgeon, who is asked to make an artificial drainage of the CSF, it is not relevant whether all signs of communicating hydrocephalus are present if only a tumor causing occlusive hydrocephalus was ruled out.

In computer tomograms there is quite frequently a bilateral dilatation of circumscribed parts of the lateral ventricles which, hitherto, was not found in the pneumoencephalographic literature. Bilateral dilatation of occipital horns is observed most frequently; sometimes anterior horns are dilated. In single cases there is also an isolated dilatation of temporal horns. The reason for the isolated dilatation of ventricular horns is unknown. The validity of these findings in respect to surgery is not clear. The conjecture that occipital horn dilatation indicates the necessity of CSF shunts has still to be proven with more cases.

After obstructive and communicating hydrocephalus we will now discuss brain atrophy in the larger sense. Brain atrophy is visualised on computer tomograms by alterations of internal and external CSF spaces. The extent of external hydrocephalus may be judged from the basal cisterns, the insular cisterns, the interhemispheric cisterns and the sulci. The computer tomographic findings in brain atrophy are variable. Also, the age of the patients is important. In younger patients brain atrophy has a more significant diagnostic value than in elder patients. The extent of atrophy at the cortex and at the ventricular system may be unproportional or proportional. Internal hydrocephalus with normal cortex may be found in low pressure hydrocephalus. In pneumoencephalography there are rather constant criteria for low pressure hydrocephalus: symmetric ventricular dilatation and lack of air in the subarachnoidal spaces. Computer tomography may replace pneumoencephalography, which in patients with a low pressure hydrocephalus is rather badly tolerated. Computer tomography will however not give additional results to the pneumoencephalographic findings. JACOBS/KINKEL (4) compared

computer tomography and pneumoencephalography and found that in 7 out of 20 cases with low pressure hydrocephalus there was cortical atrophy on computer tomograms, which was not found in pneumoencephalography. On the other hand, the computer tomographic finding of an internal hydrocephalus with normal cortex does not necessarily indicate low pressure hydrocephalus, because we have observed cases which in all additional special examinations had negative results. In a single case a dilatation of the occipital horns of both lateral ventricles was observed in normotensive hydrocephalus.

Computer cisternography with Amipaque may, however, yield new results which are related to the results found by radiopharmaceutical. GREITZ/HINDMARSH (2) reported on the use of Amipaque and computer tomography in 1974 for the first time, in order to prove intracranial disturbance of CSF circulation. After lumbar application of Amipaque, computer tomographic pictures were obtained after 1, 3, 5-6, 24, 48 and 72 hours. According to HINDMARSH/GREITZ (3), the diagnosis of communicating hydrocephalus may be supported. Computer cisternography permits evaluation of CSF dynamics. Figures 1-6 show ventricular reflux in a patient with low pressure hydrocephalus. The interpretation of paraventricular zones of low density in figure 5 is rather difficult. GREITZ/HINDMARSH (2) believe that it is related to subependymal places of CSF resorption.

Computer tomography may replace pneumoencephalography in nearly all cases. Computer cisternography may yield new results on CSF dynamics in the future. More detailed examinations quantitating absorption values may elicit low pressure hydrocephalus, and may revise some of the criteria hitherto believed to be certain.

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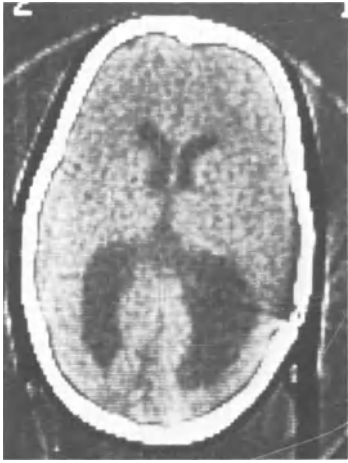


Fig. 1. Hydrocephalus; bilateral dilatation of occipital horns



Fig. 2. Hydrocephalus; bilateral dilatation of frontal horns

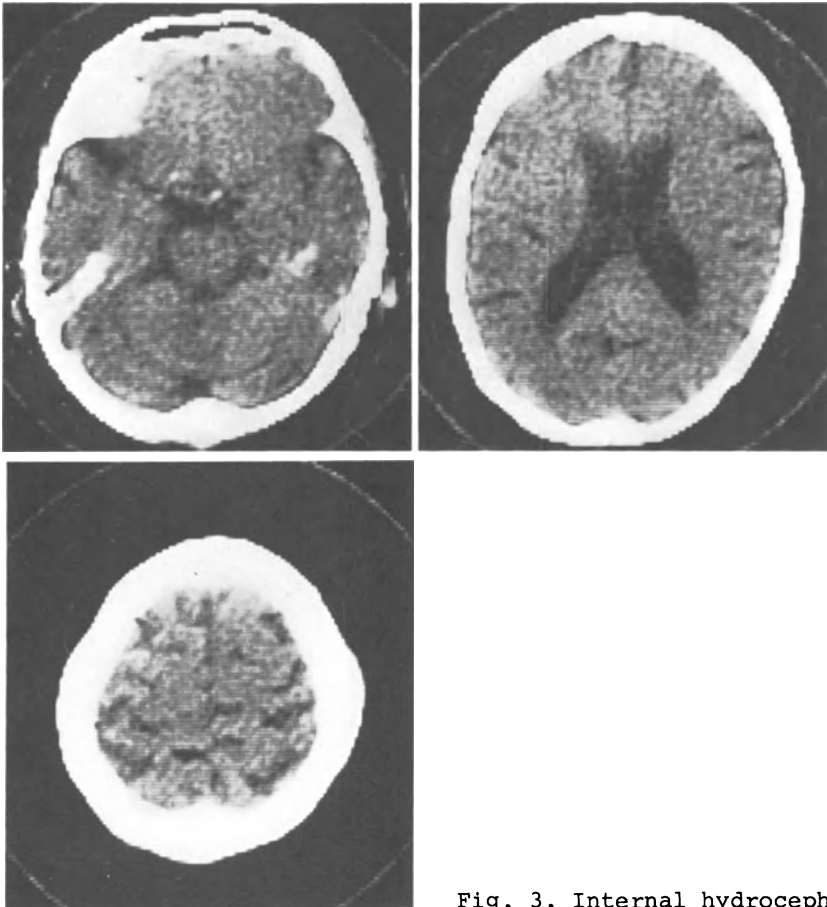


Fig. 3. Internal hydrocephalus; brain atrophy

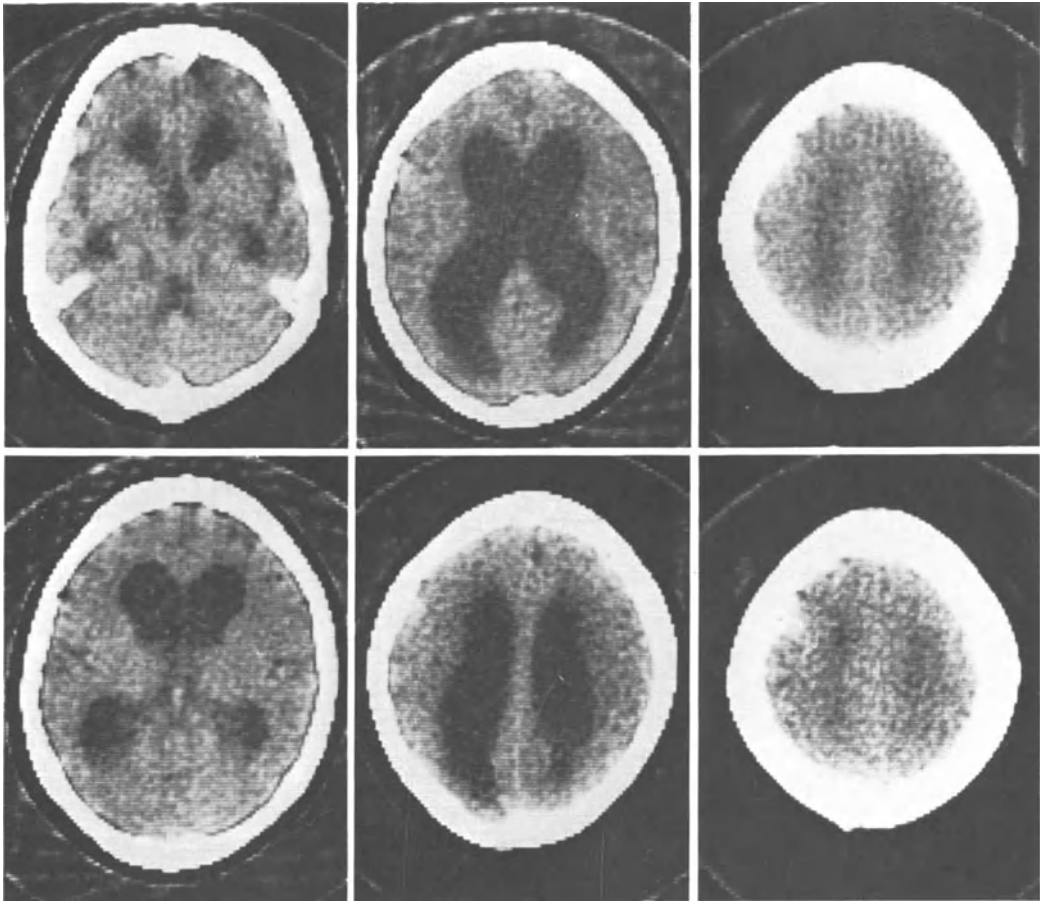


Fig. 4. Computer tomogram of a 72 years old patient with low pressure hydrocephalus: internal hydrocephalus, no cortical atrophy

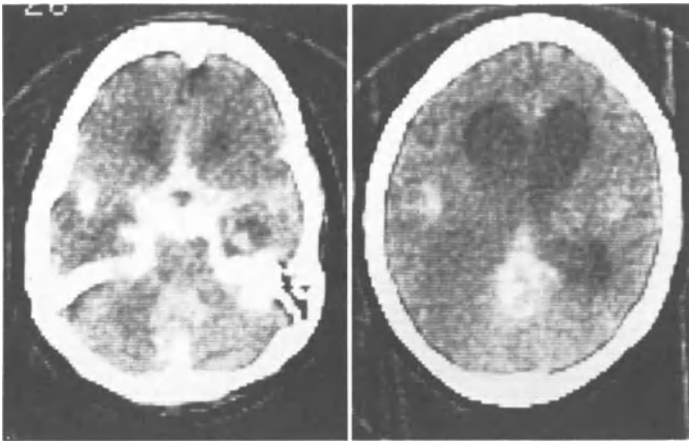
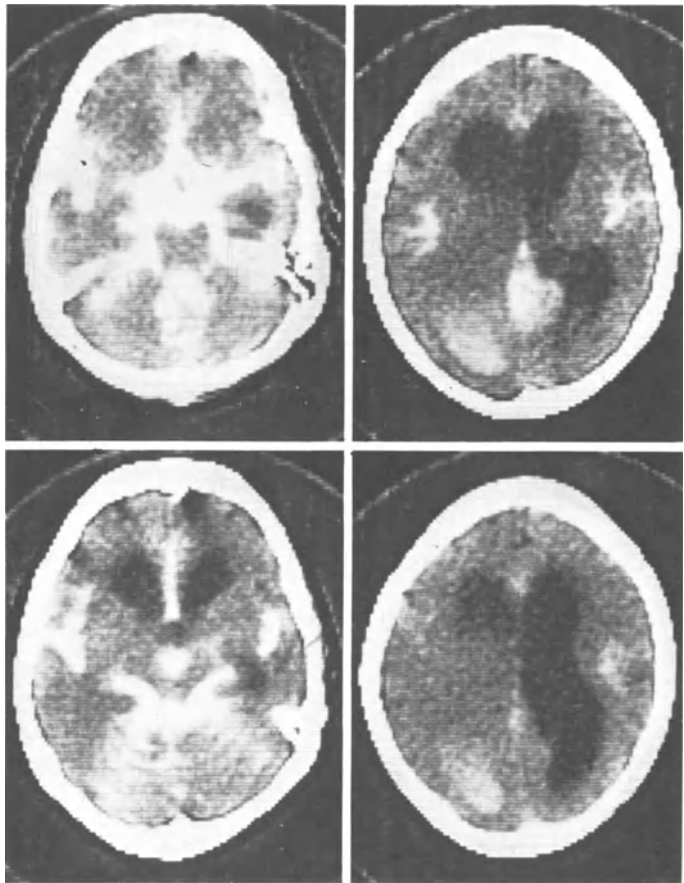


Fig. 5. Computer cisternogram 1 hour after application of Amipaque: contrast medium in the basal cisterns, reflux into the IV. ventricle and the left lateral ventricle



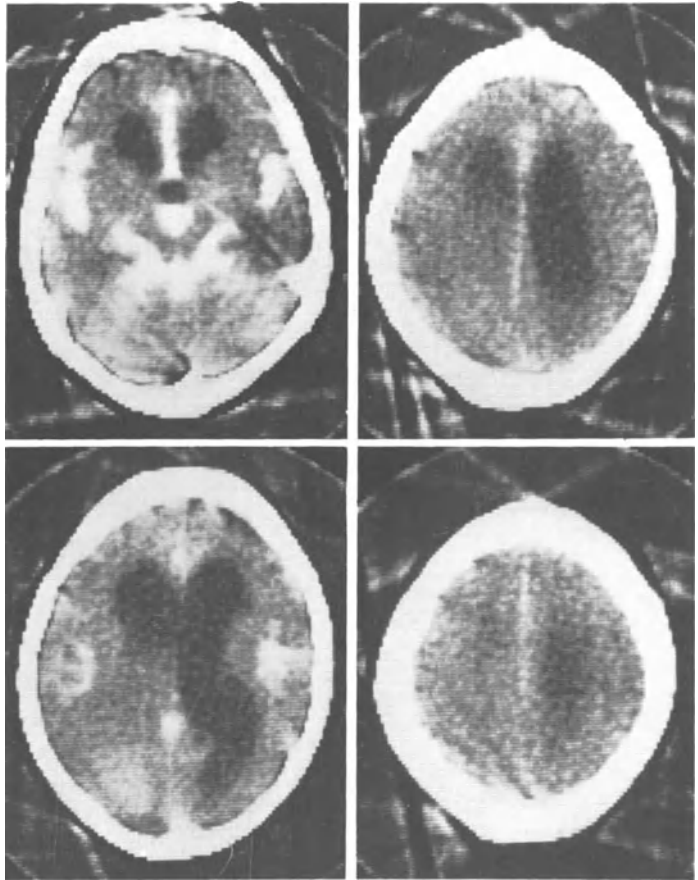


Fig. 7. Computer cisternogram 5 hours after application of Amipaque: minor contrast in the lateral ventricle, contrast medium in the mid-line



Fig. 6. Computer cisternogram 3 hours after application of Amipaque: strong sedimentation of contrast medium in the left lateral ventricle. Basal cisterns are still considerably filled

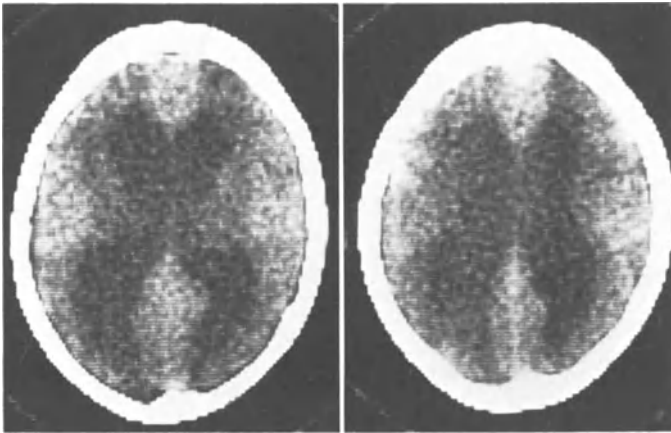


Fig. 8. Computer cisternogram 24 hours after application of Amipaque: basal cisterns free. Diffused high density in the ventricular system. Paraventricular low density zones

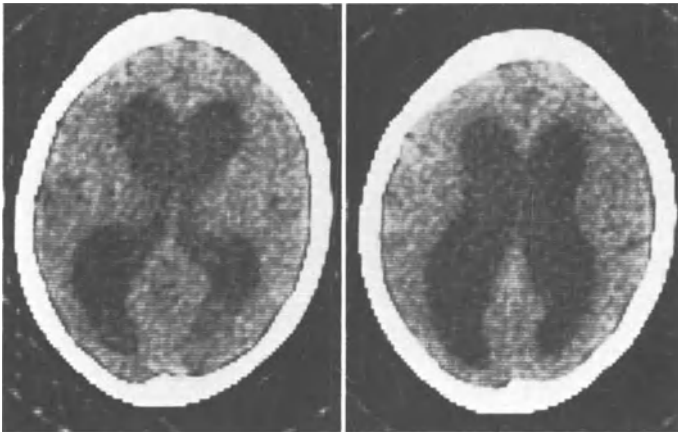


Fig. 9. Computer cisternogram 72 hours after application of Amipaque: finding as in the native scan

Free Communications

Results of Conservative and Surgical Early Treatment of Cervical Spine Injuries

E. HAMEL, A. KARIMI-NEJAD, R. A. FROWEIN, and H. KUNST

Introduction

In our country, indication of surgical early treatment of cervical spine luxation fractures is not done consistently. Because of consistent disappointing results produced by laminectomy, it happens quite frequently that surgical stabilization by ventral fusion is also advised against (GUTTMANN, 1969).

For this reason, a census was made of all patients treated in both the Neurological and Neurosurgical University Clinic of Cologne between 1952 and 1976 to allow a comparison between 30 patients with conservative treatment and 30 patients with surgical treatment by stabilizing ventral fusion, both of these groups with comparable primary neurology. They belong to a total of 161 patients with cervical spine injuries.

1. Cervical Spinal Cord Contusions

Table 1 shows that - on admission - with 53 patients suffering from cervical spine trauma showing no radiological evidence of bone injury consequences the severity of the neurological syndrome was less than with patients having cervical spine fractures. A complete transectional syndrome was to be found with 20% of the patients having contusions but with 57% of those with fractures.

2. Cervical Spine Fractures

Table 1 shows the number of cervical spine fractures and the stage of the neurological syndrome on admission. Out of a total of 108 patients with cervical spine fractures, 57% showed a complete and 24% an incomplete transection. It was only in 12% of the cases that a radicular syndrome was found. 8 patients with luxation fractures and considerable dislocation did not show any neurological reductions.

Course Determining Factors

1. Grade and Severity of Spinal Cord Lesions

It proved true that the course determining factors were greatly dependent on the severity and the grade of the spinal cord injury. All patients with a complete transection of C4 or higher died in the course no matter what kind of treatment they were given. 40% of the patients, however, survived when the transection was a lower one, even if just by one segment, i.e. C5.

Table 1. Grade of severity of 161 cases of cervical spine injuries

	Number	Complete transection	Incomplete transection	Radicular syndrome	Without neurological reductions	Total
Contusion of cervical spinal cord		11	35	8		53
	%	20%	66%	14%		100%
Cervical spine fractures	Number	61	26	13	8	108
	%	57%	24%	12%	7%	100%

2. Development of the Syndrome

A complete and lasting primary neurological post-trauma syndrome resulting in 37% lethality showed a more negative prognosis than a syndrome with symptoms increasing secondarily. With only 26% lethality, these latter cases offered much more chance of mastering the reductions by surgical treatment.

Comparison of Different Kinds of Therapy

Table 2 gives a summary of the kinds and results of different therapies. A comparison is made of:

1. the method of simply keeping the patient quiet and flat without extension,
2. extension by either Crutchfield tongs or Glisson sling,
3. surgical reposition and stabilizing ventral fusion.

1. Conservative Therapy, Simply Keeping the Patient Flat without Extension

Lethality in cases of luxation fractures treated without extension was immense, being as high as 53% independent of the seriousness of the neurological syndrome. It was only with 2 patients having slight neurological reductions that recovery could be achieved by simple immobilisation and keeping them on the transection bed.

2. Conservative Therapy with Extension

Much better results were obtained by extension applying either - as was usual in former times - the Glisson sling or - as is usual nowadays - the Crutchfield tongs. Considering a 35% lethality, it is in 15 of the cases that a much better recovery from neurological reductions was achieved. This favourable development, however, could only be reached in patients having an incomplete transection or radicular syndrome.

3. Surgical Treatment by Ventral Fusion

With patients who had a stabilizing surgical treatment lethality was much lower, being only 27%, than with patients having conservative treatment; in 53% of the cases a marked recovery from neurological reductions could be stated. 20% of these patients, however, did not show any recovery tendencies or remained permanently unable to walk. 2 patients with luxation fractures and complete transection syndromes showed quick and permanent signs of recovery from neurological reduction within the first 12 hours after being operated on and even were able to walk. Comparable results could not be obtained by conservative treatment. The much better results through surgical treatment - even with complete transections - were mainly obtained by the fact that an early mobilization was provided for.

To put aside the better chances of intensive therapy reached in the course of the recent 10 years and to allow an objective comparison between surgical and conservative therapy, Table 3 gives a comparison of 30 patients treated conservatively and 30 patients with surgical treatment, both of these having nearly similar bone injuries, similar syndromes and similar intensive therapies. Lethality with patients treated conservatively was slightly higher than with patients having

Table 2. Kind of therapy applied with cervical spine fractures / course

Kind of Therapy	Syndrome on admission	Exitus	No changes, unable to walk	Improvement, able to walk	Total
No extension no operation N = 30	radicular	1	3	1	5
	incompl. transect. compl. transect.	15 53%	3 6 40%	1 1 7%	4 21
Extension no operation N = 35	radicular	2	3	4	9
	incompl. transect. compl. transect.	10 34%	15 51%	1 15%	26
Stabilizing operation with ventral fusion N = 30	radicular	1	2	6	9
	incompl. transect. compl. transect.	2 5 27%	1 3 20%	8 2 53%	11 10

Table 3. Therapy results with 60 patients having a comparable primary neurology

Kind of Therapy	Syndrome on admission	Exitus	Unchanged, unable to walk	Improved able to walk	Total
Conservative N = 30	radicular syndrome	1	5	3	9
	incomplete transection	3	4	4	11
	complete transection	6	4		10
	%	33%	43%	24%	
Stabilizing operation with ventral fusion N = 30	radicular syndrome	1	2	6	9
	incomplete transection	2	1	8	11
	complete transection	5	3	2	10
	%	27%	20%	53%	

surgical treatment, the first being 33% and the latter being 27%. Under conservative treatment an attractive recovery from neurological reductions was achieved with 15% of the patients in general (see Tab. 2) and in their best phase of treatment with 24%, whereas 53% were reached with those patients who had surgical treatment.

Summary

From a total of 161 cases of cervical spine injuries treated in the Neurological and the Neurosurgical Clinics of Cologne University a comparison was made of the results of different kinds of therapy (the conservative one and the surgical one with ventral fusion). When comparing 30 patients treated conservatively and 30 patients with surgical treatment by stabilizing ventral fusion - both of these having similar bone injuries and similar neurological syndromes on admission - it was quite obvious that the results obtained by surgical therapy were pronouncedly better.

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Prognosis of Severe Head and Brain Injury in Childhood

D. TERHAAG

In recent publications a favourable prognosis of children with severe head and brain injuries has been reported by various authors. Observations of LANGE-COSACK and our experience do not confirm such a good chance of survival after brain trauma in the first decade of life.

The chance of survival and the degree of social rehabilitation that could still be expected was investigated in patients up to 10 years of age.

For this study, 262 children were selected from a series of 566 children with severe head and brain injuries from the years 1964 - 1973: 104 children died on the day of the accident and 158 were unconscious for more than 24 hours. Of the latter group 90 survived - which means a mortality rate of 42%.

Unconsciousness, the most obvious symptom indicating brain disfunction, has been clinically defined in recent publications by FROWEIN in accordance with LINDGREN's or TEASDALE's and JENNETT's definition as a person's state of complete insensibility to his environment. Following this definition of unconsciousness, the duration of this disfunction was particularly important in predicting the chances of survival and social rehabilitation.

Also in the clinical courses of children with severe head and brain injuries there is a good correlation between the duration of this disfunction and the chances of survival and/or the degree of social rehabilitation that can still be expected.

Figure 1 shows the important part played by age. On the average the mortality rate rises from 42% in the first decade of life to 86% among the patients over sixty years of age. But regarding different groups -- 0 - 3, 4 - 7 and 8 - 10 years of age -- we see, that the younger children have a very high mortality rate of 66%.

The following Figure 2 shows the record of the 90 survivors according to the duration of unconsciousness and grouped on the three separate ages. The total of each group is 100%. Thus it can be seen, that only 50% of the surviving children had more than 4 - 6 days of unconsciousness. Even in this 50% mark the younger children form more the mower belt and have with 4 days unfavourable courses. The important age difference in the first decade is particularly clear in regard to the 5% limit of those children, who survived this period of unconsciousness. 5% of the 4 - 7 year-old children had a period of unconsciousness of 18 days. The 5% limit of the 8 - 10 years-old patients was 15 days. The longest period of unconsciousness - primary after head and brain injury - we have seen in the group up to 3 years-old children was only 11 days. This shows the poor prognosis of toddlers.

In surveying the degree of social rehabilitation achieved, the follow-up medical histories of children with longer periods of unconsciousness were investigated by LANGER in particular, as there was special interest in ascertaining their upper marginal limits.

The degree of the recovery of the capacity to work or to attend school - classified as fully fit, slightly incapacitated, considerably incapacitated and unfit - was examined in relation to age at time of the accident, length of period of unconsciousness and depicted in the diagram of the Figure 3. Two lines illustrate the upper marginal limits observed for full and slightly restricted working capacity in the individual decades of life.

In the most favourable cases, injured children 4 - 7 and 8 - 10 years-old achieved full capacity to work or do school lessons only after a period of unconsciousness lasting not longer than 3 or 6 days. In the group of children less than 3 years old complete recovery was not seen if they had been unconscious for more than 24 hours.

Slightly reduced social rehabilitation resulted for children 4 - 7 and 8 - 10 years-old after as many as 12 or 17 days of unconsciousness. But the limit for children up to 3 years-old was 5 days - likewise notably lower than for the older two groups of children with long lasting unconsciousness.

Summary

The observations by various authors, that the prognosis of children suffering from head and brain injuries is favourable, could not be confirmed by our investigation. Particularly poor is the chance of survival and of complete social rehabilitation in children of the younger group.

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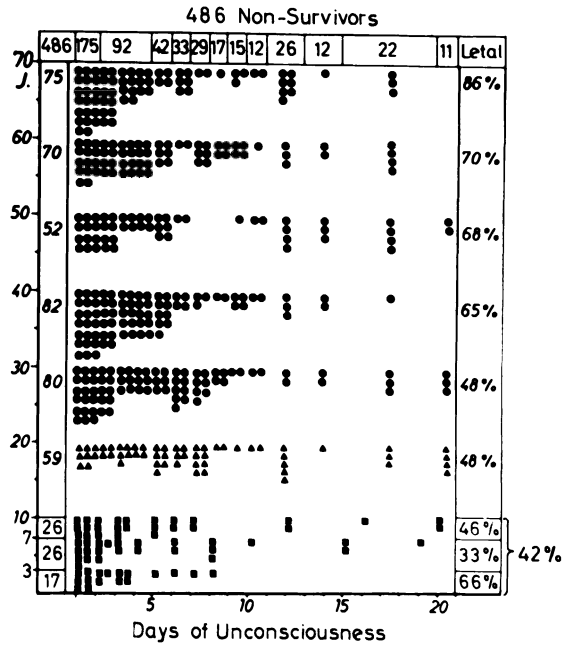
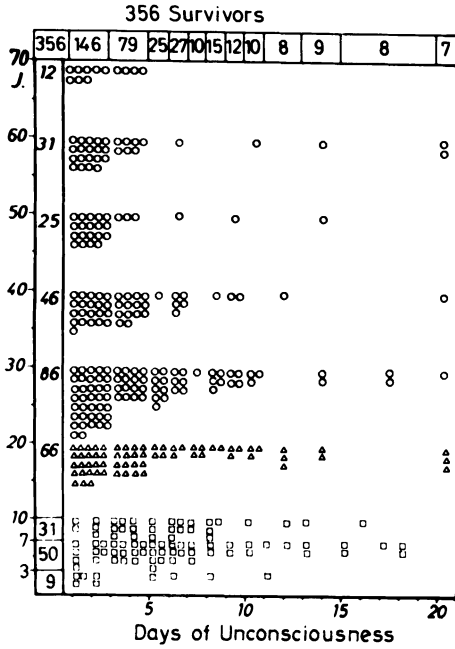


Fig. 1. Relationship between age and duration of unconsciousness playing the important part with regard to mortality. 842 cases of severe head injury, all with more than 24-h unconsciousness (excluded those dying in 24 hours)

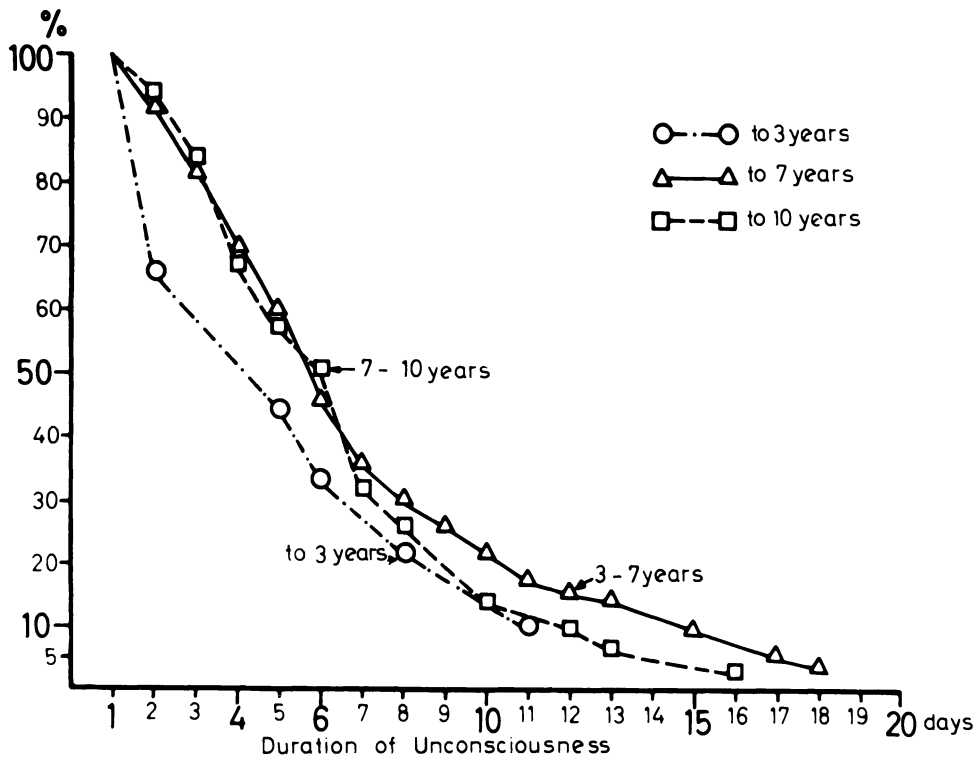


Fig. 2. Record of the 90 surviving children. According to the duration of unconsciousness there are 3 separate groups - up to 3, 4 to 7 and 8 to 10 years of age. The individual groups are treated as units of 100%.

Long-term unconsciousness after head and brain injury

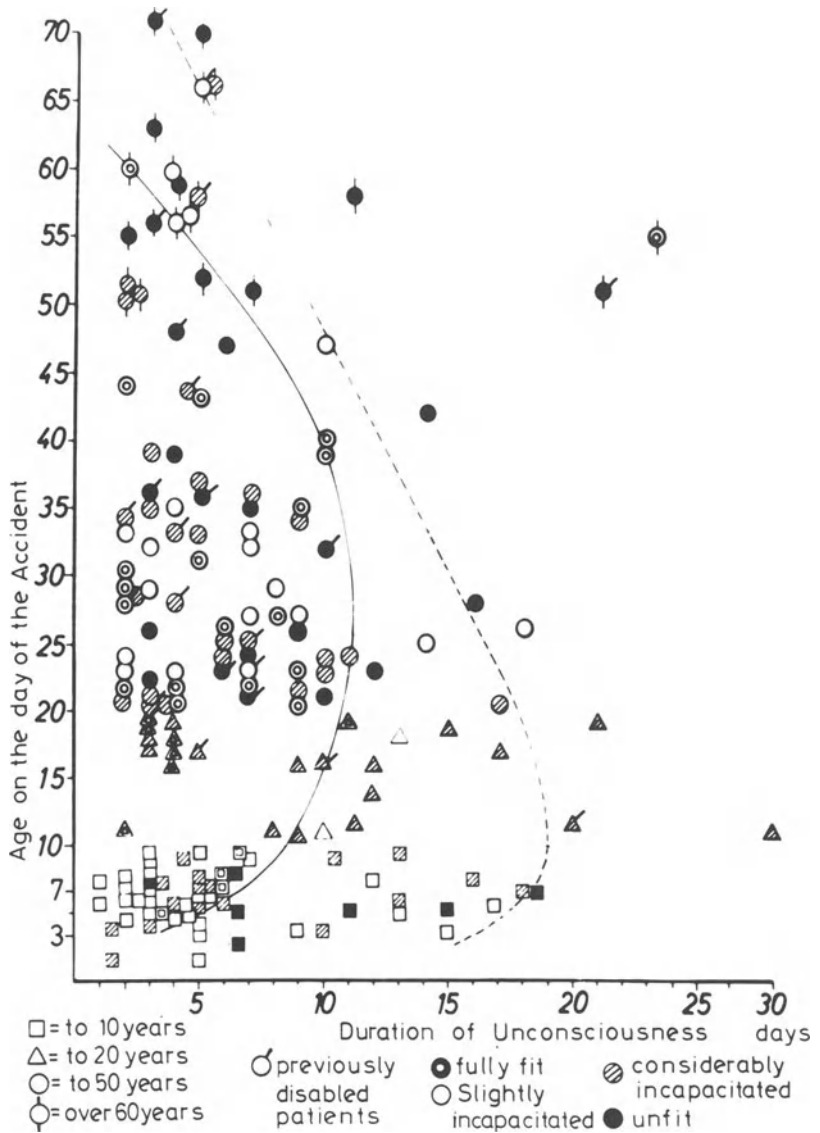


Fig. 3. Record of the follow-up medical histories of survivors with long-term unconsciousness. The degree of recovery was depicted in the diagram in relation to age and length of period of unconsciousness. Two lines illustrate the upper marginal limits observed for full (—) and slightly restricted (---) working capacity.

Social rehabilitation after long-term unconsciousness

Secondary Blood Coagulation Disturbances After Severe Brain Injury

W. MAUERSBERGER, E. C. FUCHS, and A. GRIMMER

BELL and ALTON proved in 1954, that an outstanding characteristic of the brain tissue is its high thromboplastin concentration. After a severe brain injury and due to a simultaneous alteration of the blood-brain barrier, tissue thromboplastin can enter the systemic circulation, activating first factor VII (proconvertin) and in a later phase factors X (Stuart) and V (proaccelerin). Under the influence of the platelets phospholipids, prothrombin is converted to thrombin and fibrinogen to fibrin (Fig. 1). At the same time an increase in the activity of the fibrinolytic system takes place.

If the process so induced overcomes the synthesis speed of the coagulation factors, the latter can be significantly decreased and so lead to a consumption coagulopathy. This problem is basically the same to the one present, for example, in amniotic-fluid embolism, Gram negative sepsis and muscle destruction in cases of polytrauma (2).

The first reports on coagulopathies after brain injuries are to be found only during the past few years and most of these papers deal with isolated cases (4-8). In order to have an overall view of the frequency of these alterations, we examined a group of 52 patients with severe brain injury demonstrated by clinical signs, angiography, computerized axial tomography and/or operative findings and in who, previous coagulopathies had been ruled out.

Among the paraclinical studies taken in these patients at their admission platelet count, fibrinogen, prothrombin time, partial thromboplastin time were performed. In those cases where the patients condition allowed it, these examinations were repeated during the following hours.

Ten cases showed pathological figures (Table 1). The prothrombin time in 9 patients was under 75% and the fibrinogen under 2 gr/l. In 8 the thrombin time was over 16 seconds. The partial thrombin time was proved to be over 39 seconds in 6 of them. A thrombopenia under $150.000/\text{mm}^3$ was found in 6. In 3 of them the figures were well under $75.000/\text{mm}^3$.

These coagulation disturbances are to be attributed to the above described pathophysiological mechanism, which indicated that the released tissue thromboplastin plays a very important role in activating the blood coagulation system. The low platelet count and fibrinogen level seem to confirm the hypothesis. The decrease in prothrombin time, showed by 9 of our patients speaks also in favour of a disturbance of the exogen coagulation system with subsequent decrease in factor X, VII or II. The most meaningful parameter of a consumption coagulopathy however is the low fibrinogen level (2). The increase in thrombin time can be attributed to a fibrinogen decrease or to an increase of the activity of the fibrinolytic system, with the subsequent presence of fibrin polymerisation inhibitors (3). The pathologically high par-

Table 1. Laboratory records of 10 cases with evidence of a consumption coagulopathy after severe brain injury

Case	Age (years)	Time after trauma (hours)	Platelet count	PT n=75-140%	PPT n=24-39"	TT n=12-16"	Fibrinogen n=2-4 gr/l
1.	36	1	254,000	54	42	21,9	0,90
2.	44	2	126,000	49	32	26,3	1,20
		6	104,000	47	30,5	16,6	1,00
3.	56	19	153,000	52	31,6	18,3	1,45
		27	-	46	30,4	15,5	2,15
		36	79,000	100	25,3	16,6	2,30
4.	67	5	-	73	34,5	13,5	2,15
		9	64,000	65	39	25,7	2,10
		19	36,000	65	34,5	17,9	2,25
		33	65,000	45	27,7	14,3	4,50
		45	211,000	100	33	13,4	5,50
5.	45	2	186,000	42	3min.	3min.	1,45
		5	-	61	49	21,3	1,55
		10	146,000	70	38,3	16,9	2,00
6.	42	12	26,000	29	150	150	2,60
		36	62,000	120	-	17,5	-
		50	23,000	47	111	30,7	1,90
7.	63	4	101,000	58	64	21,6	1,35
8.	47	13	132,000	44	47	14,2	1,10
		16	56,000	40	49	13,3	1,70
9.	24	7	176,000	75	34	13,4	1,50
		11	214,000	90	34,9	12,3	1,75
10.	21	2	192,000	59	27,9	17,8	1,40
		14	205,000	64	44	12,4	2,00

tial thrombin time was always accompanied by a simultaneous reduction in the prothrombin time values, and this suggests a deficit in factor X or V (3).

These alterations were present in 9 patients already during the initial examination and obviously during the time in which the majority of the operations had to be performed. These complications represent, because of the evident increase in the technical difficulties, an extra handicap for the patient who must be surgically treated, even in those cases in which clinical evidence of an underlying coagulation

disturbance is not present. Because of lack of experience with heparin administration in animal experiments or neurosurgical patients, the substitution therapy with fresh blood or plasma, cryoprecipitate and fibrinogen is still the most adequate treatment. If available, the use of platelet concentrates should be considered in presence of platelet counts under $75.000/\text{mm}^3$.

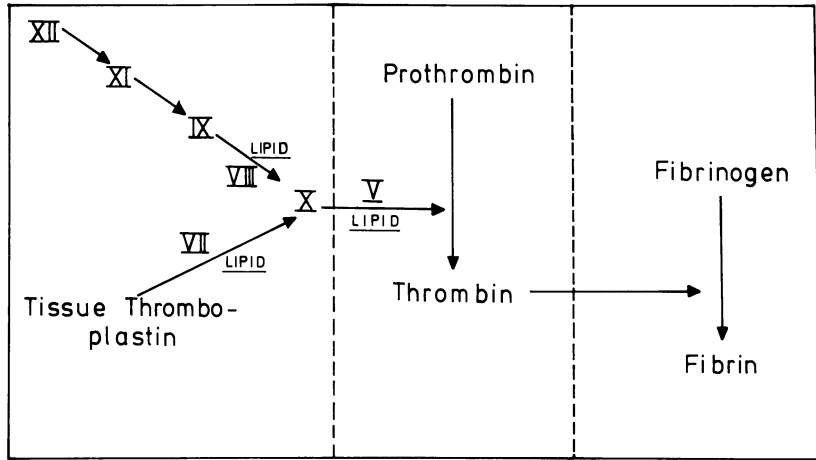
In case of emergency this therapy should be carried out simultaneously to the rest of preoperative cares. In some cases even before knowing the laboratory findings, although this may lead to an overuse of blood products and an increased risk of hepatitis.

Summary

The release of tissue thromboplastin following a severe brain injury can lead to a consumption coagulopathy. In a group of 52 patients with severe brain injury platelet count, fibrinogen, prothrombin time, partial thromboplastin time and thrombin time were investigated. 10 showed pathological laboratory findings. These alterations were demonstrated during the first hours following the trauma and represented an extra handicap for the patients who had to be surgically treated. Substitution therapy with fresh blood or plasma, cryoprecipitate and fibrinogen is recommended.

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Factor XII = Hageman, XI = PTA, X = Stuart, IX = PTC (Christmas), VIII = AHF,
 VII = proconvertin, V = proaccelerin.

Fig. 1. Schematic representation of the coagulatory system, which shows how the process can be initiated by the release of tissue thromboplastin

Clinical Double-Blind-Study on the Effects of Dexamethasone on Severe Closed Head Injuries

G. FAUPEL, H.-J. REULEN, D. MÜLLER, and K. SCHÜRMAN

Although the efficacy of dexamethasone upon brain edema in brain tumors and abscesses is well established, the question is still open, whether a similar favourable effect is exerted in severe head injury. Controlled and statistically significant results were not available in the literature when this study was planned. Experimental studies, however, with cold injury as a model of brain lesion showed a favourable influence of steroids on brain edema, if very early and high dose administration was used (2, 3, 4, 6). Therefore, a double-blind study was performed comparing placebo with low and high dose of dexamethasone.

Patients and Methods

All critically ill patients admitted to our hospital following severe closed head injury were included in the study with the exception of children and patients in terminal stage, with open head and missile injuries, impression fractures. Immediately after the initial neurological examination the patients received dexamethasone¹ (Decadron) or placebo according to a continuous random number, supplied in identical appearing vials, containing the same volume of a clear solution. Thus, physicians and nursing personal were unaware of the material being used. Group I received placebo. Group II received dexamethasone; loading dose 12 mg i.v. followed by 4 mg every 6 hours for 8 days i.m., tapered off by daily reduction of 4 mg. Group III received dexamethasone, loading dose 100 mg i.v., after 6 hours again 100 mg i.m., followed as described at II. Medical care, clots and focal mass evacuation as well as nursing, ventilation etc. were provided in the same way for all patients in an intensive care unit. It should be stressed that the "placebo-group" received the routine intensive care as developed during the past 10 years, except for dexamethasone. Patients were examined neurologically and scored at admission and, by the same neurosurgeon, on day 3, 7, 11 using a patient evaluation sheet (7). A final examination was performed at discharge and the results were transformed to a disability status scale (5). The optimal total neurological score is 45 points and 274 points with brain death. Before opening the randomisation plan, 5 patients had to be excluded: 3 of them (all placebo) were brain dead, one patient (low dose) died due to uncontrollable respiratory insufficiency, one patient (placebo) had received dexamethasone on day 5-7. There remained 95 patients in the study, 73 men and 22 women. For statistical comparison chi squared test was used.

¹ Decadron-phosphate was kindly supplied by SHARP & DOHME GmbH, Munich, Germany.

Results and Comments

When the code was broken and individual therapy was identified, it was found, that 28 patients had received placebo, 33 the low and 34 the high dose dexamethasone (Table 1). Comparison of the 3 groups showed, that overall lethality was significantly lower ($p < 1\%$) in the pooled dexamethasone group. Similar results have been published recently by GOBIET et al. (1). Also, our results indicate a dose-dependent effect (1): lethality in the high dose group was markedly lower than in the low dose group. Reduction of lethality was more pronounced ($p < 1\%$) in the older age group. A comparison of the efficacy of the early (< 6 hrs) and delayed (> 6 hrs) administration disclosed an important and significant difference (Table 2): with early injection lethality could be diminished from 71% (placebo) to 21% (dexamethasone pooled, $p < 1\%$). The respective values for the delayed administration were 43% and 28% (difference not statistically significant). It must be considered, however, that patients admitted early after injury usually have a more severe trauma. Evaluation according to diagnosis showed contusions and subdural hematomas most frequently represented. Their lethality was significantly ($p < 5\%$) reduced by treatment, too. Individual neurological courses from day 1 to 11 show even better than the average score the beneficial effect of dexamethasone. In many patients of the placebo group the neurological status deteriorated and they died early. In comparison, the high dose group showed a continuous improvement, even during edema development; only 2 patients died early. Although the high dose of 100 mg dexamethasone was given only initially and after 6 hours, the superiority of high dose treatment is significant. This difference can also be expressed when comparing the main cause of death during this early phase: 44% of the deceased patients in the placebo group died due to brain swelling and secondary midbrain compression as compared to 60% in the low and only 17% in the high dose group. Serious complications were increased, not exceeding 6%. Partly they even were reduced. If the neurological and mental status of the final outcome (at discharge) is presented as a disability status scale (Fig. 1), we find that in the dexamethasone treated group less patients died, much more patients remained unconsciously stabilized (apallic syndrome), but more patients recovered totally.

Table 1. Survey of cases and lethality

	Placebo	Dexamethasone		
		Low Dose	High dose	Pooled
Survived	12	23 ^a	28 ^b	51 ^a
Died	16 (57%)	10 (30%) ^a	6 (18%) ^b	16 (24%) ^a
Total	28(100%)	33(100%) ^a	34(100%) ^b	67(100%) ^a

^a $p < 5\%$, ^b $p < 1\%$.

Table 2. Interval between injury and 1st injection of dexamethasone (Lethality)

	Placebo	Dexamethasone pooled
< 6 hrs total	14	38 ^a
died	10 (71%)	8 (21%) ^a
> 6 hrs total	14	29
died	6 (43%)	8 (28%)

^a $p < 1\%$.

It may be assumed that with very early administration of the steroid as well as with a continuous high dose during about 9 days the number of patients remaining unconsciously stabilized can further be reduced. It seems conceivable that the consequent use of diuretics, hyperventilation or hyperosmolar substances as an adjunct to decrease intracranial pressure may contribute to reach this goal.

Summary

The present study discloses the efficacy of a high dose dexamethasone treatment in severe head injury. It caused an early and persistent improvement of the neurological course and reduced lethality. Serious complications are rare. Evident improvement of the final outcome is opposed by an increase of apallic syndromes. Nevertheless, the favourable influence upon midbrain compression syndrome may be enhanced by a very early administration and probably continuously high dose of dexamethasone.

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Placebo	%	Dexamethasone
	3,6	Recovered totally 13,4
28,6		Moderate neurological deficit 25,4
	7,1	Severe neurological deficit 11,9
	3,6	Unconscious stabilized 25,4
57,1		Died 23,9

Fig. 1. Final outcome of the placebo group and the pooled dexamethasone group

The Influence of Dexamethasone on the Pattern of Intracranial Pressure Distribution in Patients with Brain Tumors

H. WIEGAND, C. ZILLIG, W. TAMBURUS, M. BROCK, and H. DIETZ

Although the favorable influence of dexamethasone on focal and general symptoms of patients with intracranial tumors has been well known to every neurosurgeon (1, 5, 7), a satisfactory explanation for the mechanisms involved is still lacking. Particularly, the effect of dexamethasone on intracranial pressure remains controversial.

Methods

In 12 patients with supratentorial and 8 patients with infratentorial tumors intracranial pressure was recorded continuously for diagnostic or therapeutic reasons (2, 3, 6). On the day before the onset of therapy with dexamethasone (a single dose of 12 mg i.v., followed by 4 mg i.m. every six hours) and on the second day after the onset of therapy frequency analysis of intracranial pressure was performed for a 6-hour period. The full scale of pressure was divided into ten pressure classes and a corresponding pressure distribution was built (4). The pressure classes were recorded on the horizontal axis, while the percentage of time during which pressure was at a certain level was recorded on the vertical axis. The histograms were compared graphically and statistically (MANN-WHITNEY-Test). Number and duration of plateau waves were also registered.

Results

1. Intracranial Pressure

In 8 patients with supratentorial tumors and in 6 patients with infratentorial tumors intracranial pressure was reduced by at least one pressure class by dexamethasone. This reduction was statistically significant.

2. Plateau Waves

During the 6-hour periods of frequency analysis plateau waves were present prior to therapy in 2 patients with supratentorial and in 4 patients with infratentorial tumors. Their total duration was 235 min., their number 25. On the second day after the onset of therapy the total duration of plateau waves was reduced to 51 min., and their number to 10. In 3 patients plateau waves disappeared completely.

3. Intracranial Pressure Distribution

The number of pressure classes over which the pressure histogram extended was reduced by dexamethasone therapy. This means that pressure deviations from the mean value became less, and that the histograms became steeper. This phenomenon, which corresponds to a decrease in fluctuations of intracranial pressure and, thus, to an improvement of cerebral perfusion pressure was called barostabilization (2).

Discussion

We conclude that dexamethasone leads to a significant lowering of intracranial pressure with reduction of the total duration and number of plateau waves. Since this effect is especially marked in patients with posterior fossa tumors and obstruction of CSF-pathways, the favorable effect of dexamethasone seems to depend, at least partly, on alterations of CSF production or resorption. The improvement of CBF by barostabilization is supposed to play an important role in the improvement of the patient's clinical condition.

Summary

Intracranial pressure was recorded in 20 patients with supra- and infratentorial brain tumors, and 6-hour pressure histograms were obtained prior to and 48 hours after the onset of therapy with dexamethasone. Intracranial pressure was lowered significantly, the number and total duration of plateau waves were reduced and fluctuations of intracranial pressure decreased, leading to an improvement of the patient's clinical condition.

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Resolution of Peritumoral Brain Edema Following Combination Therapy with Dexamethasone and Furosemide

G. MEINIG, A. AULICH, S. WENDE, and H. J. REULEN

The favourable effect of dexamethasone (D) in the treatment of brain edema associated with brain tumors has been confirmed manifoldly. The response, however, is limited and seems to vary with the type of tumor (2). An attempt was made to enhance the antiedematous effect by combining D with furosemide (F), a drug which probably has a different mode of action on edema.

Material and Methods

Following craniotomy small tissue samples from cortex and white matter were removed adjacent to the tumor in 77 patients and analyzed for their water and electrolyte content. The water and electrolyte content of 18 patients preoperatively treated with dexamethasone¹ (4x4 mg for 4 - 6 days) and furosemide² (3x40 mg for 2 - 4 days) were compared with 28 patients preoperatively treated with D (4x4 mg or 3x8 mg for 4 - 6 days), and 31 patients which did not receive D or F. In patients treated with D and F CT-studies were performed at intervals of 2 - 3 days. In some patients with inoperable tumors D/F therapy was continued with a reduced dose and CT studies were performed at intervals for several weeks or months. In order to judge the degree of resolution of peritumoral brain edema in the CT-study, an attempt was made to evaluate the extension of the peritumoral area planimetrically. In addition the reduction of shifts or midline structures (septum, pineal body, third ventricle) was measured in the CT pictures. Attention was given to the displacement and regression of compressed ventricles, sulci and cisterns.

Results

The normal water content of white matter is about 70% (4). As shown in Figure 1, the average water content of the peritumoral white matter of patients preoperatively not treated with D and F was increased by about 10%. Following the treatment with dexamethasone the water content decreases statistically significant ($p = < 0.05$) by about 2.5%. However, patients treated with the D/F combination therapy show a further significant diminution of peritumoral edema. The reduction in white matter sodium content parallels the decrease in water content.

CT studies were done before and during the D/F therapy at intervals of 2 - 4 days. It seems that this new technique enables the direct visualization of the extension of the area of edema and probably also

¹ Decadron.

² Lasix.

the dynamic process of development and resolution of edema. Secondary alterations due to edema, such as shifts of midline structures, displacement and compression of ventricles can be measured with this method. The CT following D/F therapy often shows impressive reduction of peritumoral brain edema (Fig. 2 and 3). The problem, however, is to express the drug effect quantitatively and numerically and to find firm and reproducible criteria. The planimetric measurement of the area of edema may be difficult, if the edema is not well delineated. Moreover, the exact comparison of repeated CT pictures is dependent particularly on the reproduction of identical plains. In contrast, the determination of shifts of midline structures (septum pellucidum, pineal body, third ventricle) is less problematic. The planimetric measurement of the area of the edema as well as the determination of the dislocation of the septum pellucidum and pineal body showed in 15 out of 16 cases a reduction following the D/F combination therapy. However, the time delay until occurrence of the resolution of brain edema as well as the extent of the resolution varied considerably. It may be assumed that this different response to therapy is related to the nature of the brain tumor.

Comments

The present results show that resolution of peritumoral brain edema is markedly better following the combination therapy with dexamethasone and furosemide than with dexamethasone alone. The additive effect may be explained by a different mode of action of both drugs. Although the mechanism of action of dexamethasone is not completely known, it is assumed that it decreases the extravasation of edema fluid site of the defective blood-brain barrier (4). Diuretics such as furosemide or ethacrynic acid, which are known to reduce CSF production rate with subsequent decrease of intracranial pressure, may increase the clearance of edema fluid from the tissue to the ventricular or subarachnoid CSF (3, 4). The reopening of the ventricles and probably the subarachnoid spaces may be an important factor to improve the clearance of edema fluid. Finally it must be stressed, that this approach to enhance the resolution of edema is still at the stage of clinical trial and further experience must be accumulated.

Summary

18 brain tumor patients were preoperatively treated with dexamethasone (D), 4x4 mg i.m. for 4 - 6 days, and furosemide (F), 3x40 mg p.o. for 2 - 4 days. The water and electrolyte content was determined in tissue biopsies removed from peritumoral cortex and white matter intraoperatively and was compared with the results from 31 patients not pretreated and 28 patients treated with D alone (16-24 mg i.m./die for 4 - 6 days). While the water content in cortex does not change significantly, it falls in white matter from 79.90 ± 0.81 in untreated to 77.29 ± 0.76 in D treated and to 75.53 ± 1.03 in D/F treated patients. Using computerized axial tomography diminution of the peritumoral edematous area, a reduction of the shift of midline structures (dislocation of septum pellucidum, pineal body, third ventricle etc.), reopening of compressed ventricles as well as regression of displaced ventricles could be observed following the combination therapy.

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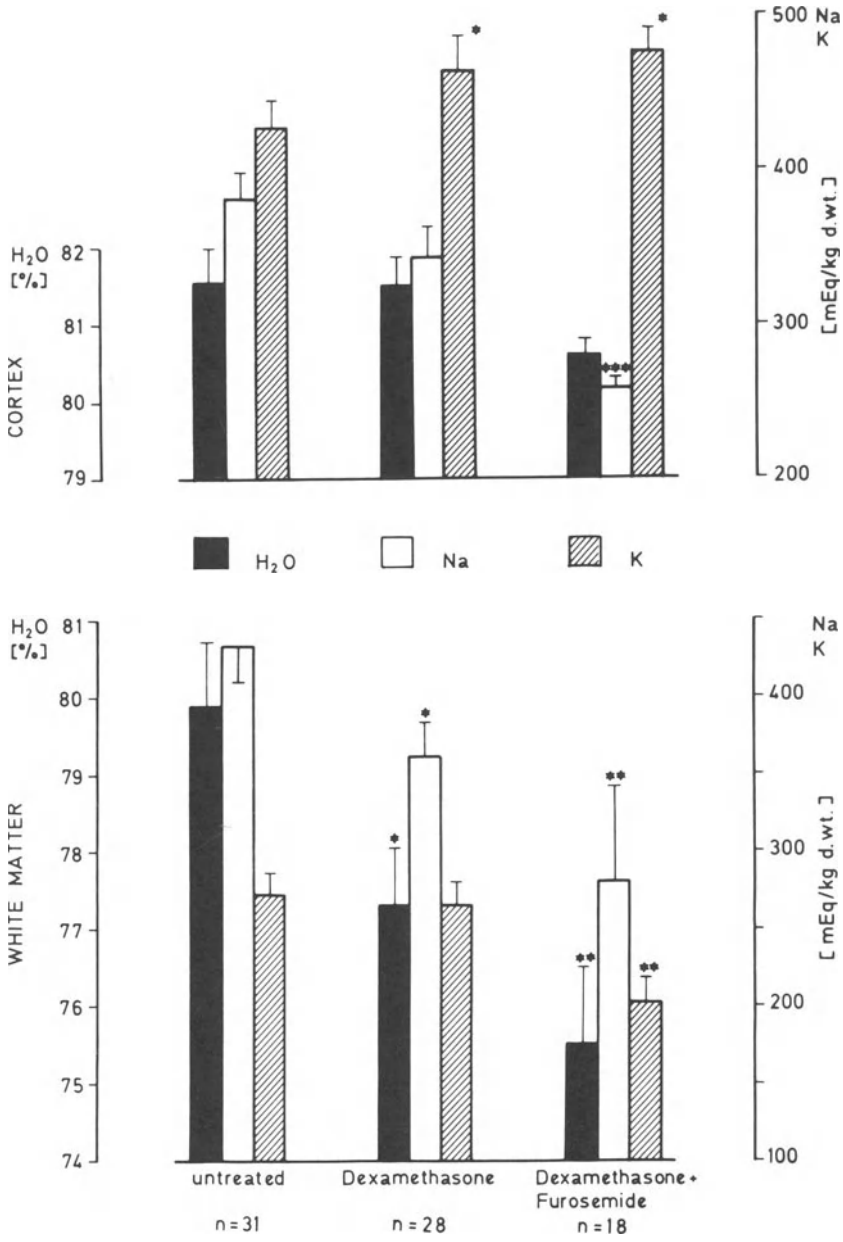


Fig. 1. Water and electrolyte content of peritumoral cortex and white matter in patients preoperatively pretreated with dexamethasone or with the combination of dexamethasone and furosemide. Comparison is made with a previous group of patients (2) not pretreated with the two drugs

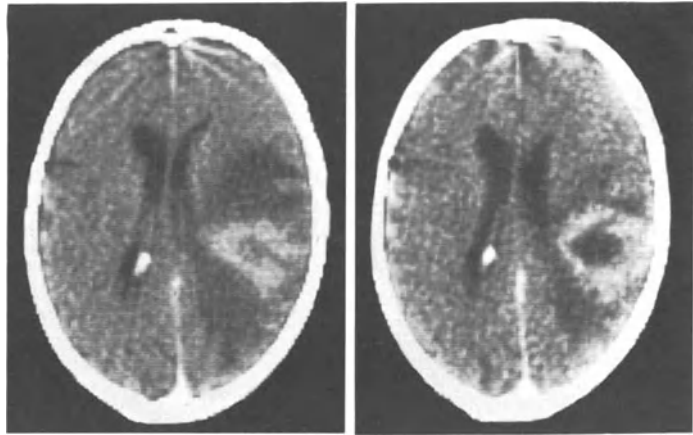


Fig. 2. CT showing decrease of brain edema associated with a right-sided parietal glioma following combination therapy (dexamethasone 4x4 mg i.m./die and furosemide 3x40 p.o./die) for 13 days

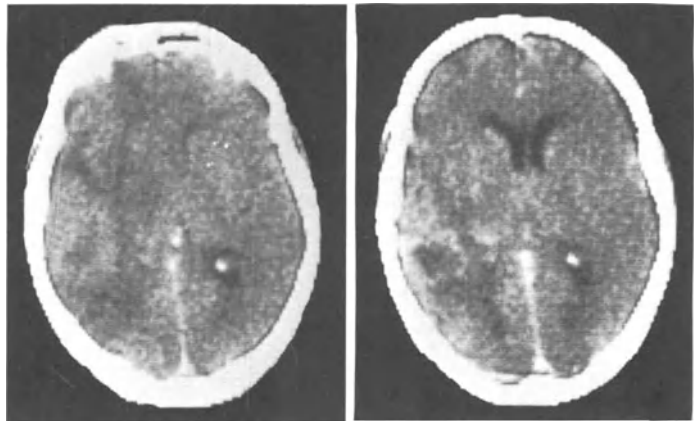


Fig. 3. CT showing diffuse brain edema caused by a left-sided temporal glioma compressing the ventricular system. Following the combination therapy (dexamethasone 4x4 mg i.m./die and furosemide 3x40 mg p.o./die) brain edema is disappearing, ventricles are reopening

Effects of a Local Cryogenic Lesion on Enzyme Activities in Cat Brain

A. WEIDNER, D. STOLKE, and H. DIETZ

Biochemical studies on brain edema have dealt primarily with changes in electrolyte concentration, glycolytic metabolites and energy-rich phosphates in the edematous area. There are few reports on changes in enzyme activities in the edematous brain (1, 8). Enzymes are unable to alter the equilibrium of a chemical reaction. However, they can change the rate at which this equilibrium is reached and so influence brain metabolism. Furthermore, enzyme activities can be modified by substrate concentration, intracellular pH, hormones and drugs. We studied the effect of a local cryogenic lesion on the activities of certain enzymes involved in glycolysis and energy production in both the edematous and the unaffected area. The following enzymes were assayed:

1. Creatine phosphokinase (CPK), an enzyme that contributes to ATP maintenance in the brain.
2. Glucose-6-phosphate dehydrogenase (GDH), an important component of the pentose-phosphate shunt participating in the formation of myelin (4).
3. Lactate dehydrogenase (LDH), responsible for oxidation of NADH.

Methods

Six groups of five to ten adult cats were used. The animals were anesthetized with 30 mg/kg of Ketamine. Three groups were subjected to a cryogenic lesion by a 13x9 mm probe, cooled to -70°C and applied for 45 seconds to the exposed dura overlying the right suprasylvian gyrus. Three control groups were sham operated, but received no cold injury. Experimental and control animals were sacrificed at 24, 48 and 72 hours after procedure. In each case the brain was removed and the necrotic area discarded. The white and gray matter of both hemispheres was separated and homogenates prepared. CPK, GDH and LDH activities were measured in these homogenates (6, 2, 3).

Results

Figures 1 - 3 illustrate our results: the enzyme activities (U/g fr. wt.) in the injured and uninjured hemisphere are expressed in percentage of the control value (= 100%).

At 24 hours cortical CPK (Fig. 1) was found to be decreased in the injured hemisphere when compared both to the control value and to the uninjured hemisphere. At 48 hours the cortical activity of both the damaged and uninjured hemispheres were increased when compared with the control. Changes were more pronounced in the uninjured hemisphere. At 72 hours the CPK activity of both hemispheres was diminished. These changes were significant ($p < 0.05$). Changes in the white matter were similar to those of the cortical activity but to a smaller degree.

The GDH activity (Fig. 2) was significantly higher in the cortex of the injured hemisphere at 24 hours after cold lesion when compared to the uninjured hemisphere. No significant differences were found at 48 hours. At 72 hours, however, the cortical activity in the injured hemisphere was higher than that found in both the uninjured tissue and the control value. In the white matter at 24 and 48 hours the alterations were different to the change of enzyme activity in the cortical tissue: In the white matter we found a significant decrease of GDH activity when compared to the control value. At 72 hours the changes were similar to those in the cortex: a slightly higher GDH activity was detected in the damaged tissue when compared to the control group, but not when compared to the uninjured hemisphere. The changes in LDH activity (Fig. 3) were not significant in both the white and gray matter at 24 and 48 hours. Only at 72 hours after cold lesion we found a significant decrease in both injured and uninjured gray and white matter when compared to its control values.

Discussion

Changes in cerebral enzyme activities may result from the invasion of reactive microglial cells after injury. Our observation of increased GDH activity in the cortex correspond to the histochemical findings of RUBINSTEIN et al. (8) in the reactive microglial cells after cold injury. Changes are also due to the varying enzyme-protein contents, and this in turn is determined by synthetic and degradation rates in the brain tissue at a particular time. These rates were not measured in our study, therefore our results have to be interpreted cautiously (9). Furthermore, they are obviously "in vitro" measurements, which may or may not reflect similar "in vivo" changes. An increase in the concentration of an enzyme must not be associated with any change in the actual rate of its reaction "in vivo", although it may be considered as a potential increase in the capacity of the system to carry out this reaction (5). In addition the overall metabolic consequences of such enzymatic changes remain purely speculative at the present time. However, an interesting observation was that significant alterations in enzymatic activities were found both in the injured and contralateral hemisphere. This finding - whatever its ultimate significance may turn out to be - indicates that localized cerebral tissue injury can lead to biochemical changes elsewhere in the brain, probably as the result of humoral mediators that have to be defined yet (7).

Summary

The activities of CPK, GDH and LDH in the white and gray matter in both hemispheres were analyzed 24, 48 and 72 hours after a local cryogenic lesion (-70°C, 45s) through the intact dura in cats under Ketamine anesthesia (30 mg/kg). The enzyme activities were compared to activities in control groups, which were sham operated, but received no cold injury.

Significant alterations in enzyme activities were found in both the injured and contralateral hemisphere and indicate that localized cerebral tissue injury can lead to biochemical changes elsewhere in the brain.

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Fig. 1. Creatine phosphokinase activity (CPK) in cortex and white matter 24, 48 and 72 hours after cold lesion in % of control values

Fig. 2. Glucose-6-phosphate dehydrogenase activity (GDH) in cortex and white matter 24, 48 and 72 hours after cold lesion in % of control values

Fig. 1

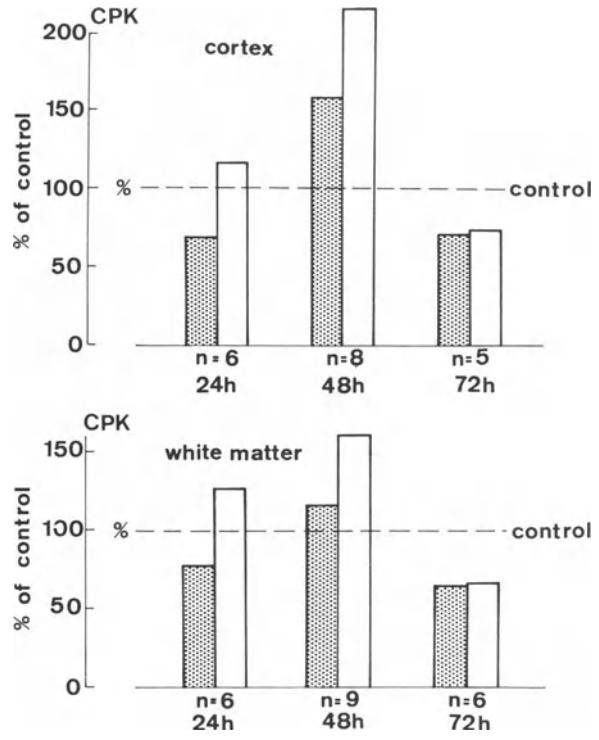
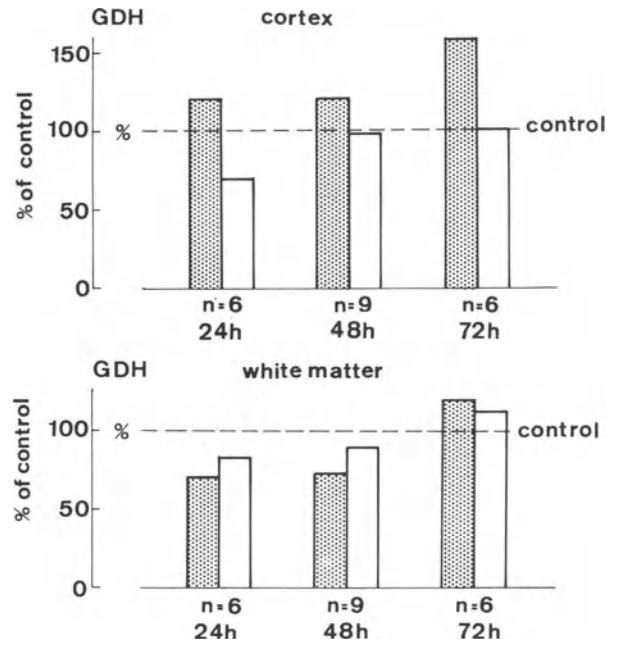


Fig. 2



■ injured hemisphere
□ uninjured hemisphere

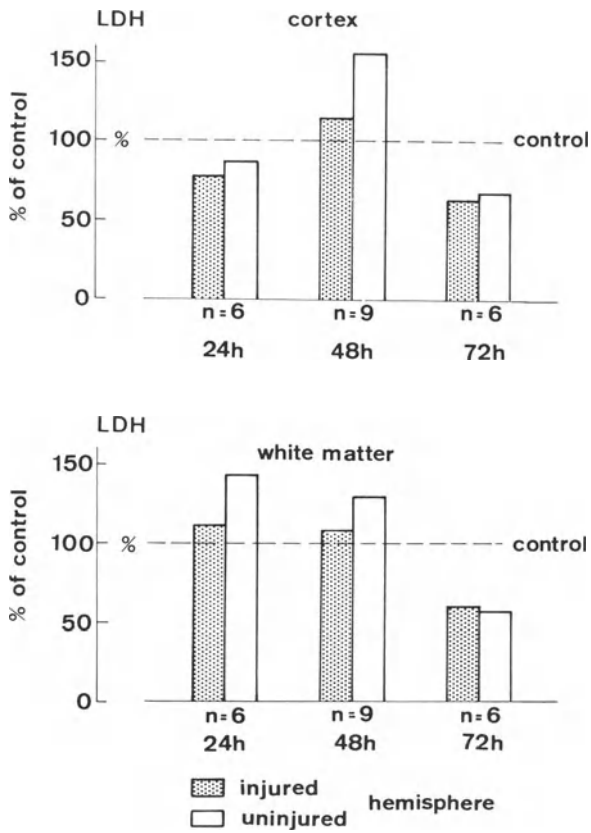


Fig. 3. Lactate dehydrogenase activity (LDH) in cortex and white matter 24, 48 and 72 hours after cold lesion in % of control values

Therapy of Experimental Brain Edema in Cats

M. GAAB, O. E. KNOBLICH, K. DIETRICH, J. SCHUPP, and U. FUHRMEISTER

Introduction

Up to now, continuous experimental monitoring of the acidotic tissue metabolism (2, 10) in brain edema has been impossible. If biochemical tissue analysis is used, the effectiveness of various forms of treatment can only be established by investigation of large series of animals. However, some *signs* of brain edema can be recorded continuously. The accumulation of tissue fluid and the vasoparalysis in the edematous tissue will increase the brain volume, this causing a rise of *intracranial pressure* (7, 13, 16). On the other hand, the disturbance of the tissue function will affect the *bioelectric activity* (6, 8, 11). We monitored the effects of various methods of therapy on experimental brain edema in cats by continuous recording of both ICP and EEG. As local edemas may be accompanied by *pressure gradients* (9, 15, 16), we measured the ventricular pressure (VP) as well as the epidural pressure (EP) over both hemispheres. For a continuous assessment of therapeutical effects on both EEG and ICP, a computer was used to evaluate the EEG activity.

Material and Methods

In 35 cats, anesthetized and artificially ventilated, we trephined the right parietal bone. A copper stamp of 2 cms diameter with a constant temperature of -73°C was placed on the dura for 5 min. Then we closed the trepanation by a Palacos graft which had been prepared before the cold injury. Using Statham transducers, the arterial pressure (aP) and the central venous pressure (cvP) were recorded by angiocatheterisation. For monitoring the VP, the left lateral ventricle was punctured. Epidural pressures under the right and left parietal bones (rEP, lEP) were measured by newly developed transducers (4) which were implanted in coplanar contact with the dura.

The EEG was recorded via bipolar electrodes screwed in fronto-occipitally on both sides. Both channels were evaluated by *fast Fourier transformation* (FFT, Intertechnique Plurimat S). For this study, only the total power was evaluated in a range between 0.5 and 25 Hz. We used the mean power before the trauma as a reference value (= 100%) (8). Treatment began as soon as the ICP recordings showed a marked increase (VP no less than 40 mm Hg). At this time, usually 1 to 2 h after the operation, there were already marked changes in the EEG. The serum osmolality was measured by cryoscopy.

Results

Before the trauma, the results of rEP, lEP, and VP measurements are nearly equal. Fluctuations of cvP will set up small sympathetic fluctuations of all ICP values, whereas aP fluctuations ranging from 70

to 150 mm Hg are not affecting the ICP. This is a sign of intact cerebral autoregulation. The EEG power will fluctuate up to $\pm 35\%$ around the value of 100% (depth of anesthesia).

Following the trauma, the *intracranial pressures* will rise quickly. The rates of pressure increase vary from one animal to another. The pressure recorded over the lesion (rEP) will increase considerably faster than the pressure over the opposite side (lEP). The pressure gradient may be as high as 80 mm Hg (Fig. 4). The lEP always reaches higher values than the VP, with differences between the two pressures up to 40 mm Hg (Fig. 1, 4).

The EEG power will decrease immediately after the trauma. The decrease of power is more marked over the side of the lesion. After 2 to 3 h, the EEG will reach the zero line, on the right side up to 10 min. earlier than over the left hemisphere.

Osmotherapy by means of either a 10% glycerol¹ (Fig. 1, 1560 mOsm/kg) or 20% mannitol (1310 mOsm/kg) infusion will lower the ICP exponentially. The rEP reading will remain higher than both lEP and VP, which are approximately equal. Between 30 min. and 1 h after the infusion, all pressures will increase again, although serum osmolality remains raised. Now, due to vasoparalysis, aP fluctuations cause marked synchronous ICP fluctuations. The EEG will improve only over the left hemisphere, which was not traumatized, and will deteriorate again quickly after the infusion, while the ICP remains still low and the aP has not yet dropped.

Infusions of higher osmolality, such as 40% sorbitol (Fig. 2, 3200 mOsm/kg) and 20% glycerol¹ (2900 mOsm/kg) will lower the ICP much faster, and even the rEP over the lesion will reach normal values. The serum osmolality increases more markedly. Both aP and cvP will rise temporarily. Following the infusion, the decrease of these pressures accelerate the rate of decrease of the ICP. The EEG power markedly improves on the left side only. This improvement, however, is more noticeable than in Fig. 1. Here again, the EEG then breaks down quickly while the ICP is still low.

Treatment with THAM buffer (Fig. 3) will cause a noticeable reduction of the ICP over both hemispheres. After this drastic drop, ICP will increase again, slowly at first, and then more quickly after the infusion is stopped. A second application of THAM has similar effects. Infusion of THAM will also cause a remarkable recovery of EEG power. After the second infusion of THAM, the EEG on the left side will improve far beyond the 100% mark, while on the right side there is a marked improvement as well. In this case, the EEG power is maintained much longer than after osmotherapy. The EEG will reach zero as late as 3 h or more after the end of therapy.

Figure 4 shows the results of resection of the edematous brain tissue. All pressures will return to normal after the dura is opened and they will remain normal even after the graft is reinserted. The recovery of the EEG power, which in this case will go beyond 100% as well, does not occur immediately after decompression but only after the edematous tissue has been resected. For the entire duration of the experiment, the EEG power measured on the left side will remain high, and even on the right side the EEG will not drop to zero in spite of the loss of part of the cortex.

Only the animals treated in this fashion still show spontaneous respiration as late as 8 h after the trauma.

Decompression without resection of the edematous tissue will normalize the ICP, but the EEG collapses as quickly as after osmotherapy.

¹ Glycerol in isotonic electrolyte solutions.

Discussion

According to the measurements of VP and EP on both sides, only before the trauma the ICP can be regarded as a uniform value. After the lesion, there will be a considerable *pressure gradient* between the EP measured over the lesion and the EP over the opposite side. This gradient can be interpreted as an effect of the elastic and viscous properties of the brain tissue (17). In addition to this, the rigid falx acts as a barrier. For an interpretation of the pressure gradient between VP and EP, the elastic property of the dura is also to be considered. Measurements of EP have increasingly been employed in clinical studies (3, 18). But because of the pressure gradients, the EP is only a *limited indicator of ICP*.

Analysis of EEG power shows the drop in bioelectric activity which is associated with the increase of pressure. However, the rise of the ICP can not be regarded as the only causal factor for the drop in bioelectric activity. A mere ICP reduction by either osmotherapy or decompression only produces a momentary improvement of the EEG, probably due to improved circulation. But the EEG breaks down soon afterwards, while the ICP is still low. The EEG recovery produced by treatment with THAM buffer is much more noticeable and remains long after the ICP reduction has ceased to be evident. The ICP reduction produced by THAM treatment is probably caused by vasoconstriction which depends on the pH value (1, 5). This illustrates the contribution of vasoparalysis to the increase of the ICP.

Surgical removal of the edematous brain tissue proved to be the best therapy for cold-injury edemas in cats, and it was not decompression but the removal of the edematous tissue which caused the EEG to improve for a prolonged period of time.

The results of osmotherapy, buffer therapy, and surgical resection indicate that brain edemas cause *two vicious circles* which have to be treated:

First, the increasing ICP which must be lowered to prevent further progression caused by tissue hypoxidosis, which in turn is caused by reduced circulation.

Second, there is the acidosis of the edematous tissue (dysergic metabolic state", according to MYERS (14)) which must be treated to stop the dysbolism from spreading through vasoparalysis and H⁺-diffusion.

Summary

After inducing a cold-injury brain trauma we measured the EEG, the ventricular pressure, and the epidural pressure of the experimental animal over both hemispheres. The EEG was evaluated using Fast Fourier Transformation. Both osmotherapy and surgical decompression serve to lower the intracranial pressures but improve the EEG only briefly. THAM therapy improves the EEG power over longer periods of time. The ICP is lowered as well, but only briefly. Resection of the edematous tissue brings the pressure back to normal and causes the EEG to improve for prolonged periods.

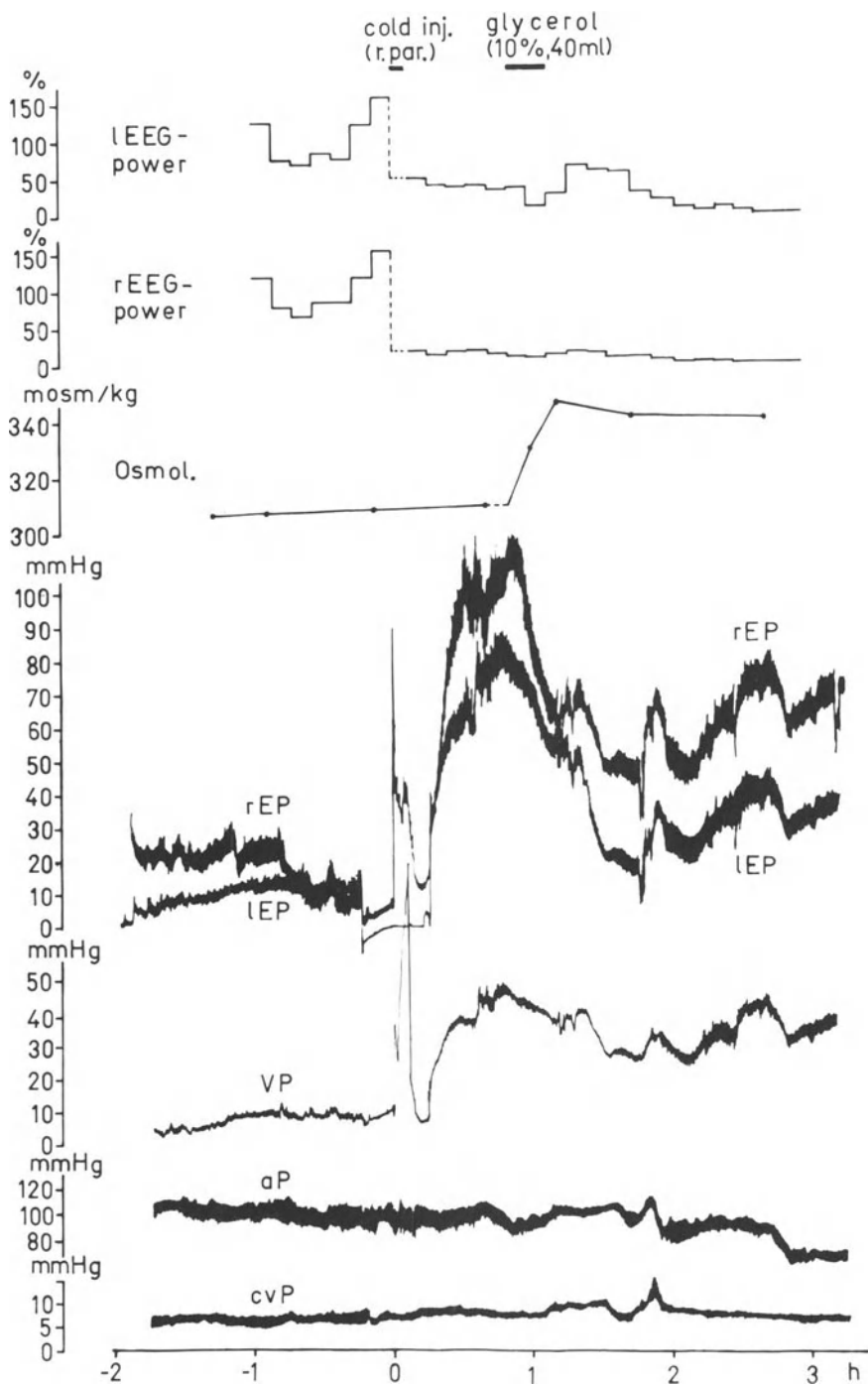
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Fig. 1. *Infusion of 10% glycerol*. As serum osmolality increases (Osmol.), all brain pressures (rEP, lEP, VP) drop. The EEG power improves only over the non-traumatized side (lEEG). 1 h after the infusion, pressures increase again despite a high osmolality. The EEG power drops to zero while brain pressures are still low. Note pressure gradients. r.par. = right parietal



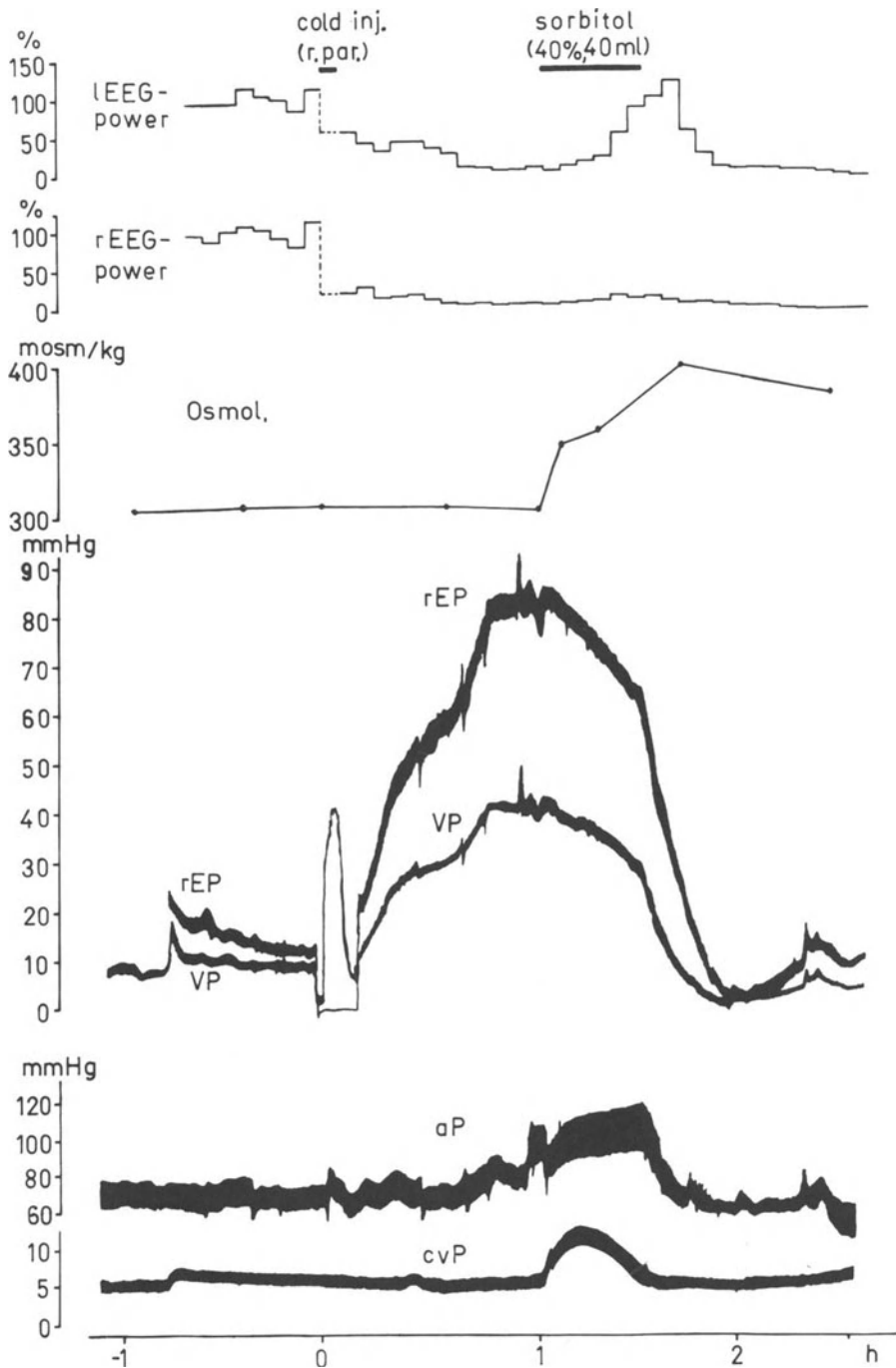


Fig. 2. Infusion of 40% sorbitol. All pressures drop swiftly (lEP was not recorded), increasingly after the infusion while aP and cvP are still dropping. After the infusion is stopped the EEG, which improved markedly only on the left side, breaks down swiftly while brain pressures are still normal

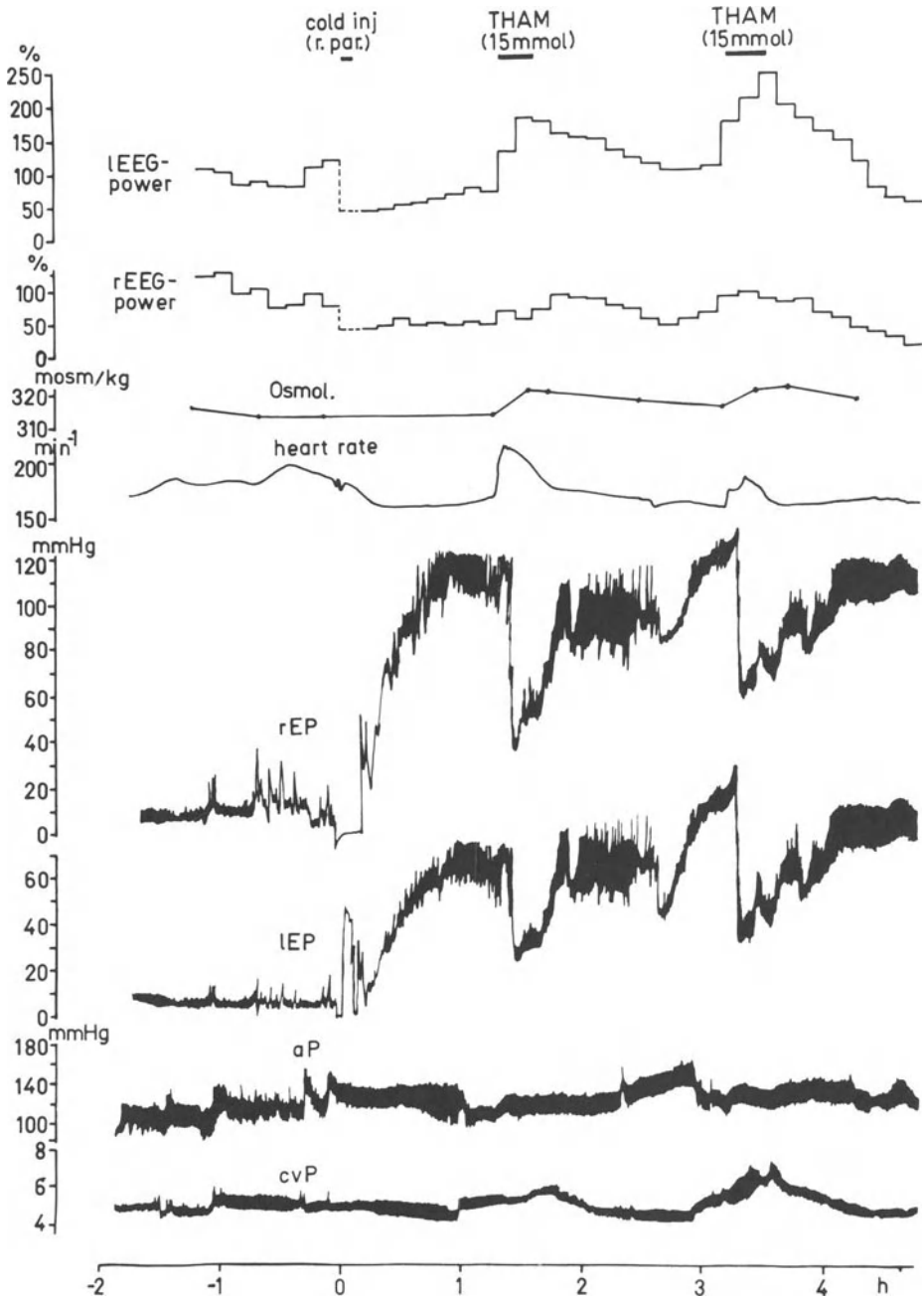


Fig. 3. *Infusion of THAM.* Shortly after the onset of the infusion, all pressures drop quickly (VP was not recorded), beginning to rise again some time later. The EEG improvement is more marked than that produced by osmotherapy. This applies to the right side as well

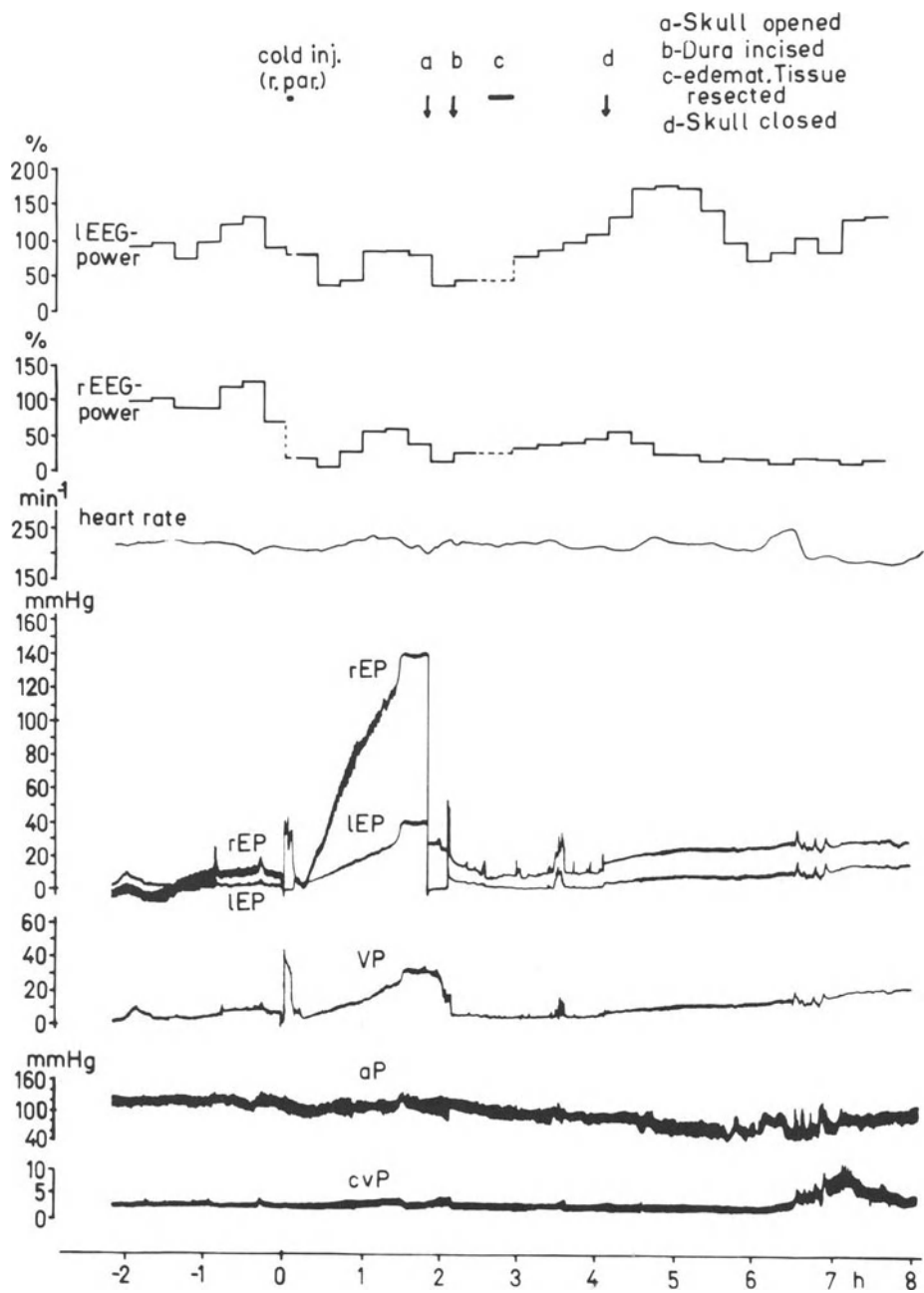


Fig. 4. *Surgical removal of the edematous tissue.* All pressures return to normal after the dura has been opened. They remain low even after the graft is reinserted. The EEG improves only after removal of the edematous tissue. The EEG power remains high over the left side, and will not drop to zero on the right side in spite of the loss of brain tissue

EEG-Monitoring During Early Phases of Neurosurgical Intensive Care. Posttraumatic Limbic Epilepsy¹

F. MILTNER and N. SOERENSEN²

Introduction

With neurosurgical patients the perisurgical period is often characterized by coma, dysregulation of autonomic functions and pathological motor events. In intensive care units polygraphic monitoring of autonomic phenomena is essential for therapeutical decisions. Conventionally heart rate, respiration, body temperature and arterial and venous pressures are recorded. More recently intracranial pressure monitoring and EEG-parameters were added in order to get further information about fundamental pathophysiological processes such as rhythmic events and focal bioelectrical signs and synchronization phenomena. Increase in synchronization of bioelectrical activity is well-known to neurophysiologists with comatose patients. Seizure discharges without motor events are, however, suspected to be of less importance (8).

Methods

The investigation was performed in 220 (100%) comatose patients before and after neurosurgical interventions. EEG-activity was recorded monopolarly and bipolarly of convexity of the skull and base (tympanal leads) over periods of up to three days. Potential shifts were amplified and stored on magnetic and paper tape by use of a conventional 8-channel EEG-recorder.

Hypersynchronous potentials and seizure patterns were analysed visually. Anticonvulsive drugs were applied intravenously. Anticonvulsive effects of Diazepam, Clonazepam, Hydantoin and barbiturates were measured and the results compared with each other.

Results

With 220 (100%) comatose patients EEG-activity was recorded. It was observed that in 96% of records the overall activity was more or less severely slowed down. Focal seizure events were recorded with 13% of patients. Seizure states were found with 3% of patients. Clinical signs were often weak and more intense observations were necessary. Sometimes tonic head movements, myoclonic, hemifacial and brachial twitches occurred. Hypersalivation, dysregulation of body temperature, heart rate, arterial pressures as well as hyperglycemia were recognized.

¹ Supported by the "Deutsche Forschungsgemeinschaft", SFB 33 (Arbeitsgruppe A 3).

² We gratefully acknowledge the competent technical assistance of M. Stolz.

EEG-recordings of the convexity of the skull during clinical seizure states not rarely showed nonspecific variations (Fig. 1, 2, 3).

Tympanal leads recorded synchronously sharp waves, multispike-wave patterns or focal increase in theta-waves (Fig. 1, 2, 3).

As a rule tympanal bioelectrical activity corresponded quite well with the patients' behaviour. Focal seizure activity spread from one tympanal lead to the other one (Fig. 3). Hemilateral propagation of discharged were observed (4).

Diazepam and Clonazepam abolished limbic seizure activity most effectively (Fig. 2). Hydantoin lowered the hemilateral propagation of seizure discharges (Fig. 3).

Discussion

It is well-known to electroencephalographers who have recorded from deep structures in patients with epilepsy that electrical seizure activity may occur in depth without seizure spread to the cortex and with only weak clinical signs (1, 2, 5, 6, 7). During seizures high coherences were found to develop between the EEG-activity from deep structures and from cortex (2).

This investigation shows that the tympanal EEG-activity mainly originates from subcortical, limbic structures. Interictal focal seizure activity was recorded from the base of temporal lobes without spreading out to the convexity via thalamus. Spreading discharges were regularly recorded from the opposite temporal base via hippocampal psalterium.

Intravenous application of Clonazepam and Diazepam rapidly interrupts ictal discharges and desynchronizes overall activity. These findings with comatose patients are in accordance with the results of M.A. BRAZIER (2, 3). EEG-monitoring during early phases of neurosurgical intensive care may improve our knowledge in posttraumatic limbic epilepsy. Further investigations are necessary.

Summary

Cerebral bioelectrical activity of convexity of the skull and base (tympanal leads) was monitored sequentially with 220 (100%) neurosurgical patients over periods up to three days. Potential shifts were stored on magnetic- and papertape.

EEG-data have proved to be a very useful background information for therapeutical decisions. With unconscious patients (95%) changes in vigilance-levels could be evaluated. Status-like seizure patterns - often without motor events - were discovered (16%). Drug effects on different seizure patterns were investigated.

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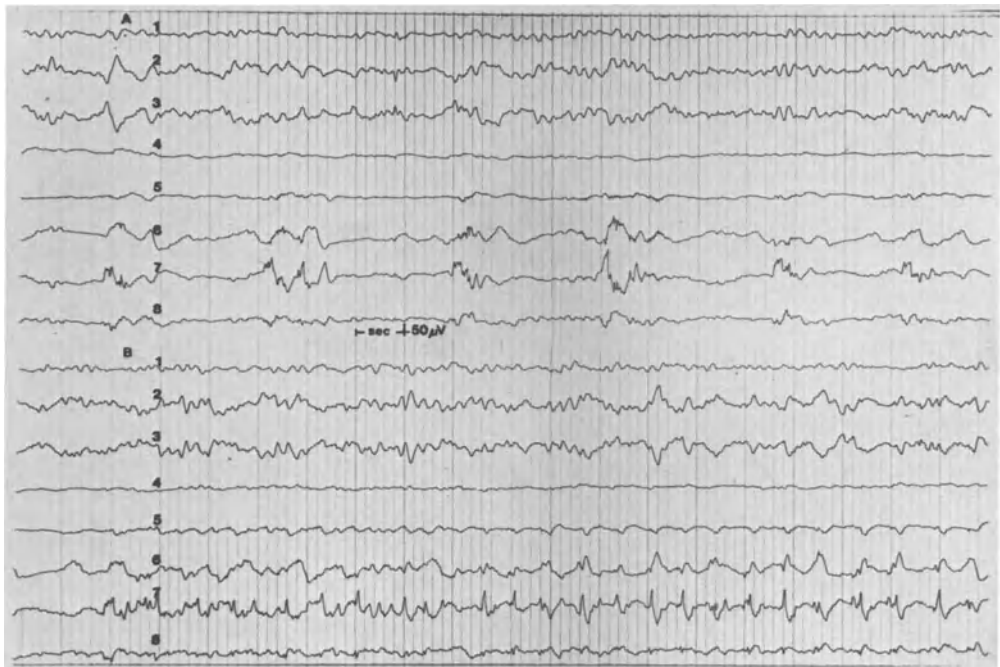


Fig. 1 A and B. EEG excerpts of two comatose patients with hypersalivation, hyperthermia, hyperglycemia. Bipolar recordings. Basal longitudinal rows of the 10-20 system; T₃ and T₄ are used as tympanal electrodes. Note: focal seizure patterns right tympanal (traces 6, 7)

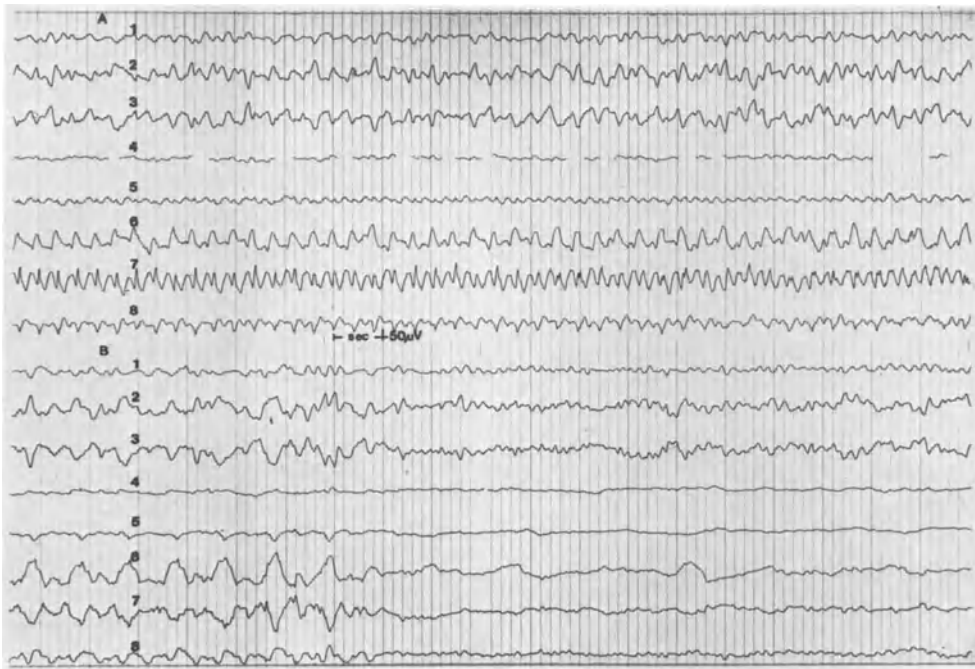


Fig. 2. Two EEG excerpts of a comatose patient during a limbic seizure with adverse movements, clonic hemifacial twitches and autonomic disregulation. Basal longitudinal rows (10-20 system), T₃ and T₄ are used as tympanal electrodes

A Onset of seizure right tympanal

B After injection of Clonazepam seizure activity was interrupted

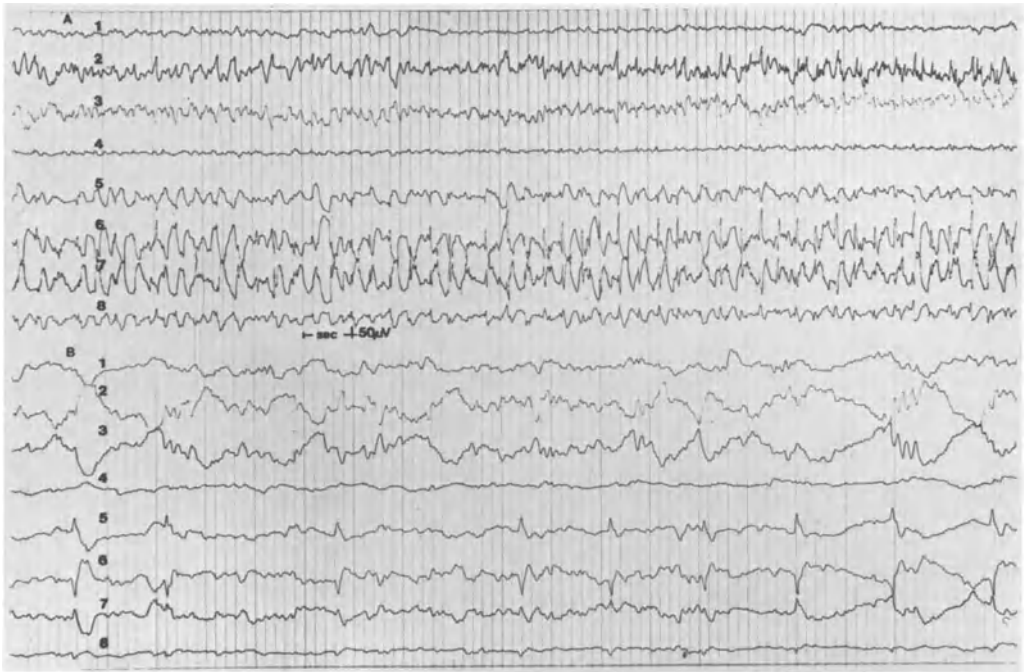


Fig. 3.

A Focal seizure pattern right tympanal (traces 6, 7), spreading discharges out to left tympanal (traces 2, 3)

B Modified seizure discharges after application of Hydantoin and Pheno-barbital

Cliniconeurological and Computer-Analysed EEG Investigations of Patients in Coma Following Operation for Cerebral Trauma

J. KRÜGER, W. I. STEUDEL, M. SCHÄFER, and G. DOLCE

Even today the cliniconeurological examination has remained the best method at the patient's bedside, in order to recognize and assess the depth of coma as a result of pathological removal of the reticular, mesodiencephalic growth system (11). Since BERGER (1) the EEG has become an essential contribution to the clinician, especially if the possibility for follow-up studies is available (14). Such follow-up studies provide so many data, that in the normal-visual-interpretation, only a small number of patients remain for investigation. Over the last decade, due to the rapid development of the computer-technique, the discovery of the Fast-Fourier-Algorithmus by COOLEY and TUKYE (4) and the segmentation procedure by WELCH (17), a well-based method could meanwhile be found for the computer evaluations of the EEG (2, 3, 5, 6, 9, 10, 15, 18). From the submitted-prospective-studies, arose the question if one can use the EEG records for follow-up studies with the aid of this computer-technique so that they allow prognostical indications.

Method

Patients in deep coma were cliniconeurologically examined on the 3rd, 6th, 9th, 12th, 15th and 18th postoperative days. Here the specified examination formular from GERSTENBRAND, LACKNER and LÜCKING (7) served as an example. The patients were examined on each occasion by the same doctor, so that subjectively different examination results would be eliminated as far as possible.

On the above-mentioned days, over approximately one hour in each case, the EEG was directed to both fronto-parietal, parieto-occipital and temporal regions with the aid of platinum needle electrodes. They were registered together with heart and breathing activities via an ALVAR-EEG machine and stored on magnetic tape (JOHNE and REILHOFER 8 K60) under oscillographic control. By Fast Fourier Transformation (FFT), power density spectra of the EEG were computed off-line on an "AEG-Telefunken Bio-Signal Prozessor Bio 16 (Programme ESAP)". EEG-samples of 4 sec duration (that means a resolution of frequency of 0.25 Hz) were used. The periodograms so obtained were smoothed by a triangular window. One average spectrum was computed from 45 spectra, i.e., from 180 sec of EEG corresponding to each situation. From the average spectra the percentages of alpha, beta, theta and delta intensities were calculated. Apart from that the crosspower spectra, intra- and inter-hemispherical and coherences were calculated. The cross spectra were evaluated from two EEG-signals of different localities and produce the spectral-EEG-components of which both signals are common. The coherence function relates the statistical association of two time-function; it is a normalized function which fluctuates between 0 and 1 and is defined by the following formula:

$$C = \frac{(S_{xy})^2}{S_x \cdot S_y} .$$

C = Coherence, S_{xy} = cross spectra, S_x = spectrum of one signal, S_y = spectrum of the other signal.

Mathematically it means that the synchronization of signals at one and the same time is especially high - 1 - or especially low - 0 -. Higher values result from a constant phase relation inter- or intra-hemispherical (12) (Fig. 1).

Special Investigations

With the aid of the above-mentioned method, 15 patients (5 females, 10 males) between the ages of 12 and 74 were examined. All patients on admission to the clinic and three days after the consequent operation were in coma stage II or III according to FISHGOLD and MATHIS 1959 (8).

The brain injuries which lead to these disturbances of consciousness, were as follows - 7 epidural hematomas, 3 subdural hematomas, 2 intracerebral hematomas, 2 impressions fractures and one combined epidural and intracerebral hemorrhage with involvement of the ventricles. The treatment was the same for all patients, namely reduction of edema, prevention of infection, equalization of metabolism and nutrition. All patients were nasally intubated at the time of the coma.

Results

In order to maintain as far as possible a similar group of patients at the beginning of the investigation, only those injured patients were selected who had suffered from a localized cerebral trauma and who had the intracranial lesion operatively removed, and who were also in deep coma on admission to the clinic and remained comatous during the following operation. Seven patients had extension spasms in the first days, which in one case was also generalized.

Two patients recovered completely, so that they could be reintegrated into their former social surroundings, two suffered as a result definite defects, four remained in prolonged coma and seven died (during the 9th and the 13th postoperative days). The visual interpretations of the EEG produced in general severely changed activities in all cases with predominance of the delta-activity. Focal spasm-sources were evident in 5 cases, although on one occasion the focus was first demonstrated on the 15th postoperative day. In two cases spindles occurred in the 3rd and 4th postoperative days; from these patients one was in prolonged coma and one healthy. The alpha-EEG could not be observed in any one case (13).

The spectral analyses of EEG, i.e. the visual evaluation, produced at first a predominant output in the delta-range, which was lower in the theta- and in general no longer relevant in the alpha- and beta-ranges. At the same time, the autospectra above the area of the brain were differently defined; in some cases better above than opposed to the operated sections (contre-coup), in some cases worse above the operated sections, although here it was a question of operatively determined additional contusion lesions.

During the follow-up studies, the development of the spectral analysis was relevant to the clinical picture; by improvement of the neurological symptoms an increase of the total power generally occurred, which moved parallel to a displacement to the right of the curve in the direction of the higher frequencies and - as an important criterion -

became apparent as a peak in the 8-12 Hz-range (Fig. 2). By development of the prolonged coma only a moderate improvement slowly appeared although we were not able to see a peak at 8-12 Hz in any patient (Fig. 3). By clinical deterioration and death the spectral power became also poorer, although those which at first were in better condition, for the most part deteriorated (Fig. 4).

The cross-power-spectra showed as expected a well-defined appearance at the point where the autospectra of both areas of the brain in comparison to one another had also shown a good improvement. Their series corresponded to the autospectra.

The coherences were throughout poorly defined; in every case they were, above all those who had taken a fatal outcome. The "independent" behaviour of the coherence in the case of one patient following an epidural hematoma was especially clear. In the beginning the patient appeared to have a good prognosis on the base of the clinical studies and the EEG spectral values, but nevertheless developed a prolonged coma. Here the curves of the coherence activities - from the very beginning poorly defined - already showed a falling-off on the 3rd day although the autospectra had revealed an improvement up until the 12th postoperative day.

Discussion

Despite the vast number of scientific investigations concerning the coma, neither purposeful treatment nor prognosis is possible. For the assessment of coma, the state of consciousness is of decisive importance. In cases with disturbed consciousness, one can define two different forms: a disturbance of vigilance and a disturbance of the area of consciousness (PLUM et al. 15). The coma is characterized by a massive disturbance of vigilance. It can be established by thorough cliniconeurological examinations, although subtle changes would not be disclosed. We have a better indicator of the vigilance disturbance in the EEG, although the results can be substantially improved by the computer analysis - especially the quantitative analysis.

The autospectra of our 15 patients all showed at the beginning relatively high values in the delta-range. In the further series an increase in the total power with displacement in the higher frequency ranges (improvement) or a decrease with withdrawal in the lower ranges (deterioration) was recorded in accordance with the clinical picture. The early appearance of a peak in the alpha-range proved to be particularly advantageous.

The spectral analysis of the EEG provides not only a quantitative analysis, but also an evaluation of the coherence function. Our investigations indicated that the coherence function between different areas of the brain in one and the same patient are not the same, but are dependent on the degree of severity of injury, thus well or poorly defined. In our cases the coherences were mainly very low and lay between 0.2 and 0.6 at the bottom of the frequency ranges.

Before drawing conclusions from the degree of the coherences, further investigations are necessary.

Summary

A group of 15 patients in deep coma following head injury were cliniconeurologically and electroencephalologically examined every 3 days, from the 3rd to the 18th postoperative day. The EEG was interpreted visually and with a computer in the Fast-Fourier-Transformation analysis. The results were discussed and special emphasis was placed on the development of autospectra and coherences.

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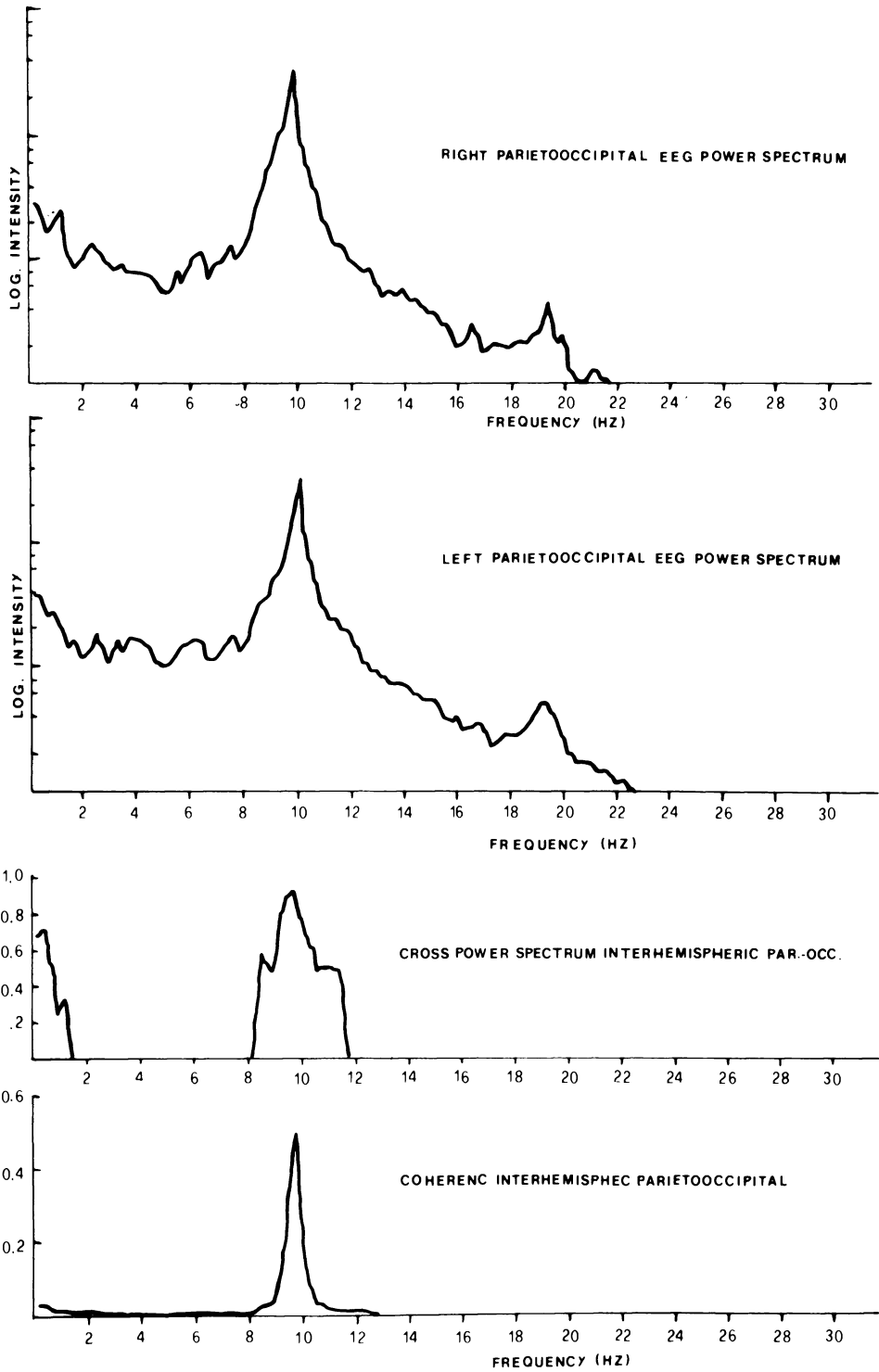


Fig. 1. Auto- and crosscorrelationspectra and coherence from a normal alpha-EEG (30 year old man)

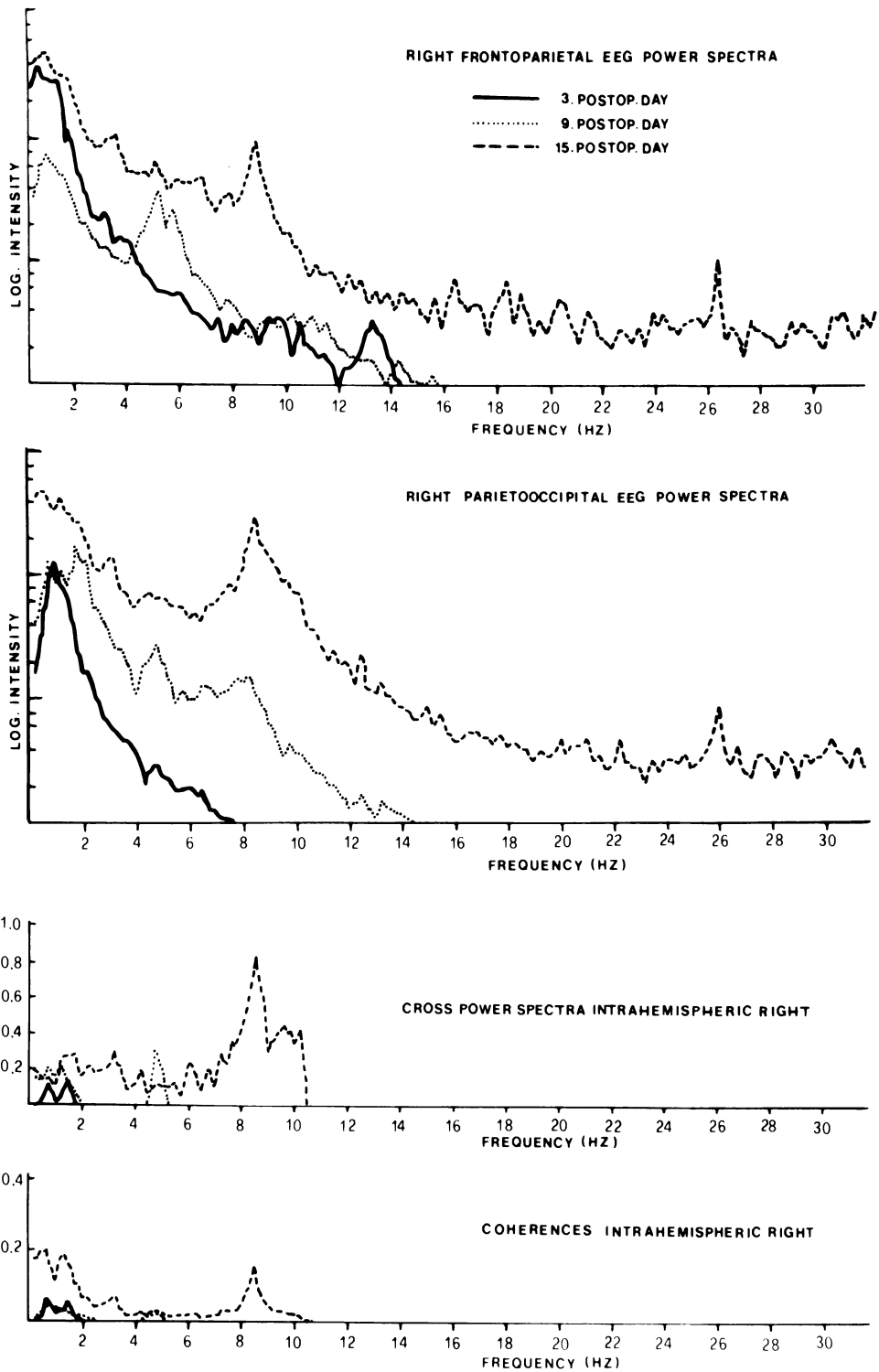


Fig. 2. The development of auto- and crosscorrelationspectra and inter-hemispheric coherences from patient (patient W.K., 20 year old) with an intracerebral hemorrhage in the right occipital region. Recovering with an alpha-peak

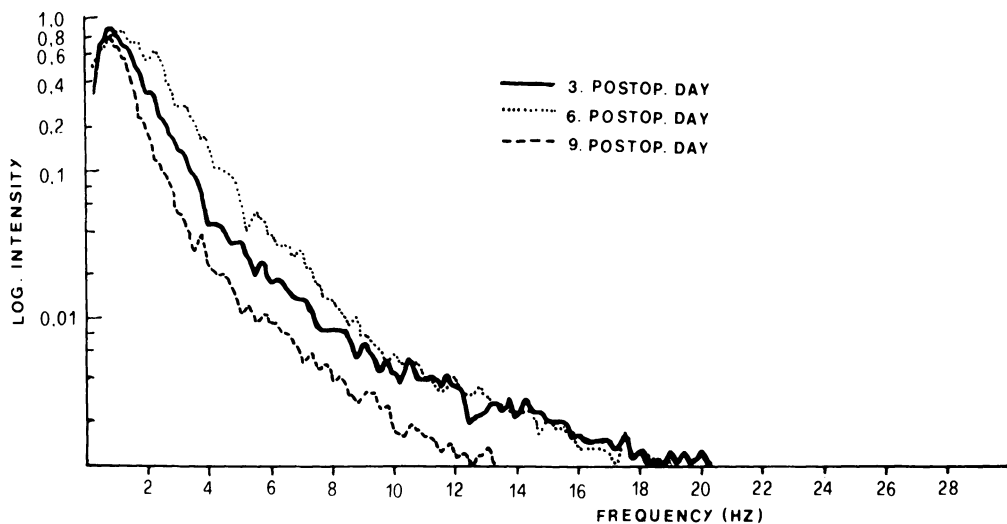


Fig. 3. The development of the autospectra from the right frontal region. Patient G.B. (51 year old man) acute subdural hematoma at the right. Prolonged coma

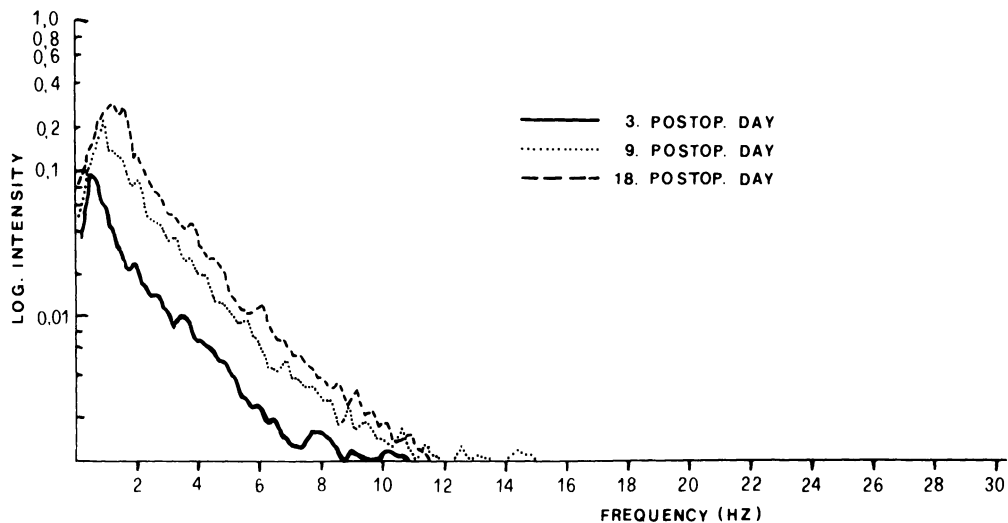


Fig. 4. The development of the autospectra from the left occipital region. Patient K.P. (35 year old man) epidural hematoma in the left parietal region, he died on the 11th day after surgery

EEG-Analytical Follow-Up Study of Stroke Patients Under Hyperbaric Oxygen Treatment

H. WASSMANN and K.-H. HOLBACH

Introduction

Electroencephalography (EEG) is helpful in showing the effects of various treatments in patients with cerebral lesions. For this reason and encouraged by the findings of others (1, 4), we applied EEG several years ago to detect the effect of hyperbaric oxygen (HO) therapy in cases of brain trauma and cerebral infarction (2, 3). The conventional EEG examination and evaluation, however, complicated this task because of the rapidly increasing amount of data. We, therefore, used an automatic EEG-interval-amplitude-analysis-system, which is keyed to the visual evaluation of the EEG curve (5, 6); the system proceeds by measuring and counting, provides quantifiable and reproducible results, and permits an interpretation of the findings by means of customary EEG concepts.

Methods

Forty patients (24 men and 16 women between the ages of 8 and 68; average age 46.9 years) were studied; 20 patients with occlusion of the internal carotid artery and 20 with an obstruction of the middle cerebral artery. Twenty of these 40 patients were in a more or less acute post-stroke stage (stroke without or with only a partial improvement within the first four weeks), and 20 were in a chronic post-stroke stage (permanent neurological symptoms beyond the fourth week). After identification of the brain artery occlusions by angiography, each patient had a series of 10 to 15 HO treatments, which were performed daily.

HO therapy was applied under spontaneous respiration of oxygen at a pressure of 1.5 atmospheres absolute (ata) and a period of exposure of about 40 minutes in a specially constructed hyperbaric chamber. At the same time, frontal, parieto-occipital and temporal EEGs were recorded simultaneously from the hyperbaric chamber in bipolar form on six channels in order to diagnose the artefact, and stored on magnetic tapes. These EEG-analytical tests occurred before the phase of pressure under spontaneous respiration of air, twice during respiration of oxygen under 1.5 ata, after lowering the pressure to 1 ata under respiration of oxygen, and finally 15 minutes after the change from oxygen to air respiration.

EEG-analysis-system determines and prints out the following characteristic measures (Fig. 1): the incidence of events (a) in the respective interval class, the incidence of sums (b) results by adding the incidence of events of five interval classes of every EEG-range during the analysis time, the mean frequency (d) is obtained by dividing the incidence of sums by the analysis time in seconds, the amplitude information (c), adjoined to the respective interval class, results from measuring the amplitude. The interval-amplitude-histogram, developed from these values, connects frequency and amplitude and reveals the

main range of activity. Electrical power equivalent (EPE) (e) results from adding up the amplitude information in an EEG-range and dividing it by the measured time. It constitutes a mean amplitude value per unit of time. This quantity has an informational substance comparable to the power spectrum and indicates the local electrical brain activity.

Results

The forty patients were divided into three groups according to the increase in electrical brain activity over the affected brain region, which was determined at the end of the complete HO treatment (Fig. 2). Group 1 (11 patients) showed a considerable improvement in electrical brain activity, i.e. an increase of EPE values of more than 30% compared to the initial values. In group 2 (21 patients) we noticed an increase in electrical brain activity between 10 and 30% and in group 3 (8 patients) no definite change occurred between the initial and final EPE values. These findings correlated well with the cliniconeurological changes, as the following typical case indicates.

A 39-year-old female patient with occlusion of the right middle cerebral artery and a nearly complete left hemiparesis was given HO treatment one week after her stroke. The EEG-analysis carried out during the first HO session showed above the brain region affected a decrease of theta-wave activity and, in particular, an increase in alpha-wave activity (Fig. 3). This improvement only partially receded after conclusion of the HO session. After the 14th HO we registered a considerable increase in alpha- and beta-wave activity over the affected brain region, coinciding with a moderate decrease in theta- and delta-wave activity (Fig. 4). On the contralateral side we also found a distinct increase in alpha- and beta-wave activity. At the conclusion of the HO treatment, there was a considerable improvement in the electrical brain activity on both sides and a nearly complete recovery of the hemiparesis.

Discussion

Thrombotic or embolic occlusion of the internal carotid or middle cerebral artery can cause an inadequate perfusion of the lateral cerebral cortex. The inherent cerebral hypoxia, ischemia or a combination of these results in accentuated EEG changes over the temporal region. Improvement of electrical brain activity observed at the conclusion of the HO treatment and, particularly, during the period of increased inspiratory oxygen pressures may be attributed to an improved oxygenation of the affected brain tissue. These positive effects occurred in the acute as well as in the chronic post-stroke stage. This EEG-analysis-system enables an immediate and clear presentation of the changes in electrical brain activity and also a statistical evaluation of the data.

Summary

Forty patients with ischemic, hypoxic cerebral lesions caused by occlusion of the internal carotid or middle cerebral artery were given hyperbaric oxygen (HO) therapy. EEG-analyses performed during the HO-sessions showed, that in 80% of these cases the electrical brain activity increased during the respiration of oxygen at a pressure of 1.5 atmospheres absolute. At the conclusion of the HO treatment consisting of 10 to 15 sessions, there was a marked improvement in elec-

trical brain activity in 27%, a moderate one in 53%, and in 25% of these patients no change of the electrical brain activity occurred. The EEG-analytical findings correlated well with the clinical neurological course.

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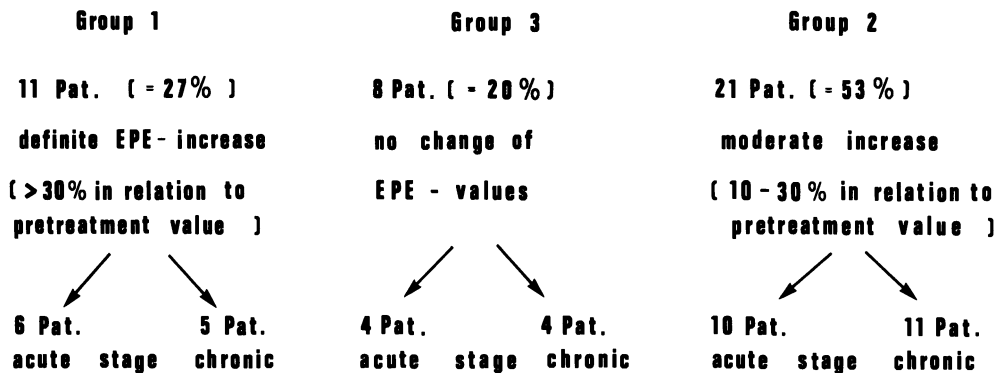


Fig. 2. Changes of electrical brain activity in 40 stroke patients after HO treatment

EPE

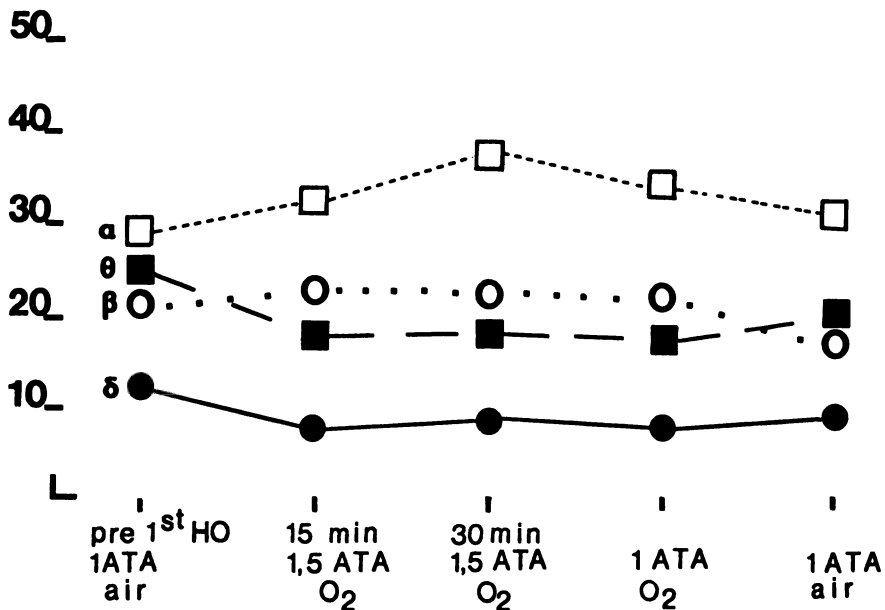


Fig. 3. Changes of electrical brain activity during a first HO treatment (AR = affected region, CR = contralateral region)

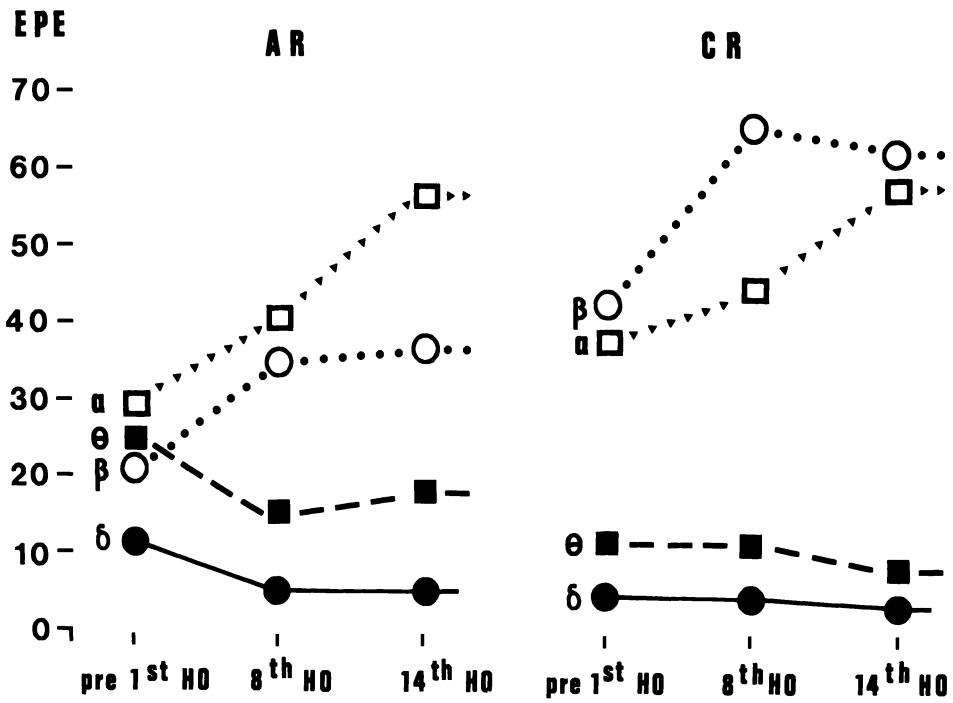


Fig. 4. Changes of electrical brain activity during an overall HO treatment (AR = affected region, CR = contralateral region)

Arousal-Reactions with Unconscious Patients Elicited by L-Dopa, Amantadine-HCl and Akineton¹

F. MILTNER and J. WICKBOLDT²

Introduction

It is generally accepted that the function of aminergic mesodiencephalic systems is to regulate the continuity of vigilance from arousal to deep sleep (4, 5). Vigilance changes following the circadian and BRAC rhythms (90 min.) are based upon intact neuronal systems located at the pontine level (5). The physiological mechanisms of sleeping and waking were investigated since the pioneers' work in the late twenties of this century (5). Little is known, however, about the pathophysiological mechanisms underlying other stages of reduced awareness. More recent investigations propose the concept of a disintegrated arousal system (1, 3, 10). Data indicate that histologically verified lesions as well as metabolic disturbances of the reticular formation of the brain stem produce coma (10).

Cholinergic structures of the brain stem as well as systems with catecholaminergic neurotransmission are involved in the arousal systems (1, 3, 5). Neural systems with serotonergic transmission are known to be sedative in nature and found out to be responsible for the induction of sleep. Phasic and tonic arousal are distinguished. Phasic arousal is thought to be essential for neocortical information processing. Tonic arousal is maintained by limbic circuits and probably facilitated by the individual's orienting reaction to external stimulation (1, 3).

Several studies indicate that a variety of neuropharmacologically active substances elicit tonic arousal (2, 6, 7). This clinical investigation is focussed on behavior and electrophysiological arousal with comatose patients that could be elicited by injections of L-Dopa, Amantadine-HCl or Akineton.

Methods

The present investigation was performed with 540 (100%) comatose patients of both sexes, weighing 56-85 kg, aged 16-63 years. For clinical assessment of the extent of impaired consciousness, the "Glasgow Coma Scale" (8) (TEASDALE and JENNETT, 1974) was used. Bioelectrical activity was recorded bipolarly and monopolarly (GOLDMANN-OFFNER) from the convexity of the skull (needle-electrodes) and base (tympanal leads) by use of a conventional 8-channel EEG-recorder. At the same time, EEG-

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activity was stored on magnetic tape for later off-line-computer analysis. Fast Fourier Transformations were performed and the resulting power spectra were analyzed with respect to their percentage part of conventional frequency ranges. Recording periods varied from 90 minutes up to 3 hours to register spontaneous, rhythmic vigilance variations. External stimuli (light, pain, touch, click) were applied to trigger phasic arousal reaction. Test substances were injected intravenously. L-Dopa was given in increasing amounts up to 100 mg after treatment with the decarboxylase inhibitor Benserazid.

In addition our study was extended to anticholinergic substances and to Amantadine-HCL, which is said to influence the catecholaminergic systems. Intrathecal application of the drugs was performed only at the onset of the present study and found to be less effective than the intravenous injection of drugs. Bioelectrical activity was measured for at least 30 min. after the injection of drugs. EEG-recordings with artefacts were excluded from further examination. In several tests EEG-activity showed an increasing tendency to hypersynchronous potential shifts and seizure patterns. These recordings were analyzed visually. In a few cases EMG-activity was recorded at the same time to answer the question whether or not the drugs do affect limb extension movements. Postmortem histological verification of the sites of lesions was performed.

Results

In general bioelectrical activity of the convexity of skull and base correlated with the clinical findings which allow the documentation of changes in conscious levels along the "Glasgow Coma Scale". If low numbers in coma levels are registered, the overall activity in EEG-recordings is slowed down and occasionally dysrhythmic EEG events have occurred. Phasic arousal reactions with external stimuli of alternating modalities were reduced or even abolished. After pretreatment, rapid intravenously injected L-Dopa elicited tonic arousal reactions with a latency of 40-45 sec. EEG-recordings showed a marked decrease in amplitudes and simultaneously increasing frequencies. The arousal response was related to increasing L-Dopa doses and showed proportional variations (Figs. 1, 2).

This type of arousal response was accompanied by an improvement in the conscious levels and occurred in 73% of our comatose patients. In 21% of patients, tonic arousal elicited from L-Dopa occurred alternating with delta rhythm. This rhythmic sinusoid slow wave activity was focussed bifronto-temporal with irradiation into tympanal leads and lasted for 2-15 sec. Delta rhythms occurred spontaneously in an irregular way. As a rule, however, rhythmic delta activity was triggered by arousal stimuli with L-Dopa treated patients (Fig. 3). In 2% no signs of bioelectrical acceleration were observed after injection of L-Dopa. Coma remained unimproved in these patients. Pathological rise with extensor tonus was slightly increased. All patients who were tested under L-Dopa and remained unresponsive in EEG-recordings, died of central dysregulations within 1 or 2 weeks. Postmortem brains were exposed and prepared for histological investigations.

In addition to L-Dopa Amantadine was also tested. Similar results have been obtained. Tonic arousal triggered by L-Dopa was intensified by Amantadine-HCL. The probability of spontaneously occurring delta rhythms was increased (Fig. 3). In 4% of patients with focal hypersynchronous potentials, restricted discharges were increased. Propagation of seizure activity was facilitated. Under Akineton a marked tonic arousal reaction was observed (latencies: 20-30 sec.). Delta rhythms were not

elicited. L-Dopa triggering delta rhythms vanished when Akineton was injected and only occurred as a response to arousal stimuli (Fig. 3). Local seizure activity increased, propagation of discharges was facilitated.

Discussion

Neural systems located in the brain stem reticular core are the physiological base of waking and sleeping. Disintegrations of these systems cause coma. Structural lesions of greater extent are found to produce additional autonomic dysregulation.

In neurosurgical intensive care it is of great importance to define a patient's prognosis by means of valuable parameters. With comatose patients increasing neurophysiological and biochemical investigations were performed, the results of which are in detail contradictory. It is, however, clear that the cerebral content of dopamin and norepinephrin is lowered by a trauma, which causes coma (6, 10). It is remarkable that the serotonin metabolism is obviously increased. Also cholinergic systems are undoubtedly affected (1, 3). The facts, described above, allowed the hypothesis that neural transmissions might be disturbed, especially in catecholaminergic systems located in the reticular formation of the brain stem. Previous studies show the alerting influence of L-Dopa and Amantadine-HCL with Parkinson patients. Sleep disturbances are improved by regulation of REM-periods with unconscious patient's alerting was observed under Amantadine and Akineton (2, 4, 6, 7). The results, described above, support the concept that functional, as well as structural disintegration of arousal systems of the brain stem cause coma. Functional disintegration might be related to disturbances of neural metabolism, synthesis or storage of transmitter substances. Posttraumatic decreasing impulse conductions in central catecholaminergic systems, in addition to increasing amounts of serotonin, are perhaps responsible for loss of consciousness.

Bifrontal slow wave rhythms are known as a projected rhythm and indicate lesions in the basal ganglia (6). According to our findings with Akineton^R it is to be suggested that these rhythms base upon the activity of cholinergic - limbic midbrain circuits.

Finally it is stated that the neuropharmacological approach with comatose patients improves our understanding of the pathophysiological mechanisms of coma.

Summary

EEG-activity of the convexity of the skull and base (tympanal leads) was recorded conventionally in 540 (100%) unconscious patients and partially stored on magnetic tape for off-line computer analysis.

The effects of L-Dopa, Amantadine-HCL and Akineton^R were compared with each other. 73% of our patients showed a marked tonic arousal. With further 21% of patients phasic arousal occurred alternating with rhythmic slow wave activity. In 4% of patients hypersynchronous activity was observed. 2% of patients remained unresponsive. The latencies from injection to arousal varied from 45 sec (L-Dopa) to 20 sec (Akineton).

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Fig. 1. Two excerpts from the EEG of a comatose patient showing
 (A) a marked arousal reaction 42 sec after injection of 25 mg of L-Dopa
 (B) Further acceleration in frequencies after 50 mg L-Dopa. Bipolar recordings. Longitudinal rows Fp_1-O_1 and Fp_2-O_2

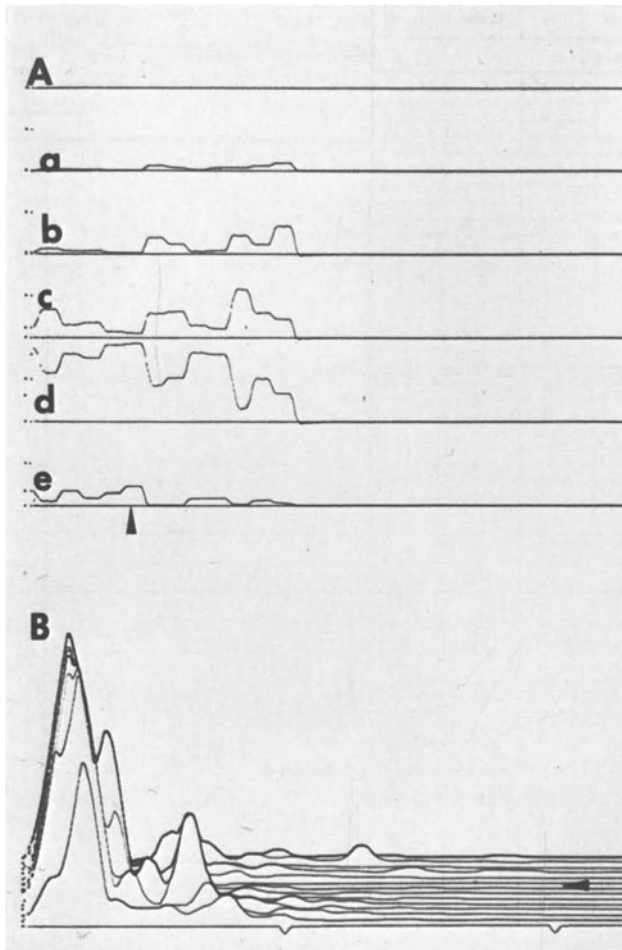


Fig. 2. Spectral analysis of a monopolar EEG record (GOLDMANN-OFFNER) from a comatose patient

(A) Percentage parts of conventional frequency ranges (beta-delta = a-d) in power spectra (total power, e)

(B) Power spectra of EEG frequencies ranging from 0.5 - 12 Hz in pseudothreedimensional registration

Note: After the injection of 25 mg of L-Dopa, increase in frequencies and lowering in amplitudes



Fig. 3. Two excerpts from an EEG of a comatose patient showing tonic (A) arousal reaction alternating with delta rhythms after the injection of 25 mg of L-Dopa i.v.
 (B) Delta rhythms, which were abolished after injection of AkinetonR, were triggered by arousal stimulation
 Bipolar recording. Longitudinal rows Fp_1-O_1 and Fp_2-O_2

Somatosensory Evoked Potentials (SEP) in Patients with Peripheral, Spinal and Supraspinal Lesions of the Sensory System

J. SCHRAMM and K. HASHIZUME

The evoked potential technique has recently become an accepted method of clinical neurophysiological research (5, 9, 10). So far rather general criteria of abnormal SEP have been used (2, 5, 7). FUKUSHIMA and MAYANAGI have proposed some criteria of abnormal SEP in 1975 (3). The purpose of this study was to describe more detailed criteria and to find out whether any specific pathologic SEP patterns are associated with certain neurological diseases and whether there is a specific pathologic SEP pattern for a lesion on every level of the sensory pathway.

Material and Methods

SEP were recorded in affected and unaffected areas in 41 patients with a disorder of the sensory pathway of various origin (Table 1). According to the neuronal organization of the sensory pathway supraspinal, spinal and peripheral lesions were discriminated. Between 6 and 40 recordings per patient were evaluated. Only early components were used in the evaluation. In half of our patients, a follow-up of up to 4 months was possible. A NICOLET 1024 signal averager was used: analysis time 100 msec, 128 summations. Stimulus duration was 0.1 msec given at a frequency of 1/sec. The stimulating electrode was either placed over a peripheral nerve trunk (median n., ulnar n., or superior

Table 1. Number of patients and types of lesions examined in this study

Peripheral lesions: 13	No of cases
Peripheral nerve trauma	6
Lumbar disc herniation	4
Cauda compression	3
Spinal lesions: 16	
Extradural space-occupying	12
Cervical myelopathy	2
Intramedullary tumor	1
Spinal contusion	1
Supraspinal lesions: 12	
Traumatic cortical laceration	3
Intracerebral haematoma	2
Thalamic tumor	1
Extracerebral intracranial tumor	1
Brain stem infarction	1
Thalamic syndrome	4
	<hr/> 41

peroneal nerve) or in the ventral part of the segmentally innervated dermatomes. The stimulating current intensity was adjusted at 5 times the voltage of the sensory threshold in segmental stimulation and above the motor threshold in peripheral nerve stimulation so that a definite muscle contraction was produced. In our laboratory we used the previously described nomenclature similar to LARSSON's (3, 6). The normal values for segmental SEP used in this study, as far as not already published (3) have been worked out in our laboratory.

Results

The normal wave form of the early component in SEP consists of a biphasic positive deflection (P_1 -N- P_2) preceded by an initial negative deflection (IN), as shown in the upper normal recordings in Figure 1. The following factors were used to describe the patterns of SEP alterations: peak latency, amplitude and wave form. In addition to these factors the topographic distribution of pathologic SEP and the change during the course of the illness have to be taken into account to describe these patterns. A *latency delay* can be slight (1-5 msec), moderate (5-10 msec) or marked (more than 10 msec). A latency delay of IN is not necessarily associated with a P_1 delay. An *amplitude reduction* below 50% of the average value is considered as abnormal. Side differences have been taken into account. The meaning of *blocked conduction* or block is evident. Apart from random potentials, the amplitude of which is very low or flat, no coordinated wave patterns are detectable. Although the changes of wave forms are difficult to classify, we have chosen 3 abnormal types. *Bluntness of wave form* means a coarsening of the shape while the typical triphasic wave pattern is basically preserved. The base of the 2 single positive deflections becomes broader and the peak to peak distance is longer. The term *deformity* was applied when a definite amplitude is measurable and the typical wave pattern is no longer preserved. In doubtful cases the discrimination against random noise is possible by the time-locked response to the stimulus. A loss of wave *components* is not necessarily pathological; for example, many segmental recordings, where the stimulation is not performed over nerve trunks, do not show the initial negative (IN) component. In a certain number of supraspinal cases, however, we have seen a loss of the P_2 component.

These single pathological factors together with their topographic distribution and change during the course of the illness were used to form a pattern of SEP alterations. We propose that this more detailed SEP pattern is used as a measure of SEP abnormality. Basically, all single criteria can be found in all types of lesions, with the exception of P_2 loss which, so far, we have only observed in supraspinal lesions. In *supraspinal lesions* we have not only seen blocks or normal curves but all other alterations as well (Fig. 4). Latency delays were found in 25%, but rarely so. A typical feature is a complete block in all recordings from one half of the body but, especially, in circumscribed cortical lesions the blocks may be confined to the corresponding region. In the follow-up, we found in 2 cases that a good clinical recovery can be accompanied by a complete recovery of pathologic SEP. Pertaining to the occurrence of single pathologic factors, there is no difference between *spinal* and *peripheral* lesions (Figs. 2 and 3). In spinal lesions, however, blocks are very common and latency delays are more often marked. Generally, the clinical sensory level is in good accordance with SEP findings (Fig. 3). In 5 spinal lesions (4 tumors and 1 epidural hematoma) SEP abnormalities could also be recorded above the clinical and myelographic level during the operative follow-up. Repeat follow-up recordings have proven valuable in showing postoperative changes to better or worse and, at the same time, give a good basis for a prognostic statement in spinal lesions:

a good recovery was found when SEP changed rapidly to the better after the removal of the tumor or when SEP alterations prior to surgery were less pronounced than the clinical findings. If a grading in the severity of SEP abnormalities were undertaken, latency delays, reduced amplitude and bluntness of wave form with peak to peak dissociation would be slightly abnormal, deformity would be moderately abnormal and a blocked conduction the most severe finding.

Summarizing the results, the following conclusions may be drawn:

1. Typical patterns of SEP alterations in all 3 types of lesions may be found but are not obligatory.
2. Any single SEP criterium is not specific regarding the aetiology and level of the lesion - with one possible exception, the P₂ loss in supraspinal lesions.
3. The use of SEP patterns including the topographic distribution in changes during follow-up is more useful than rough grading using single criteria.
4. The evoked potential method is a valuable instrument to record post-operative change and allows prognostic statements in spinal lesions.

Discussion

From the fact that a loss of the P₂ component has, so far, only been observed in supraspinal lesions, we do not yet draw the conclusion that a P₂ loss is a specific sign of supraspinal lesions. GIBLIN (4) and ALAJOUANINE and co-workers (1) have observed that in hemispheric lesions SEP are either normal or absent. Our findings, however, show other criteria (deformity, P₂ loss) to be found, too, especially in cortical lesions. Further experience with more cases is necessary, especially in order to work out differences in SEP patterns between cortical and subcortical lesions. As shown, there are no single SEP criteria specific for spinal or peripheral level: the main difference between peripheral and spinal lesions lies in the distribution of pathological recordings. Unlike the findings in multiple sclerosis (3, 8) which suggest a typical pattern to be found in MS patients, we could not establish a correlation between the aetiology and any given SEP pattern in our patients. There are typical SEP patterns to be found but they are only facultative findings. So, the lack of such a typical pattern does not rule out a lesion of the sensory pathway, but normal SEP can be used to rule out lesions of the sensory pathway, for example in cases of psychogenic sensory loss. In 3 spinal cases, we could confirm the findings of other authors (5, 9) that abnormal SEP can be recorded in segments just above or even high above the clinical and myelographic level. In 2 of our cases, the pathologic changes could have been due to further tumor growth but in 1 case of mid-thoracic tumor with a median nerve latency delay, no definite explanation is available.

Summary

In 41 patients with lesions of the sensory pathway, SEP recordings were performed. Further criteria of SEP abnormalities have been described. The possible value of patterns of SEP abnormalities is discussed. Conclusions as to the relations of single criteria and SEP patterns to the anatomical level and aetiology of the lesions are drawn. The clinical and prognostic value of the evoked potential method is emphasized.

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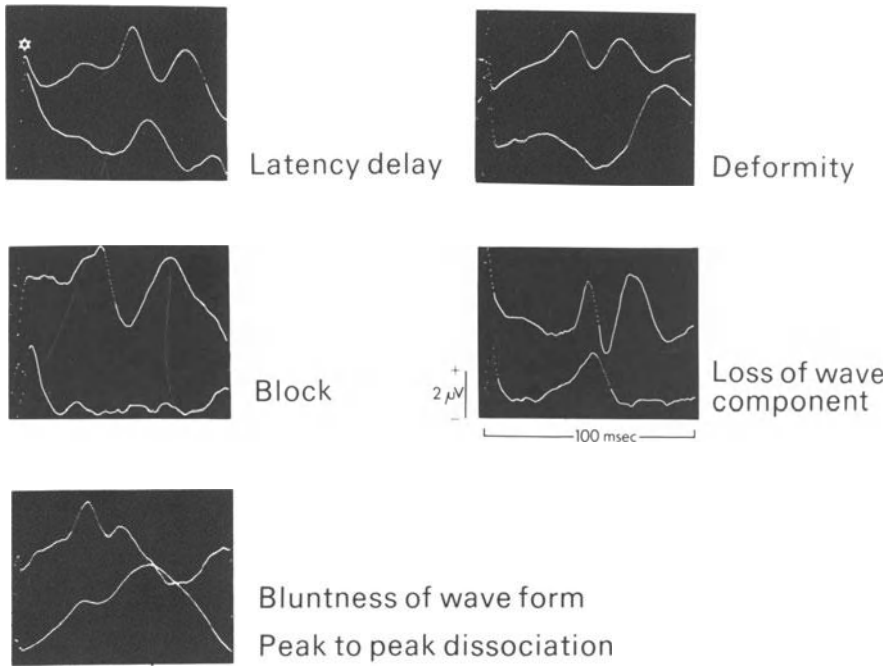


Fig. 1. Criteria of SEP evaluation and pathological changes; in paired original tracings, upper recording shows normal example, lower recording pathological one. The asterisk marks the stimulus artefact. Analysis time 100 msec., 128 summations. Stimulus length 0.1 msec. and frequency 1/sec

Cauda equina Syndrome

K.I. 57 yrs. female

Persisting deficit after resection of neurinoma :

dorsi - and plantarflexor paresis
moderate sensory impairment

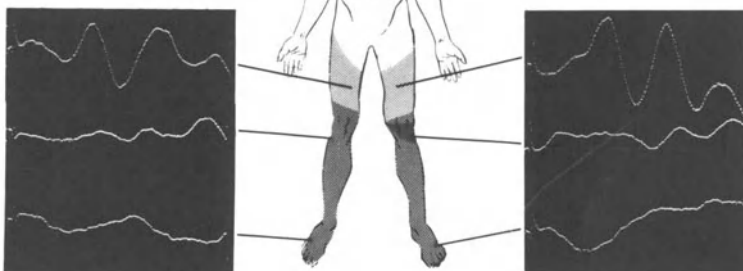
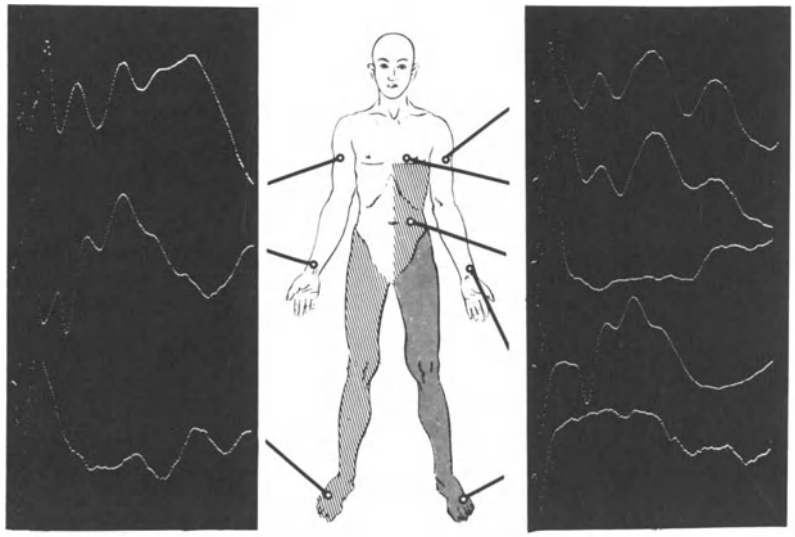


Fig. 2. Peripheral lesion: distally accentuated SEP alterations. Bilateral block at S₁, amplitude reduction with preserved wave form at L5 and normal recordings at L3. Horizontal bar indicates 20 msec., vertical bar 1 μV



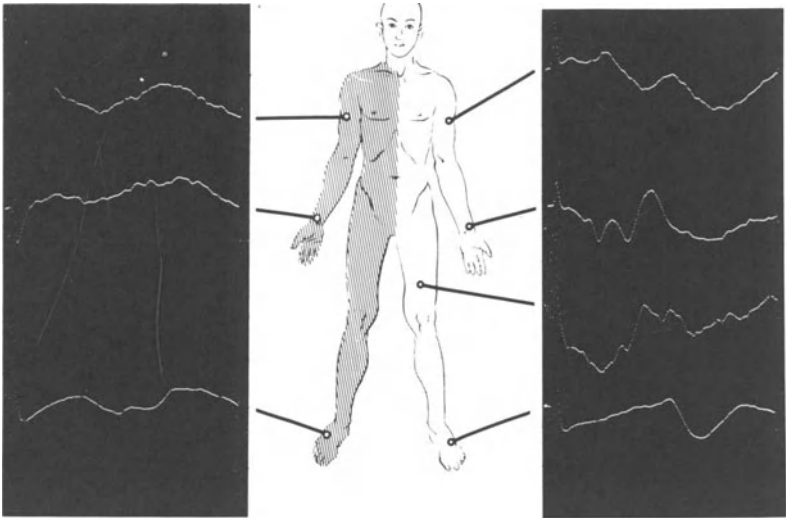
F. C. 72, female

Spinal Meningeoma Th 5/6

Spastic paraparesis

Sensory impairment below Th 4
vibration > touch and pain

Fig. 3. Spinal lesion: note the distribution of pathological SEP. There is a block at left S₁, a marked deformity at left D10 and a normal recording just above the sensory level. The right S₁ recording shows only a depressed amplitude. Postoperatively, the neurological functions on the right side recovered better than on the left. Vertical bar 1 μ V at S₁, D10; 2 μ V at other recordings



A. P. 73, male

R-sided Thalamic pain syndrome
of 2 years duration

R Hemiparesis and marked sensory
impairment of all modalities

Fig. 4. Supraspinal lesion: Right thalamic pain syndrome of post-apoplectic origin. There is a blocked conduction at right C5 and median nerve. The S₁ recording shows a markedly reduced amplitude. This confinement of pathological SEP to one half of the body is seen only in supraspinal lesions. Vertical bar 2 μ V at left upper two, 1 μ V at other recordings

The Effect of Electrical Spinal Cord Stimulation on Spastic Movement Disorders¹

J.-U. KRAINICK, U. THODEN, H. M. STRASSBURG, and D. WENZEL

Electrical stimulation of the spinal cord by implanted electrodes is established as a new approach for the relief of chronic intractable pain according to the gate-control theory of pain (3).

It is discussed whether stimulating the dorsal column leads to a modulation of activity in small and unmyelinated fibres conducting pain signals within the sub. gelatinosa (2).

This theory is supported mostly by animal experiments, whereas in man it is difficult to prove.

In our pain-patients with implanted spinal electrodes, we found an inhibition of the H-reflex in all cases of intact electrode systems.

In spasticity the disinhibition of the myotatic reflex is an essential spinal component. Therefore the effect of spinal cord stimulation seems to be an interesting possibility with therapeutic value.

Before implantations in man were performed, the following data were recorded in animal experiments (cats):

1. Monosynaptic reflexes of lumbar extensor and flexor muscles are inhibited up to 20% of the control value during dorsal column stimulation with 50 Hz and 0.2 msec impulse duration after 100 - 150 msec of stimulation.
2. The recovery time after a stimulation of 1 min. lasts for about 10 min. for monosynaptic reflexes of the extensor reflexes and is much shorter for flexor reflexes.
3. Conditioning the dorsal column by a single shock, an early inhibition with a maximum between 30 - 60 msec and a late inhibition beginning at 200 - 300 msec is seen. The spinalized preparation shows a shorter early and a stronger late inhibition of both test reflexes.
4. Increasing intensities of dorsal column stimulation raises the threshold of the test reflex only for the extensor reflex.

Having documented these data, dorsal column stimulators were implanted in 2 patients with upper motoneuron disease. These patients showed a severe spasticity of the extensor muscles and only mild pareses.

The implantation was performed by the percutaneous insertion of two electrodes into the epidural space at the level of T4 (see Fig. 1). After a test period of 3 weeks the receivers were implanted under local anaesthesia.

¹ Supported by Sonderforschungsbereich Hirnforschung und Sinnesphysiologie (SFB 70) der Deutschen Forschungsgemeinschaft (DFG) and Bundesministerium für Arbeit und Sozialordnung, Bonn/W.-Germany.

In both patients the amplitude of the H-reflex of the triceps surae muscles were inhibited up to 50% of the control value in case of strong dorsal column stimulation.

In analogy to the animal experiments, the recovery time after a stimulation time of 5 min. lasts up to 10 min. (see Fig. 2).

The spastic disturbance of synchronous and alternating movements of both feet and the alternating movements of a single foot are lowered in frequency by about 20% (see Fig. 3). The movements are smoother and faster.

The patients report an essential improvement in the subjective feeling of their spastic movements and are able to walk much longer distances.

It was shown that a stimulation with dorsal column electrodes can activate many pathways in both - the dorsal and ventral quadrants of the spinal cord (1).

On the other hand there are several theories on the mechanisms of spasticity at the spinal level.

Therefore it is up to now impossible to decide which pathways are essential for the above described modulating effects of dorsal column stimulation in spastic patients.

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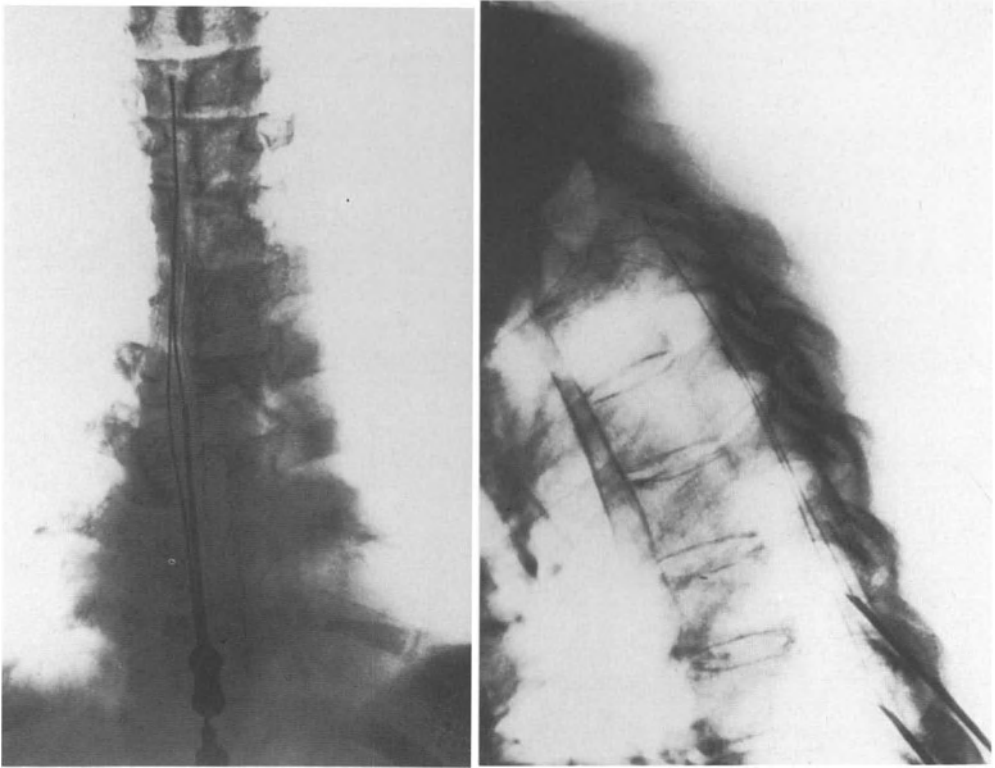


Fig. 1. Percutaneous spinal epidural implantation in a.p. and lateral view

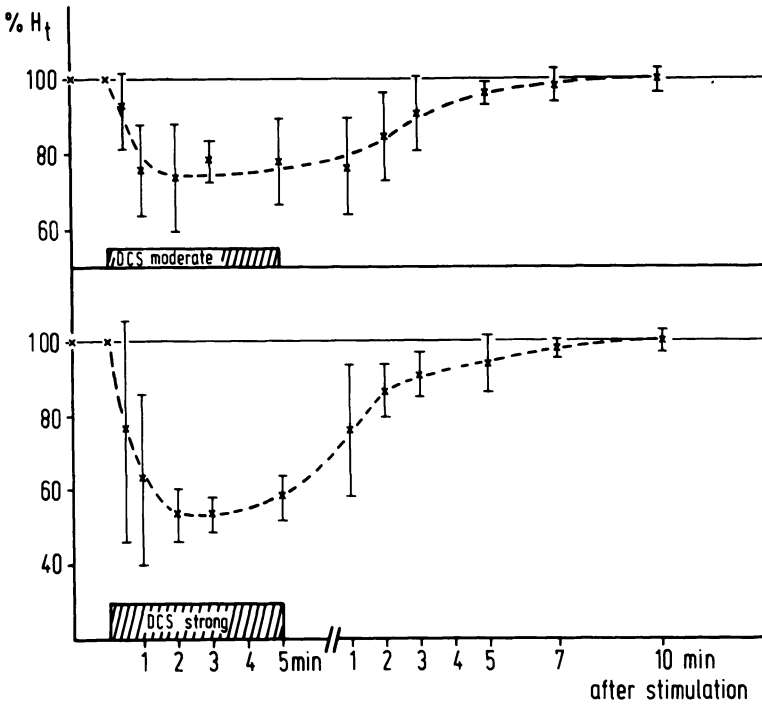


Fig. 2. Inhibition of the H-reflex during a moderate and strong dorsal column stimulation with 50 Hz and the recovery times after stimulation

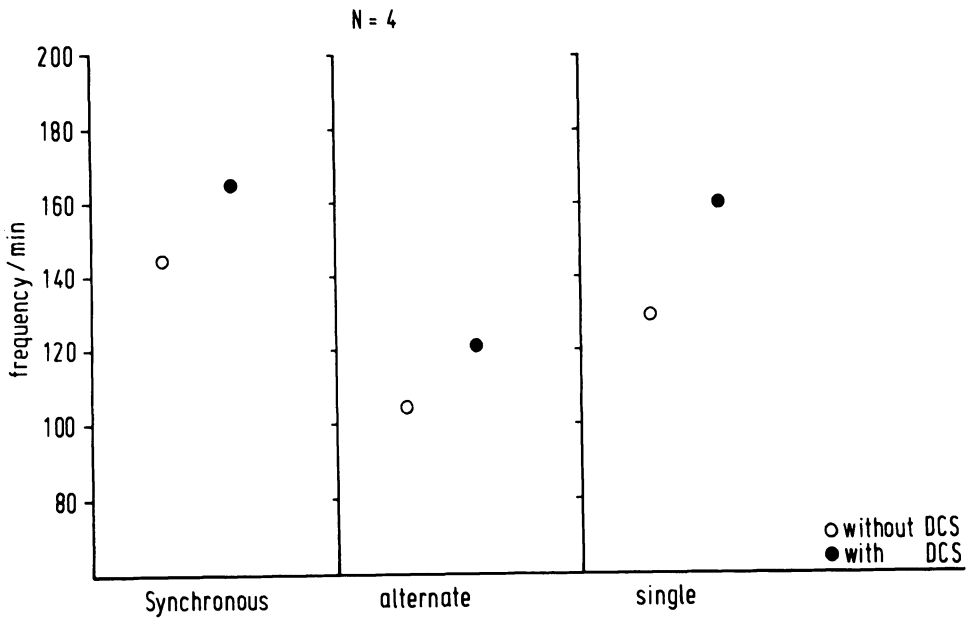


Fig. 3. Frequencies of synchronous, alternating and single alternating movements of feet

Advanced Cytological Techniques in the Examination of Human Cerebrospinal Fluid

D. DOMMASCH and M. GAAB

A morphological examination of cerebrospinal fluid (CSF) cells is useful in the clinical diagnosis of most of the inflammatory and of some neoplastic and vascular diseases of the central nervous system (15). Various sedimentation chambers (15), a cytocentrifuge (4), membrane filters (5), and other techniques (7, 14) may be used for cell preparation. Besides routine stains, cytochemical reactions are being used in CSF cytological examination, especially in the diagnosis of meningeal leukemia (11). An increased RNA synthesis of tumor cells in CSF has been demonstrated by acridine orange fluorochromation (9, 14). Mainly for an improved demonstration of tumor cells in CSF diagnosis, several authors have suggested additional cytological examinations, which require advanced techniques of cell preparation: *electron microscopy*, *cell cultures*, and *3H-thymidine autoradiography* (7, 8, 9, 10, 13).

These methods were employed in the cytological examination of CSF specimens from a 23-year-old male patient with a cerebral hemorrhage. Arteriographic findings seemed to be diagnostic for a cerebral angioma. But a tentative diagnosis of melanoblastosis of the central nervous system was made, because the patient showed multiple pigmented giant hairy nevi in various skin regions.

Methods

Cytocentrifuge preparations stained with May-Grünwald-Giemsa were used for the morphological examination of CSF cells. For the examination by electron microscopy, 5 ml of the CSF specimen were mixed with 5 ml of a solution of 2% OsO₄ and 6.6% glutaric aldehyde in 0.04 M Na-cacodylate buffer (pH 7, 4). After 50 min. fixation, the mixture was centrifuged for 10 min. with 700 g. The centrifugate was dehydrated and embedded in vestopal. For the culturing of viable CSF cells, 5 ml of CSF were placed in a sterile glass test tube and immediately centrifuged for 7 min. at 4°C with 450 g. 0.5 ml of sediment was suspended in 5 ml of EAGLE medium modified by MÜLLER (12) with 20% inactivated fetal bovine serum and gentamycine. The suspension was put into a plastic tissue culture flask (Falcon) and stored at 36.5°C in a CO₂ incubator. An inverted microscope (Zeiss UPL) was used for in vitro observations of the culture. For 3H-thymidine autoradiography, CSF cells were prepared in the same way as for the cultures but were resuspended in 2 ml of a medium containing 10% fetal bovine serum and incubated with 3H-thymidine (5 uCi/ml) at 36.5°C for 1 h. Then the suspension was prepared for autoradiography by cytocentrifugation, methanol fixation, and a dipping method using an Ilford K2 emulsion. The preparations were exposed for 7 days at 4°C in the presence of drierite. After development the autoradiographs were stained with Giemsa (2).

Results

The CSF specimen was xanthochromic, it contained 24 000/3 erythrocytes and 500/3 nucleated cells per ml. In a routine cytocentrifuge cell preparation, 50% of the nucleated cells appeared as large atypical elements with some variation in nuclear size. Very few of these cells contained a slight amount of pigmented material. The following results were obtained by supplementary investigations:

1. Electron Microscopy

Typical melanin granules (3) were found in the cytoplasm of some CSF cells (Fig. 1). They appeared as well-structured crystalline inclusions. Besides these granules the cytoplasm contained mitochondria of uniform structure, some perinuclear Golgi bodies, and a smooth endoplasmatic reticulum. In some cells of necrobiotic appearance the cytoplasm was consolidated; there were vacuoles in the wide-spread endoplasmatic reticulum. A large proportion of cells was binucleate.

2. CSF Cell Culture

24 h after the culture was started, a large proportion of the CSF cells had spread on the plastic surface. Some cells were multinucleate (Fig. 2). All the adherent cells had assumed polygonal or crescent shapes. In the following days, many mitotic cells were observed. After 1 week the cultured cells had formed a monolayer.

3. ³H-thymidine Autoradiography

Labelled cells in the autoradiographs were identified by a large number of silver granules above the nucleus (Fig. 3). Almost all of the labelled cells were atypical large mononuclear elements. The labelling index was 3%. Before the incubation with ³H-thymidine, the cell suspension had contained 50% viable cells (trypane blue stain).

Discussion

In this case, examination of the ultrastructure of CSF cells by electron microscopy revealed typical melanin granules which are well known from electron microscopic studies of the ultrastructure of pigmented skin (3). Thus, the tentative diagnosis of a neurocutaneous melanomatosis was confirmed by cytological examination of the CSF, although the most prominent alterations in the CSF were due to a cerebral hemorrhage. Routine morphological examination of CSF cells had indicated a tumor hemorrhage but the pigmentation of some atypical cells could not be sufficiently characterized by light microscopic investigation. Because of the presence of hemato-macrophages in the CSF, special stains were not used for the identification of melanin pigments.

Proliferative activity of the atypical cells was demonstrated by a CSF cell culture and by ³H-thymidine autoradiography. Amelanotic cells were dominant by the end of the culture; most of the labelled cells in the autoradiograph of this case revealed no pigmentation. The proliferation of melanotic and - to a larger extent - of amelanotic cells was confirmed by autopsy.

In most primary tumors of the central nervous system, cytological examinations of the CSF are hardly useful for clinical diagnosis. As tumor cells can be found in very few CSF specimens from these diseases (5), even advanced cytological techniques will be of little diagnostic value. In many secondary tumors of the central nervous system, e.g. meningosis carcinomatosa, the morphological examination of CSF cells will be sufficient, without application of special stains or other supplementary examinations. In the difficult diagnosis of cerebral tumor hemorrhage (15), however, as in this case, additional cytological examinations of the CSF might be useful.

When CSF cell cultures (13) or 3H-thymidine autoradiography (9) are used for tumor cell demonstration, the proliferative activity of non-neoplastic human CSF cells (1, 2, 6, 10, 12, 16) has to be considered. Especially in inflammatory diseases of the central nervous system, a high proliferative activity of non-neoplastic mononuclear CSF cells has been demonstrated (1, 2, 12). CSF cell cultures have not yet become sufficiently standardized for routine diagnostic investigations. 3H-thymidine autoradiography may be used for tumor cell demonstration only in connection with morphological examinations. A quantitative investigation of tumor cell proliferation in the CSF by autoradiography may be applied for an assessment of progression or remission of neoplastic processes in the course of intrathecal chemotherapy (2).

In this case, investigation of the ultrastructure of CSF cells by electron microscopy proved to be a useful method for the demonstration of intracellular pigmentation. A diagnostic application of electron microscopy of CSF cells might also be indicated in some cases of meningosis leukemica, especially for the demonstration of lymphoblast cells.

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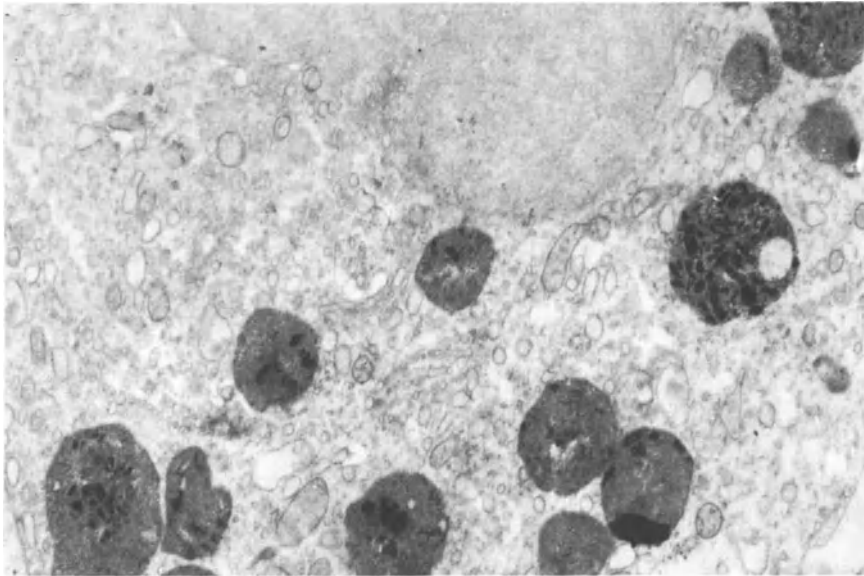


Fig. 1. Melanin granules in the cytoplasm of a CSF cell. Transmission electron microscopy. x 13 500

Fig. 1 - 3. CSF cells in melanoblastosis

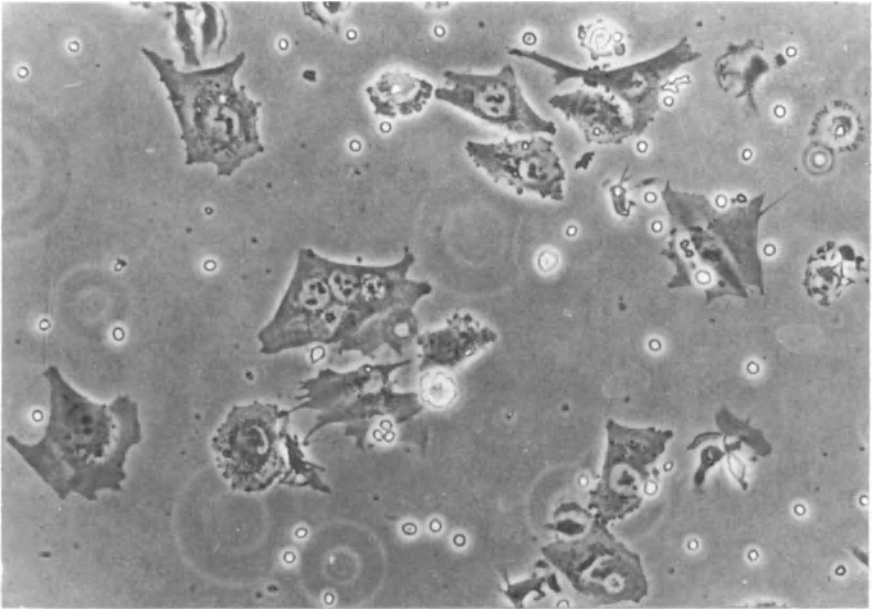


Fig. 2. CSF cell culture. Phase contrast. x 280

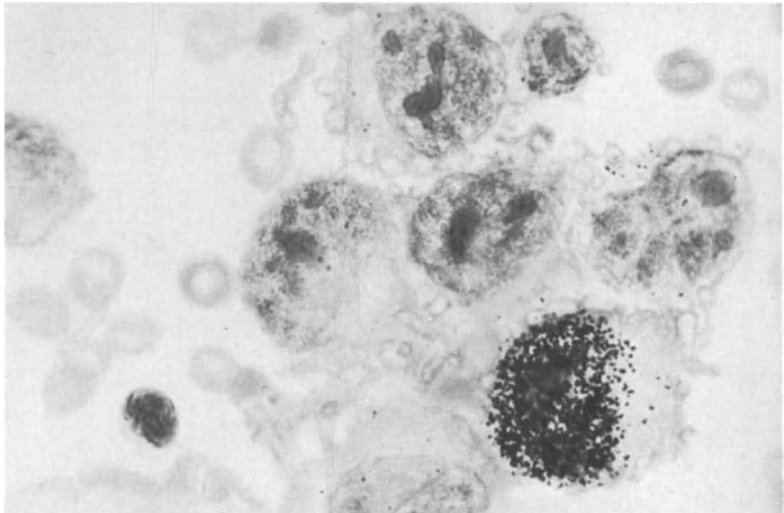


Fig. 3. ³H-thymidine autoradiography. Giemsa stain. Photomicrograph.
x 1 200

Arterio-Venous Communications in the Posterior Cranial Fossa. Anatomical Study

M. TSCHABITSCHER and A. PERNECZKY

Introduction

Many anatomical and clinical studies have investigated the arterial supply of the human cerebellum, while the venous system has mainly been the object of clinical radiological papers. On the other hand, only very few studies exist on precapillary communications of the central nervous system in the posterior cranial fossa.

Material and Method

The human cerebelli used in the study were fresh, not fixed. They were injected either in situ, starting from the vertebral artery and the internal jugular vein, or after removal from the posterior cranial fossa, starting from the vertebral artery and the tentorial sinus. The injection was performed either simultaneously using a motor syringe, or first from the arterial and then from the venous side. We used gum milk of various colours for the injection. The size of the gum milk particles did not permit diacapillary passage of the injection material.

Results

The communications between precapillary and venous system were demonstrated by intravascular mixing of colours. The gum milk particles being considerably larger than the capillary diameter, the communications must at least be of particle size.

The "mixing areas" are found in closely limited regions. We distinguish two sites of predeliction. One is located in the region of the horizontal cerebellar fissure. Here, the inferior anterior and the inferior posterior cerebellar arteries flow together, as well as the lateral group of the cerebellar veins. The other site of predeliction is found lateral to the brain stem in the region of the posterior triad. Here we find the influx of the inferior posterior cerebellar artery and the lateral brain stem veins.

Discussion

Many morphological studies of the central nervous system have centered on the existence of arterio-venous anastomoses. The comprehensive monograph by CLARA (1956) gives a survey of the literature published until then and agrees with SCHARRER (1940) that arterio-venous anastomoses exist in the pia. More recently it was, above all, HASEGAWA (1967) who pointed out the existence of such communications in the parenchyma. However, all these studies were confined to the cerebrum and its meninges, and there is no indication that the same may be true of the cere-

bellum and its meninges. The question whether the present cases represent true arterio-venous anastomoses or rather especially large arciform veins or other forms of capillary detours will have to wait until detailed histological studies have been completed.

Summary

Injected specimens, showing the arterial and venous vascular systems of the cerebellum in different colours, demonstrate "communications" between the two systems. Such "mixing areas" are predominantly found in the region of the horizontal fissure and on the lateral brain stem.

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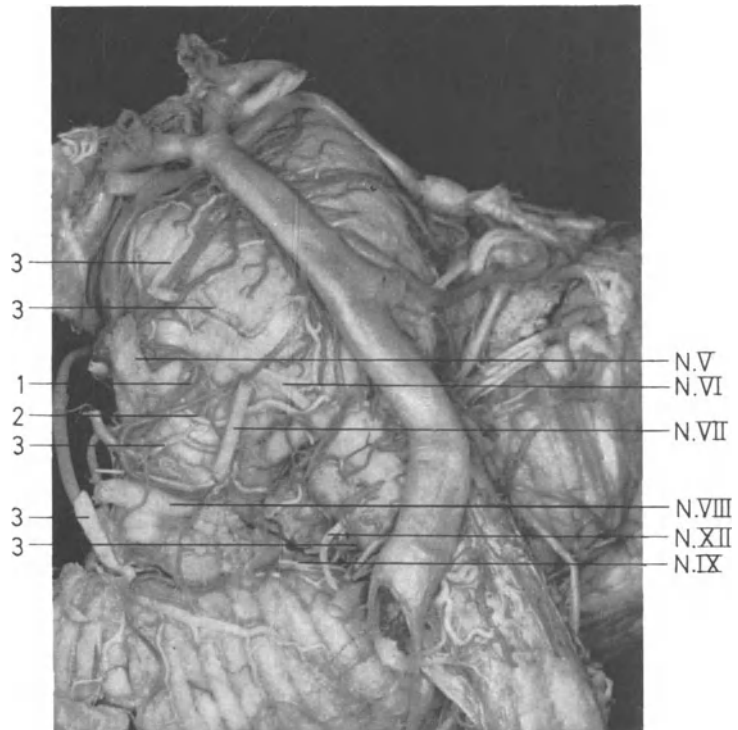


Fig. 1. Ventral aspect of the brain stem. In the original specimen the arteries (1) are injected red, the veins (2) are yellow and the "mixing areas" (3) appear in orange colour

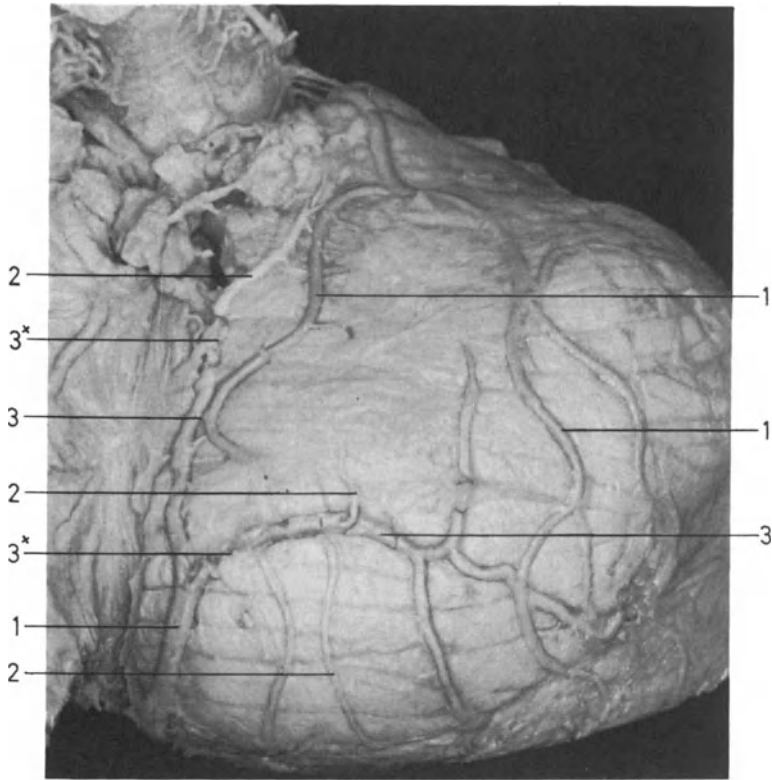


Fig. 2. Posterior view of the right cerebellar hemisphere. 3^x: artificial defect corresponding to tissue taken for histological examination
Other numbers : see Fig. 1

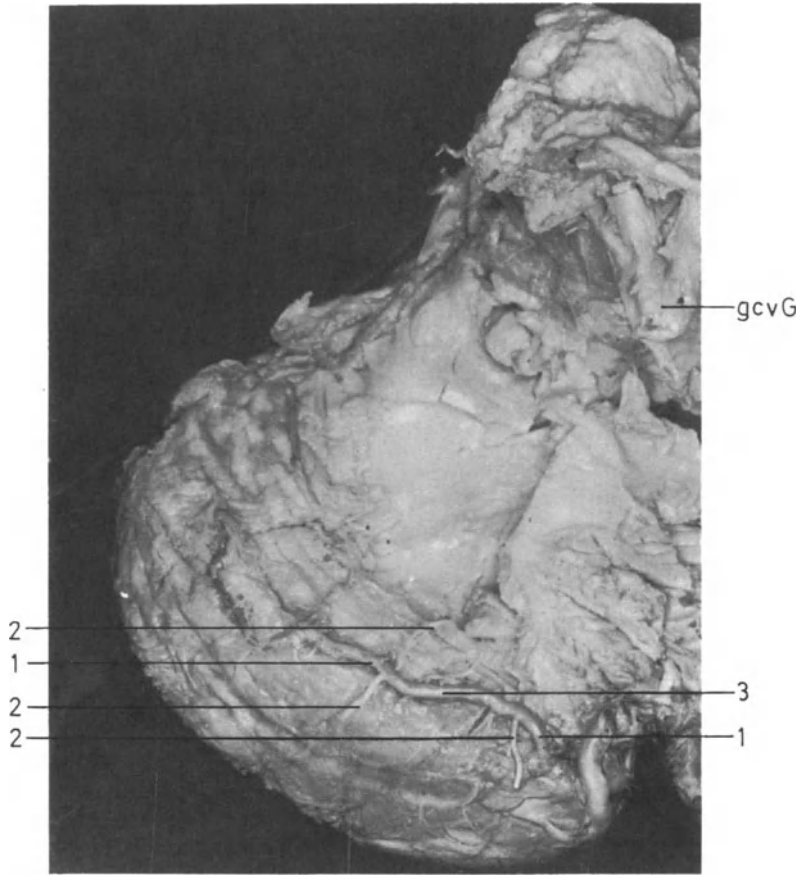


Fig. 3. Dorsal view of the left cerebellar hemisphere. gcvG: great cerebral vein of GALEN
Other numbers: see Fig. 1

Microsurgical Reconstruction of Cauda Equina Fibers. Experimental Study in the Pig

H. SOLLMANN, H.-P. RICHTER, and C. MEIER

Anatomically, cauda equina (CE) fibers are peripheral nerves but differ from these in three important respects:

1. CE fibers are without an epineurium and - compared with peripheral nerves - only show a very thin perineural layer.
2. The sensory components of the CS fibers are preceded by the spinal ganglia.
3. The CE fibers are located within the cerebrospinal fluid, which is surrounded by the arachnoid membrane and dura mater.

Only since the introduction of microsurgical operation techniques and the development of extremely thin suture material is the reconstruction of the CE fibers possible.

Our experiments were done on 21 pigs. After endotracheal intubation and in general anaesthesia, laminectomy at the levels L4 and L5 was performed and the dural sac opened. The isolation of the L5- and S1-roots was followed by three different procedures:

- a) crushing of the motor and sensory part of the spinal root for a length of about 1 cm;
- b) end-to-end-suture¹ after cutting the root;
- c) bridging of the site of cutting by an autologous graft¹.

In the region of L5 and S1 in the pig, the CE roots consist of about 12-16 sensory and 6-8 motor fascicles (Fig. 1). The end-to-end suture after cutting the root can be done in two different ways:

- a) suture fascicle by fascicle or
- b) adaptation of groups of fascicles by a loose suture.

According to our experience, the latter method is preferable for the reconstruction of sensory roots, in which 4-6 fascicles make up one group. For the readaptation of the motor roots two sutures consisting each of 2-3 fascicles are sufficient.

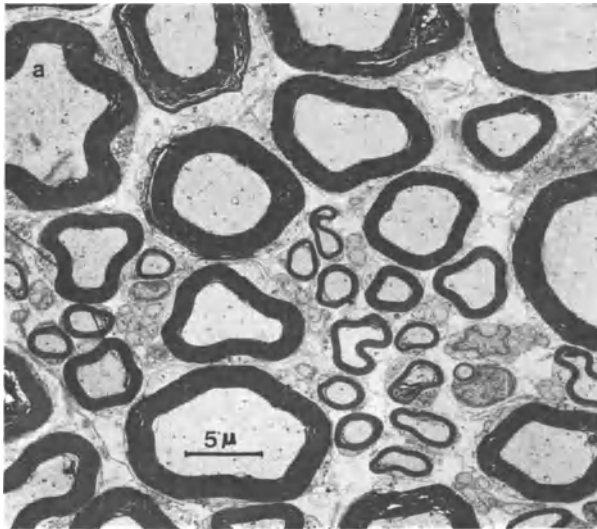
For transplantations it is advised to interpose single fascicles or small groups of not more than 3 fascicles (Fig. 2). The best material to be transplanted for the aim of reconstruction of motor roots seems to be sensory root fibers. Not necessarily the entire sensory part of a root has to be taken. Also parts of more cranially located sensory roots can be employed to render the sensory deficit as small as possible.

Because of the above-mentioned thin perineural layer, a perineural suture - as known from the interfascicular technique in peripheral nerves - is not feasible in CE fibers. In the latter case the fascicles must be pierced transversely to the direction of the axons and have to be adapted loosely by a kind of U-suture. Naturally these sutures can be applied only under the operating microscope at a 16-32 fold magnification².

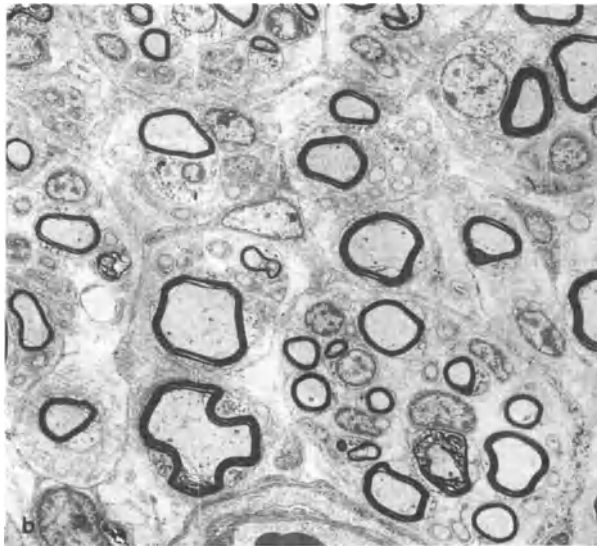
¹ 11-0 Supramid monofil, 3/8 circle (S & T).

² ZEISS operating microscope OPMI 6.

In summarizing the preliminary results of our clinical, light- and electronmicroscopic examinations 13 weeks after operation (these results will be published elsewhere), it can be said, that a regeneration of CE fibers after crushing, end-to-end suture and autologous transplantation takes place. Histologically CE fibers follow the same rules of de- and regeneration as peripheral nerves. Quantitatively we found a regeneration rate of 50% for the motor and of 35% for the sensory axons 13 weeks after suture and grafting. The clinical application of our operating technique and of the results of our experiments could be used for the patients with cauda equina syndrome for example.



a) Normal ventral spinal root (S1). The fibre spectrum shows myelinated axons possessing calibres of 1 to 10 microns and a maximal myelination of 120 myelin lamellae



b) Ventral spinal root (S1) distal to section and suture after a survival time of 3 months. The regenerating axons possess calibres of up to 6.5 microns and a maximal myelination of up to 45 myelin lamellae

Fig. 1. Regeneration of spinal roots after cutting and suture in the pig (x 4000)

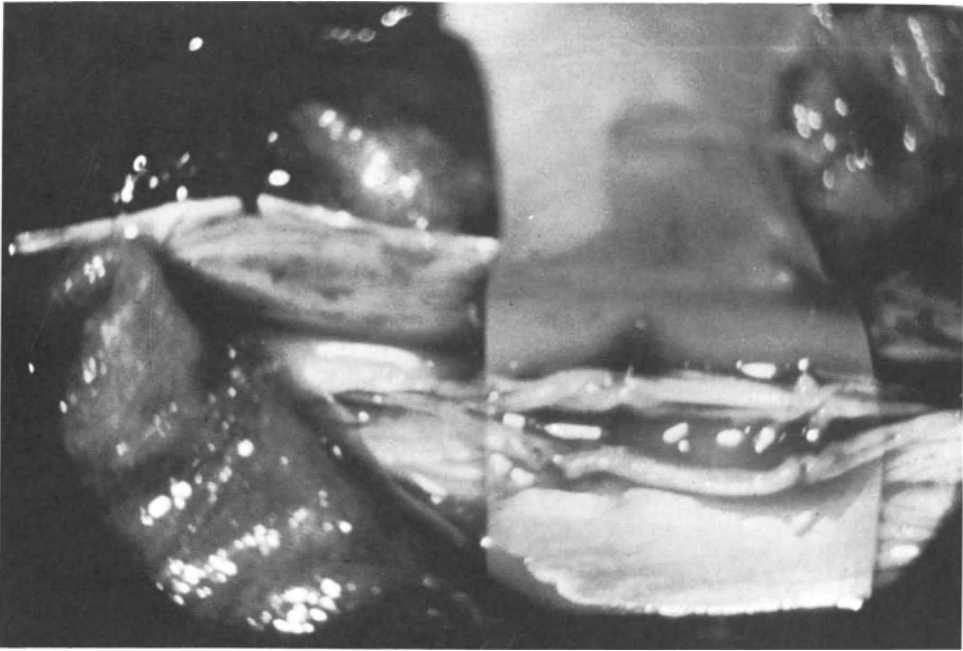


Fig. 2. Autologous graft in the sensory part of the spinal root

A Simple Method for Localizing the Foramen of Monroe in Plain X-Rays

T. HOEFER and F. MUNDINGER

Different methods used to calculate subcortical targets for stereotactic neurosurgery are dangerous or inexact.

Consequently we undertook an attempt to localize the foramen of Monroe on the plain X-ray, as this would enable us to perform guided intra-operative ventriculography during a stereotactic procedure (Fig. 1).

We used the following premises:

1. The anterior commissure - posterior commissure axis (CA-CP) is the chief axis of embryonal development in the human brain.
2. The development of the basal plates in their preformed state as connective tissue and the development of the human diencephalon and brain stem are mutually determinant.
3. In the peri- and postnatal period, brain morphology is also influenced by the development of the skull and vice versa.

Deriving our method from SCHMIDT, we used the lateral X-ray and chose four bone points which were advantageous as reference points for our measurements. The osseous reference points are the following:

Point A: Point of intersection of the frontal squama and the orbital part of the frontal bone.

Point A': Point of intersection of the lambda suture on the tabula interna.

Point B: Bregma.

Point B': Tuberculum sellae.

Thus the distance from A to A' represents the sagittal diameter of the cranium, the distance B to B' the main vertical diameter. AFM and B'FM are the partial distances from the foramen of Monroe to respective osseous reference points.

The quotients $\frac{AA'}{AFM}$ and $\frac{BB'}{BFM}$ calculated on the basis of the measurements of 403 pneumencephalograms show us an astonishing uniformity. These quotients were evaluated to find the mean values for six groups of patients according to sex and age. The standard deviations were determined.

We have established tables which permit us to read immediately directly and irrespective of X-ray distortion, the length of the distances AFM and B'FM and thus the intersection = foramen of Monroe.

In more than 300 patients operated until now, the localization of the foramen of Monroe according to this procedure was exact in 90% (Fig. 2). When 5 ml of CSF have been collected, we add 2.0 ml Dimer XR and reinject the new mixture, so we can obtain excellent ventriculograms. There were no serious complications until now.

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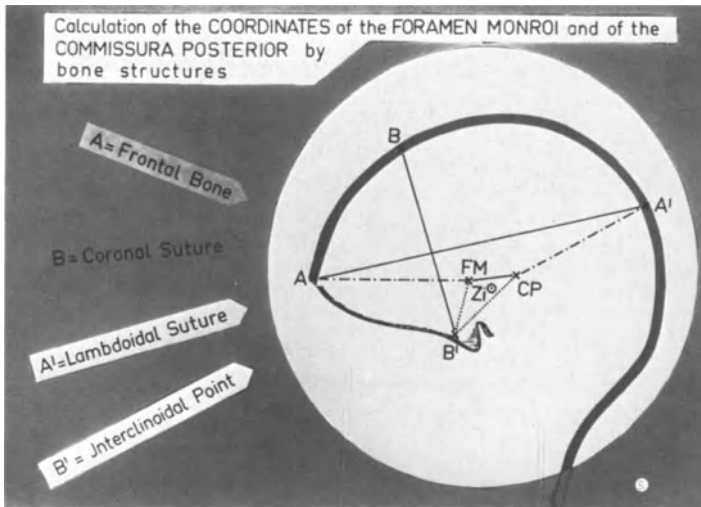


Fig. 1

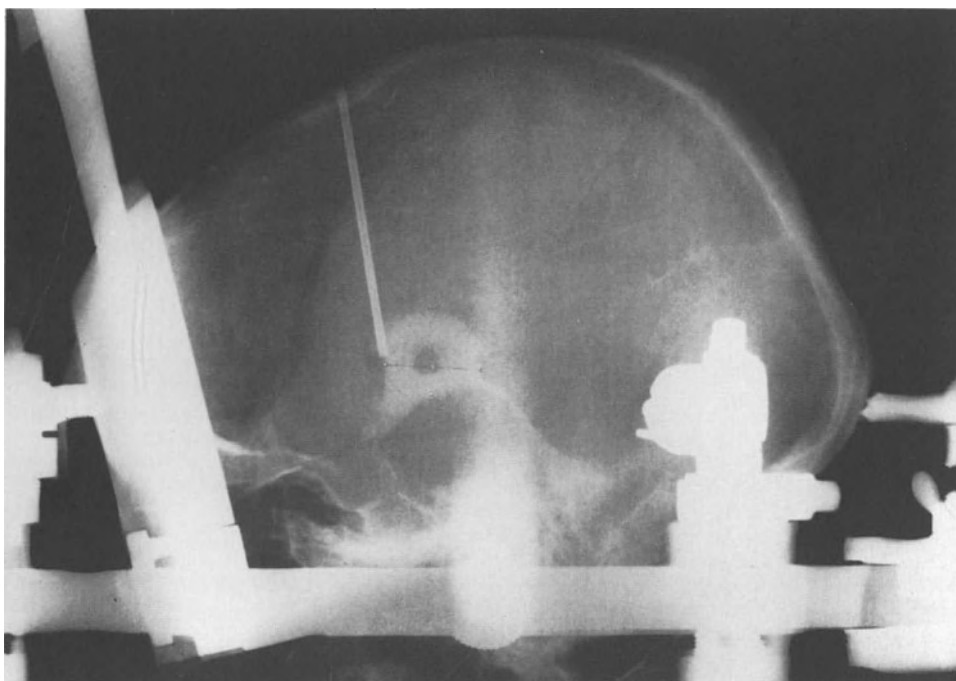


Fig. 2. B.A., female, 60 y., Guided intraoperative ventriculography during stereotactic procedure, selective representation of 3rd ventricle, aqueduct and 4th ventricle. 2.0 ml Dimer X^R and 5.0 ml CSF

On the Possibility of Indirect Respiratory Rate Monitoring¹

H. U. THAL and M. KRAEMER

Introduction

Respiratory parameters are of great interest in neurosurgical intensive care. But in practice continuous monitoring of these parameters for long periods of time is very difficult. At first sight it looks rather simple to measure at least respiratory rate continuously, but all known methods, like thermistor probe registration or electrical chest impedance plethysmography produce many artifacts or are poorly tolerated by the patients. We obtained a higher reliability and more comfort for the patients and nurses by developing new methods using the ballistorespirogram (BRG) and the central venous pressure (CVP) by an indirect measurement.

Methods

The BRG measurement is based on the ballistocardiogram (BCG) (1). While others, working on the BCG, eliminate the "respiratory artifacts", we tried to get specifically the respiratory information. The acquisition of data had been simplified by building piezo-electric load cells into the bed-posts of an ordinary hospital bed. The changing of the centre of gravity of the body during breathing leads to a signal in the load cells, which is amplified, filtered and after passing an automatic gain control is processed in a respiratory rate monitor (5). One output of this monitor is the respiration curve, others are the triggers belonging to the respiratory cycles. The respiratory rate was displayed digitally.

Instead of measuring the CVP with an electromanometer directly (4), we obtained the dynamic components of the CVP from outside of a normal infusion system, connected to a central venous catheter (CVC) implanted for other clinical reasons. It should be pointed out clearly, that the catheter inserted into the superior vena cava is normally used for infusions and so on and is not especially implanted for recording respiratory rate. As a sensor we used a sensitive piezo-electric force transducer (KISTLER type 9203), which was screwed into a block of lucite. The infusion line is clamped into a slit in the block and contacted the tip of the transducer distal to the flow regulating clamp of the infusion system. A charge amplifier (KISTLER type 5001) was connected to the transducer.

Its output represents the dynamic part of the CVP signal because of the frequency response of the amplifier and electronic circuit which do not allow static pressure measurements. This is of no importance

¹ Supported by the Bundesministerium für Forschung und Technologie, DV 5.308.

for respiratory rate monitoring. The CVP signal - like the BRG - is processed in the respiratory rate monitor.

Results

Respiratory monitoring with the BRG has been used in our intensive care unit (2, 5, 7) since 1973. As Figure 1 shows, the monitor produces correct respiratory triggers. The correlation coefficient between respiratory triggers derived from the BRG and those from a thermistor probe is about 0.83 (6). The records give a good insight into the type and form of respiration. In particular respiratory rhythms can be detected easily and without discomfort to the patient. Two beds of our ICU are equipped with this device.

The indirect CVP signal contains the dynamic components of the CVP quite exactly but not the static component (3, 8). This could be demonstrated in a number of patients as, for example, Figure 2 shows. Figure 3 gives another example of the difference of the direct and indirect CVP signals recorded in the lowest trace. It can be seen, that there is only a small difference between the two signals in the higher frequency range, when neglecting the static component. The respiratory signal is transformed into trigger sequences and the rate displayed as mentioned before.

Discussion

The described methods proved to be useful to measure the respiratory rate in ICU patients. The BRG's great advantage is patient safety and ease of handling because there is no need for direct contact to the patient. Calibrating procedures are not necessary. Disturbances occur in restless patients or in nursing manoeuvres but can be recognized by the monitor in most cases. Furthermore the indirect CVP sensor does not pose problems of sterility or electrical patient safety. The disadvantage exists in the need for an exactly placed CVC in the superior vena cava or the right atrium. One can also find artifacts in long term records depending on patient movements, changing of infusion fluids or regulating the infusion rate as seen in Figure 4. With respect to a well-trained staff, the susceptibility to faults is tiny.

Summary

There is no method which solves the problem of long-term monitoring of respiratory rate in severely ill patients perfectly. We first make use of the BRG by building piezo-electric load cells into the bed-posts. Secondly, we clamp a sensor from the outside onto the infusion line of an indwelling central venous catheter which most of our ICU patients have. These signals give a fairly true picture of the respiration curve. The respiratory rate, when processed in a respiratory rate monitor, is also obtained.

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Fig. 1. Analog recording of ECG (trace 1 from above, BRG (trace 2), respiration curve from the BRG (trace 3), respiratory triggers from the BRG (trace 4) and respiration curve from a thermistor probe

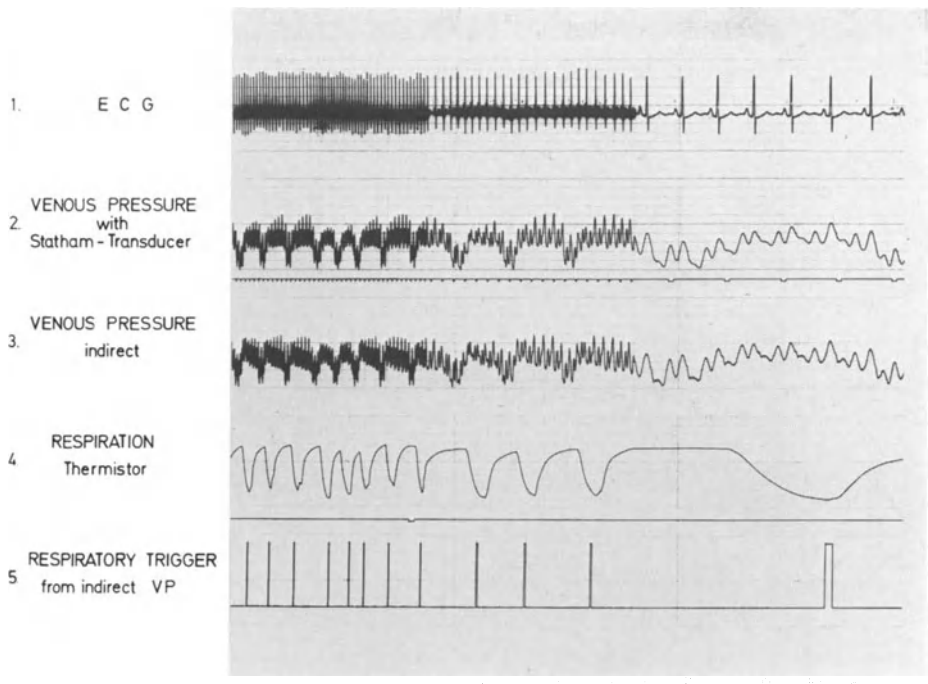


Fig. 2. Analog recording of ECG (trace 1), CVP with Statham transducer (trace 2), indirect CVP signal (trace 3), respiration curve from a thermistor probe (trace 4) and respiratory triggers from indirect CVP (trace 5)

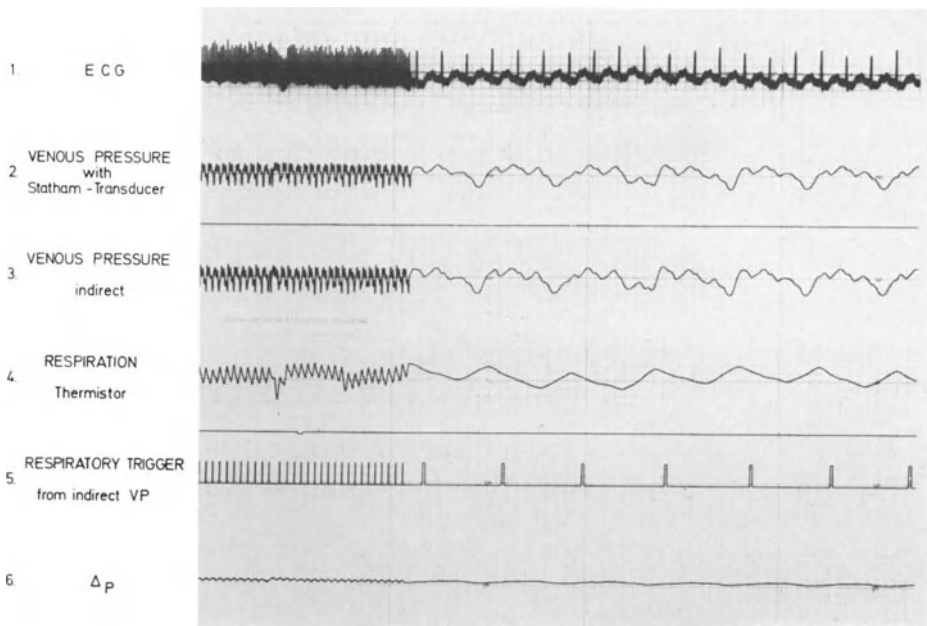


Fig. 3. Analog recording of ECG (trace 1), CVP with Satham transducer (trace 2), indirect CVP signal (trace 3), respiration curve from a thermistor probe (trace 4), respiratory triggers from indirect CVP (trace 5) and the differential pressure between direct CVP and indirect CVP (trace 6)

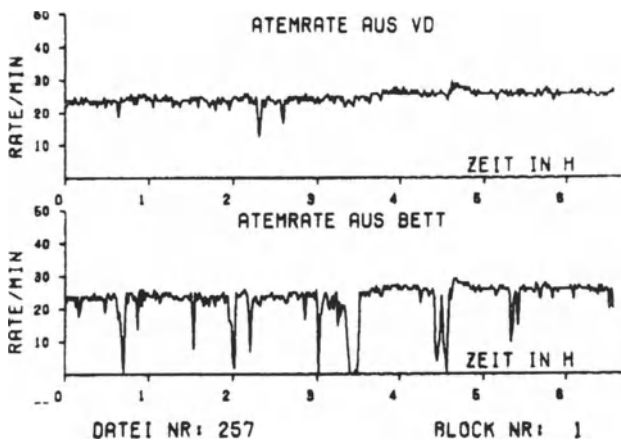


Fig. 4. Computer plot of respiratory rate derived from the indirect CVP (trace 1) and the BRG (trace 2). Time marked in hours

Simultaneous Biplane Angiotomography for the Analysis of Intracranial Aneurysms

O. SATO, M. KOBAYASHI, and K. SANO

It is very important to know the accurate spatial relationship between the stalk of the aneurysm and the parent artery or the surrounding vessels before we try the direct surgical treatment for intracranial aneurysms. For this purpose, many diagnostic procedures such as oblique projections, subtraction method, stereoangiography or magnification angiography are performed but these are not always sufficient and angiotomography is considered most suitable for such an analysis of the intracranial aneurysms.

We performed conventional angiotomography with a Polytome U in several cases of intracranial aneurysms but the pictures obtained by this method are not sharp enough for the proper diagnosis. We have now developed a new method of angiotomography in arbitrary sections using a specially devised head swing cradle. This method is simple and, moreover, the pictures are much finer. It has proved to be very valuable for the analysis of intracranial aneurysms.

Method

The head swing cradle and the diagram of the method are shown in Figure 1. The rotation axis of the cradle is constantly fixed at the stand (O) but the radiolucent plastic head rest cradle is shifted continuously to a horizontal or vertical direction for an arbitrary distance by two motor-driven changing knobs; thus the geometrical relationship between the axis and the head can be changed arbitrarily and on performing the conventional biplane angiography while rotating the cradle, simultaneous biplane angiotomography in arbitrary sections (S-section and F-section as illustrated) is possible. And if serial angiotomography is mandatory, the swing of the cradle is repeated alternately at any desired interval, so that serial angiotomography in the same cut section is possible.

The most important characteristic feature of this method is being able to change the cut section at every alternate swing of the cradle in any desired horizontal and/or vertical direction; the serial multi-section angiotomography which is most important for the good visualization of the intracranial aneurysms is possible. We usually change the cut section by 1 mm at every swing of the head and the swing is repeated four times, so that eight different serial section angiotomograms (four sagittal and four frontal sections) are obtained in a complete examination.

The swing of the head rest cradle is driven by an electric motor. The swing angle is 30 degrees in the symmetrical unilateral direction, the speed of the swing is 0.5 seconds which is the same as the time of exposure.

The practical technique for the clinical application of the method is as follows: The injection of the contrast medium into the artery is performed either by direct percutaneous puncture of the artery or by

the transfemoral catheterization technique. Although the escape of the needle from the vascular lumen during the swing of the head has not yet occurred, the catheterization technique is more certain and more suitable for the visualization of intracranial aneurysms. The injection of the contrast medium, usually 6 ml at one exposure, the rotation of the cradle and the exposure are all automatically and synchronously settled. Conventional serial biplane angiography always precedes angiotomography in order to confirm the presence of the aneurysm, to decide on the precise plane of the cut and to find the proper moment of the exposure. And then the head swing cradle is settled on the same examination table.

Results

We compared this new method with conventional cerebral angiography and magnification angiography regarding the visualization of the stalk of the aneurysm in the same cases. By this method the surrounding vessels superimposed on the stalk of the aneurysm were well cancelled out and its relationship to the parent artery was also well demonstrated.

The anterior communicating aneurysms (AC aneurysms) and the middle cerebral aneurysms (MC aneurysms) were not well demonstrated in the lateral projection of conventional carotid angiography because of the overlying main trunks of the anterior cerebral artery and the middle cerebral artery and their tributaries. But they were well demonstrated by sagittal section angiotomography. Figure 2 shows a case of the AC aneurysm; the conventional carotid angiogram can not visualize the aneurysm but the sagittal section angiotomogram visualizes not only the shape of the aneurysm but also its attachment to the parent artery. The AC aneurysms and the MC aneurysms were usually diagnosed in the frontal projection of conventional carotid angiography but their stalks were sometimes obscured by the surrounding loop of the parent arteries although they were well separated from the loops by angiotomography. Figure 3 shows a case of the AC aneurysm; the frontal section angiotomogram visualizes the loop of the anterior cerebral artery and the origin of the aneurysm well.

The internal carotid-posterior communicating aneurysms (IC-PC aneurysms) were well demonstrated in the lateral projection of conventional carotid angiography but the origin of the posterior communicating artery or the anterior choroidal artery was sometimes obscure, especially when the aneurysm was large. In such cases, angiotomography was useful for detecting the relationship between the aneurysm and the posterior communicating artery or the anterior choroidal artery. The frontal projection of conventional angiography was generally not valuable for the diagnosis of the IC-PC aneurysms because they were superimposed by the internal carotid artery. Figure 4 shows a case of the large IC-PC aneurysm; conventional carotid angiogram can not differentiate the carotid artery from the aneurysm but the angiotomogram visualizes the narrowing of the carotid artery proximal to the origin of the aneurysm. Angiotomography was also useful for the analysis of the vertebro-basilar aneurysms. For the basilar bifurcation aneurysms, frontal section angiotomography was useful for demonstrating the relationship between the aneurysms and the posterior cerebral arteries or basilar artery (Fig. 5). The arteriosclerotic basilar aneurysm which was obscured by the skull was well visualized in the sagittal section angiotomogram.

Discussion

According to the recent advances in the surgical treatment of intracranial vascular lesions such as aneurysms or arteriovenous malformations, it has become necessary to know the spatial construction of the lesions as precisely as possible. When we operate on intracranial aneurysms, it is important to define not only details about the shape, size and spatial orientation of the aneurysms, but also the relationship between the parent artery or surrounding vessels and the aneurysms. For these purposes, angiotomography is considered to be superior to the procedures already being used in addition to conventional cerebral angiography.

ROCCA and ROSADINI (7, 8) first introduced cranial angiotomography with multisection cassette and this method has been used for the diagnosis of intracranial aneurysms, tumors and the analysis of the normal cerebral circulation (1, 3, 5, 6, 9, 11). But this angiotomography using multisection cassette has some limitations in the analysis of intracranial aneurysms because of its lack of sharpness of the pictures.

Autotomography was first applied to cerebral angiography by SMITH et al. (12) in 1971. POOLE et al. (4) described the usefulness of angiotomography especially for lesions of the midline of the posterior fossa using a head cradle devised by NEWTON and HASTY. But these reports of angioautotomography were limited to the delineation of the midline structures of the brain. Our new method is applicable even for the diagnosis of off-midline structures.

The results of the analysis of the intracranial aneurysms by this method are promising and the method is also useful for selecting out the presence of the aneurysms in suspected cases. This method is superior to magnification angiography and it is not necessary to perform magnification angiography when angioautotomography is undertaken.

Summary

A new method of simultaneous biplane serial multisection angioautotomography was described and the usefulness of this method for the analysis of intracranial aneurysms was stressed.

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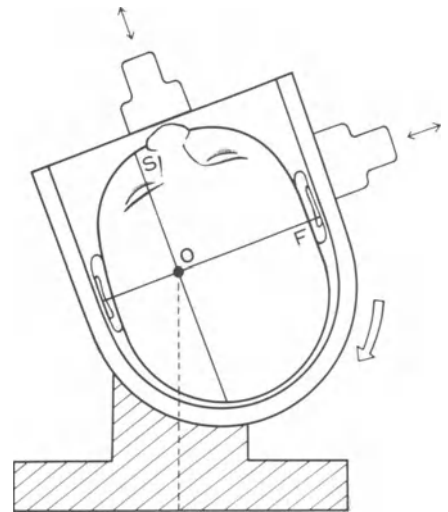
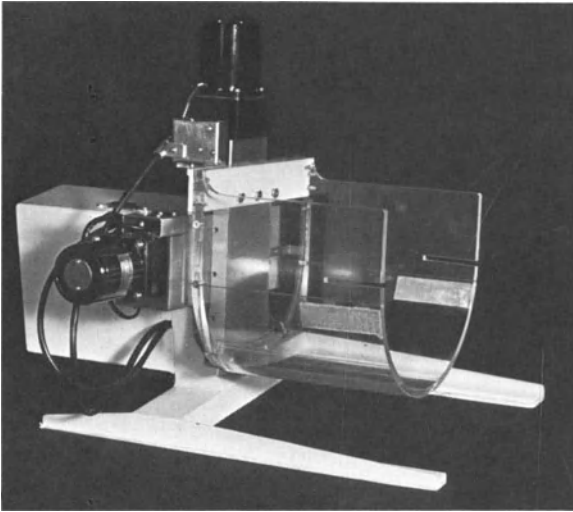


Fig. 1. Head swing cradle and diagram of method

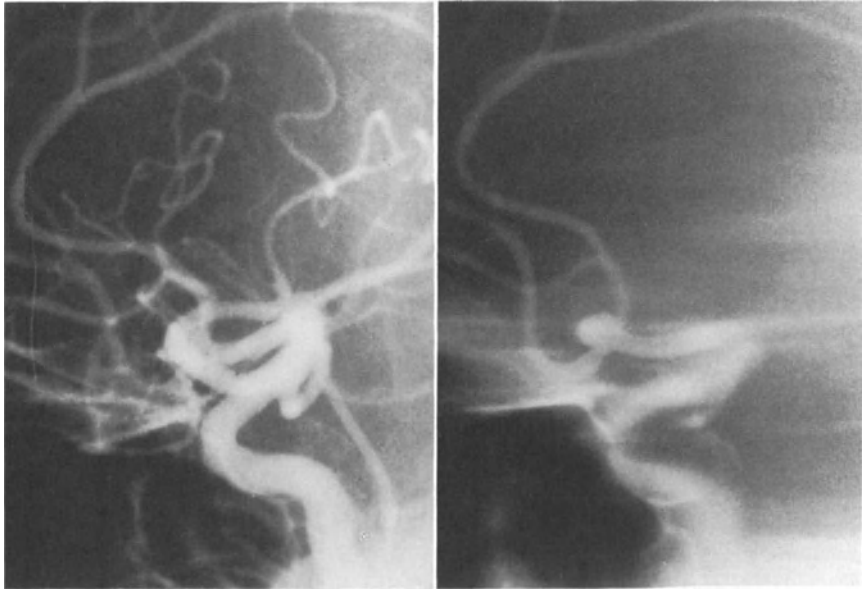


Fig. 2. Anterior communicating aneurysms; conventional carotid angiography (left) and sagittal section angiogram (right)

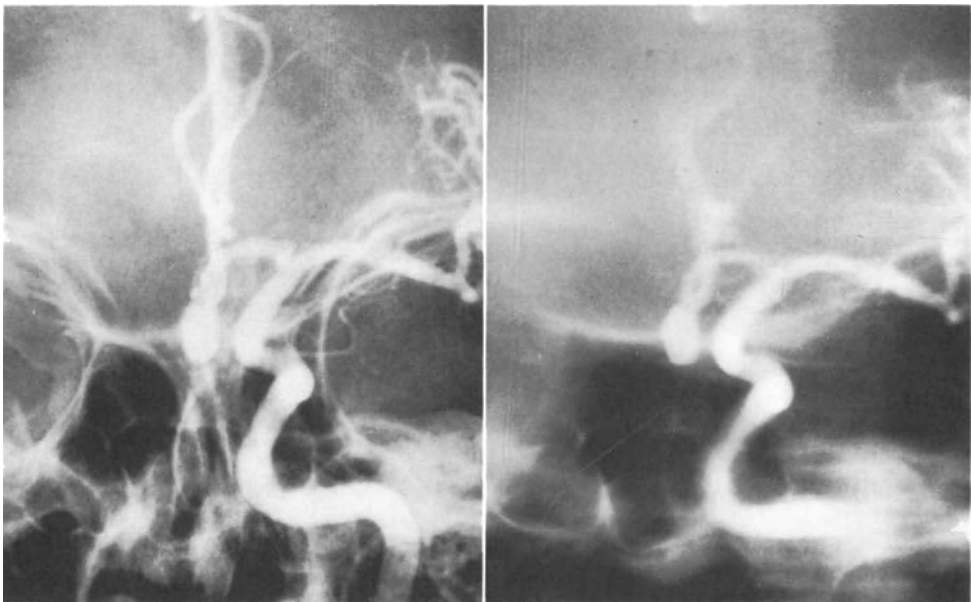


Fig. 3. Anterior communicating aneurysm; conventional carotid angiography (left) and frontal section angiogram (right)

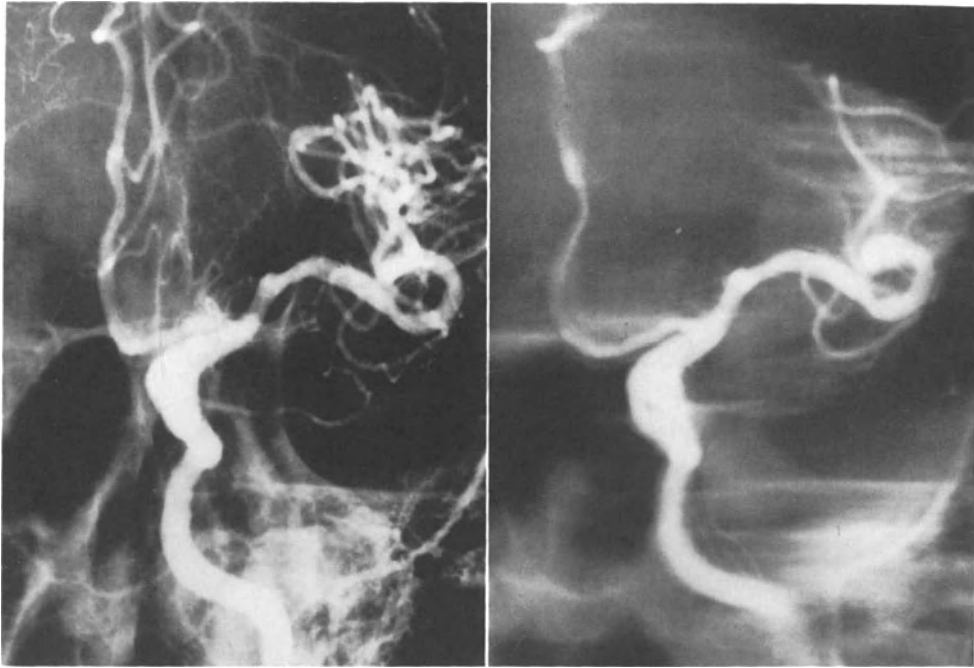


Fig. 4. Large internal carotid-posterior communicating aneurysm; conventional carotid angiography (left) and frontal section angiotomography (right)

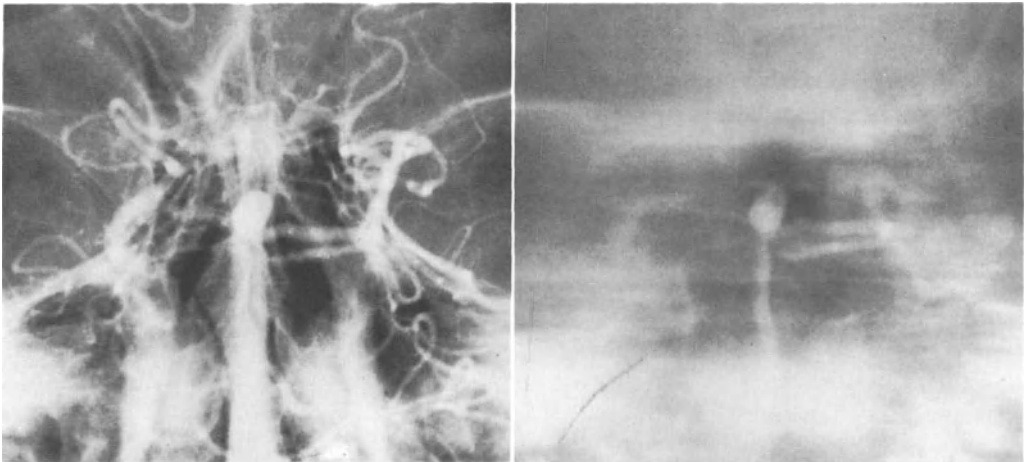


Fig. 5. Basilar bifurcation aneurysm; conventional vertebral angiography (left) and frontal section angiotomography (right)

Computer Assistance for Stereotactic Brain Operations

W. BIRG, F. MUNDINGER, and M. KLAR

For several years computer methods have been used in stereotactic brain operations together with a specially modified target apparatus. The advantages are the possibility of multiple target points, increased accuracy and reduced operational risk. Today we can present a computer program - Figure 1 shows its flow chart -, which is able to simulate the operation almost completely and to give calculative support.

Apart from the general concept of the program, we will demonstrate two features in detail: the determination of the frontal target coordinate - up to now a big problem - and the graphic display of brain sections including the electrode.

Once the basic system of the stereotactic apparatus has been attached to the patient's head, X-rays are made for the determination of five osseous reference points. By a procedure similar to that reported by HOEFER and MUNDINGER, the coordinates of the intracerebral reference points will be determined on the basis of a statistical evaluation of 500 pneumoencephalograms. The frontal coordinate can either be derived from the hemisphere width or, today, be derived with greater precision from the computer tomogram.

The second statement is true only when an appropriate representation of the tomograms is available. The polaroid pictures normally used do not respond to the requirements concerning the actual shape and the magnification.

We have developed a program for the representation of computer tomograms (Fig. 2). This representation allows an exact differentiation of brain tissues by means of their numerical absorption values in a suggestive picture. Position and width of the 3. ventricle and thereby the coordinate of the medium plane can be measured directly.

Now the coordinates of the Foramen of Monroe and posterior commissure, eventually corrected by means of ventriculography, can be determined and fed into the computer. From these values the absolute position of the coagulation target point, which has before been chosen by its intracerebral coordinates, is calculated and printed out together with the parameters for the stereotactic apparatus. This calculation can be repeated any time, so that we can choose more than one target point during one operation without changing the trepanation hole. Furthermore, the program supplies an extensive library of target points.

Small modifications of the position of the electrode, which may be necessary because of the results of controls with physiological stimuli, can be made under assistance of a variation program, which varies systematically with the target point in all three coordinates and prints out the corresponding parameters for the target apparatus.

In order to visualize the electrode's position and its neighbouring brain structures, the program supplies in a second phase brain sections, taken from the atlas by ANDREW and WATKINS, on a graphic display.

The following additional information is provided: the number of the brain section, intracerebral coordinates (Zona Incerta for the example shown in Fig. 3), angle parameters for the stereotactic apparatus and the absolute target coordinates for the patient and the X-ray. Moreover, the graphic part of the program can be used separately like an atlas with the possibility of a scaled drawing of an electrode in any desired position.

Only after inspection of the graphic representation - at this point the operating surgeon can still change the electrode path to avoid possible complications - the operation itself will start. In other words, by this program we can react by modifying the angle of approach before a possible risk of damaging certain brain structures can actually take place.

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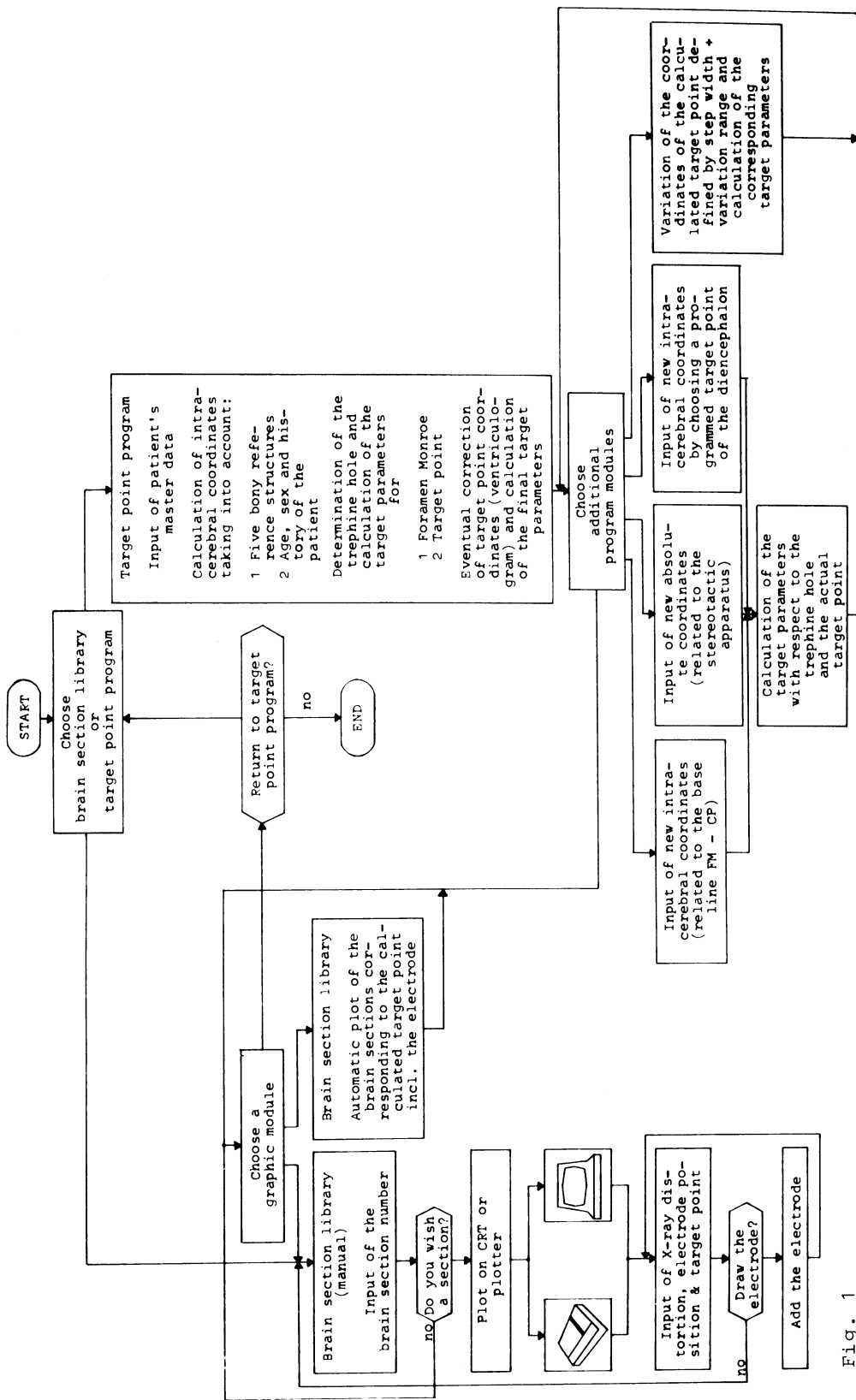


Fig. 1

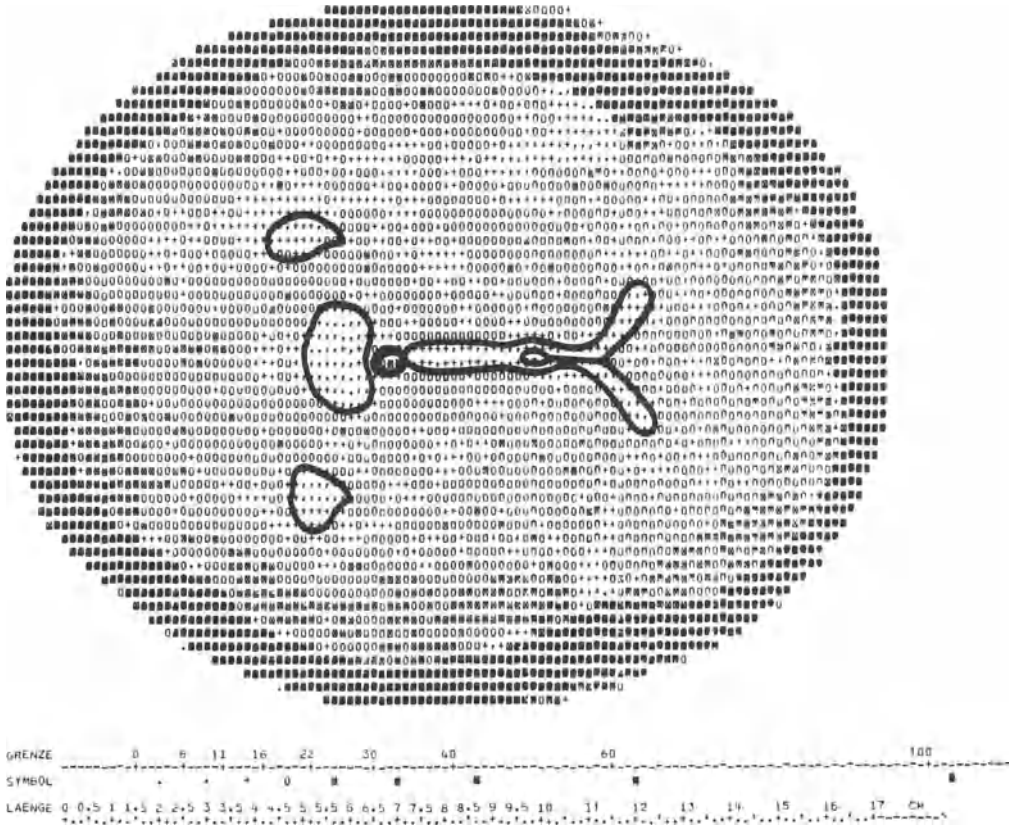


Fig. 2

AP-HIRNSCHNITT

NR. 14

INTRACEREBRALE
KOORDINATEN:

U = 8
V = 14
W = -5

PARAMETER
FUER DAS
ZIELGERAET:

HM = 67.58
SM = 79.47
NV = 3.73
NS = .6
NT = 167.51

	ROE	PAT
ZX	12.18	11.24
ZY	12.03	11.19
ZZ	55.73	51.84

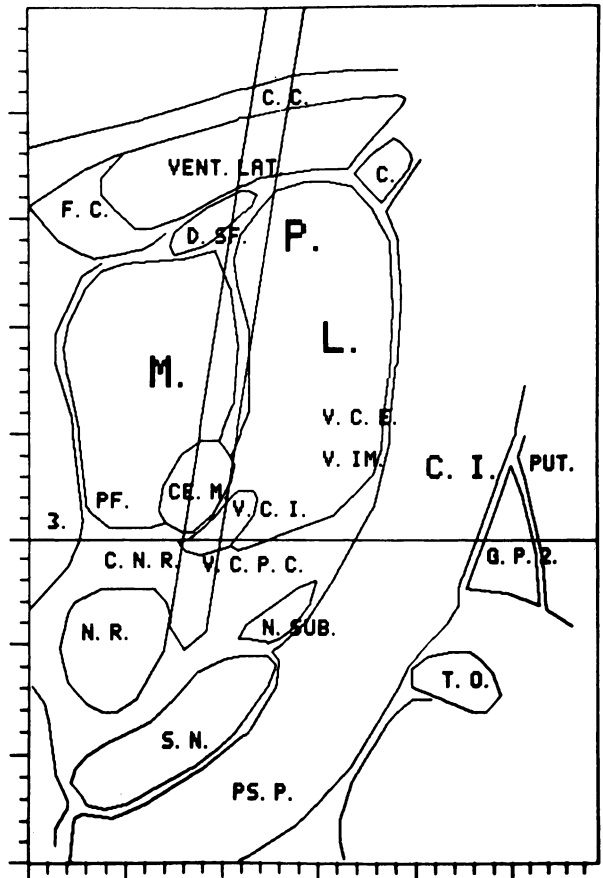


Fig. 3

Results of Operative Treatment of Acromegaly

A. KÜHNER, D. B. BARWICH, and H.-U. HAGENLOCHER

The aim of this study was to investigate whether preoperative serum Growth Hormone (GH) levels, duration of symptoms, age of patients and tumor size have prognostic value concerning the operative results. Furthermore, attention was paid to the problem of surgical and endocrinological selective total tumor extirpation.

Clinical Material

27 patients underwent surgery between 1970 and 1975. There were 15 women and 12 men between 30 and 60 years of age. Clinical symptoms could be followed up over a long period of years, ranging between 3 and 40 years. Depending on tumor size 11 patients were treated by the transfrontal route and 16 underwent transsphenoidal surgery. None of the patients were treated before admission. Tumor size was determined by means of complete neuroradiological investigation, implying plain skull film and tomogram of the sella, carotid angiography, pneumoencephalography and the operative findings, according to HARDY'y (3) classification.

Endocrine Studies

Serum GH was measured by radioimmunoassay during the intravenous hyperglycemia suppressibility-test (0.5 g glucose/kg body weight) prior to and after surgery. Controls were carried out over a period of 6 months to 5 years (average 2.1 years).

The mean values resulting from 6 single measurements were used for interpretation. The results were classified in 3 groups: good (GH level below 10 ng/ml), fair (marked reduction but not under 10 ng/ml) and unsuccessful (GH level persisted or only showed a temporary decrease).

Pituitary ACTH-reserve was assessed by the metyrapone-test (30 mg/kg body weight, plasma 11-desoxycortisol was determined by radioimmunoassay) and TSH-reserve by means of direct plasma TSH determination using radioimmunoassay.

Results

Serum GH

In 18 patients (67%) a good result was obtained. All these cases had preoperative GH levels under 70 ng/ml. All those (5 cases) with levels over 70 ng/ml presented fair (3 cases) results or were unsuccessful (Table 1).

Table 1. Operative results related to preoperative GH levels (+ = recurrence)

Results	No. of cases	Preoperative GH levels (ng/ml)			
		>10-19	20-39	40-69	70->100
Good	18 = 67%	6	7	5	-
Fair	5 = 18.5%	-	1	1	3
Unsuccessful	4 = 14.5%	1	1 ⁺	-	2
Total	27 = 100%	7	9	6	5

Table 2. Results concerning GH levels related to tumor extension

Results	No. of cases	Tumor extension				
		I	IIa	IIb	III	IV
Good	18	3	5	8	1	1
Fair	5	2	2	1	-	-
Unsuccessful	4	-	1	3	-	-
Total	27	5	8	12	1	1

There was no evidence for correlation between preoperative GH levels, age and duration of symptoms.

In regard to the tumor size (Table 2) we had good results in 3 out of 5 patients in group I, in 5 out of 8 in group IIa and in 8 out of 12 in group IIb. There was no significant difference between these 3 groups, however the majority of the unsuccessfully treated patients were found in group IIb. Our series is too small to permit any conclusions.

The best results were obtained in the transfrontal group (10 out of 11), whereas only 8 out of 16 of the transsphenoidal group had GH levels below 10 ng/ml. Among the 8 others, 4 had nonetheless a remarkable reduction of GH of over 50%. Furthermore 5 had preoperative GH levels higher than 70 ng/ml and 3 belonged to group IIb (Fig. 1).

Pituitary Insufficiency

Postoperative partial insufficiencies of the ACTH-reserve were observed in 6 patients, TSH-reserve was reduced in 5 patients. In 3 others preoperative insufficiencies remained unchanged. All these patients had good results in regard to the GH reduction (Table 3) and were solely operated by the transfrontal route. Pituitary insufficiency did not occur in the transsphenoidal group.

Table 3. Results and postoperative pituitary insufficiency related to the operative procedure (+ = preoperative pituitary insufficiency)

Operative procedure	No. of cases	Results (GH levels)		
		good	fair	unsuccessful
Transfrontal	11	10	1	-
ACTH ↓, TSH ↓		6+2 ⁺	-	-
Transsphenoidal	16	8	4	4
ACTH ↓, TSH ↓		1 ⁺	-	-

Discussion

Among all the criteria analyzed, only preoperative GH levels over 70 ng/ml had a prognostic value in our study. All good results were obtained only in those patients, who had preoperative GH levels over 70 ng/ml. This is in agreement with GIOVANELLI (4) and LEVIN (6) who even report a critical value of 50 ng/ml. ROTH (8), however, considers GH levels as irrelevant.

In 67% of our series GH levels could be lowered under 10 ng/ml. Similar results were reported by others (BECKER (1), HARDY (2)). Some authors had greater (LÜDECKE (7)) or less (GIOVANELLI (4)) success.

As for the tumor extension we obtained the best results in those cases which were operated by the transfrontal route. In this group all pituitary insufficiencies occurred, because selective removal is difficult to realize by this route, if not impossible. Although a total selective removal was assumed, intraoperatively in the majority of the transsphenoidal group, endocrine evaluation showed the persistence of pathological GH values in 50%. Three of these had tumors of the IIb-type in which HARDY (3), too, had bad results. Finally it must be outlined that there were 5 cases with rather high preoperative levels, which according to some authors seem to present therapeutic difficulties. In conclusion, we believe that transsphenoidal surgery may give better results in small tumors. But in our opinion and that of others (GIOVANELLI (4), LAZORTHES (6)) selective total removal is not always possible. The bioptic differentiation of normal and pathological tissue is sometimes difficult. In those cases, surgery should be more radical. Our results in the transfrontal group seem to confirm this. Our bad results with transsphenoidal surgery in tumors of type IIb and those reported in the literature (HARDY (3), GIOVANELLI (4)) reinforce our opinion that the transfrontal route should not be abandoned.

Summary

The operative results of 27 patients with acromegaly are reported. According to tumor size 11 underwent transfrontal surgery, 16 were operated by the transsphenoidal route. A good result was obtained in 18 patients, 10 of these belonged to the transfrontal group. Serum GH below 70 ng/ml favoured operative success. The results of both surgical procedures are compared and discussed. The problem of selectivity and total tumor removal was outlined.

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Investigation on the Prognosis of Brain Abscess

TH. WALLENFANG, H. J. REULEN, and H. SCHINDLING

With the introduction of antibiotics, the mortality of brain abscesses could be decreased considerably. Since then, however, no further reduction could be achieved and the mortality in most centres ranges between 30% and 45%. In order to obtain more information concerning the factors responsible for the unfavourable prognosis and the persistently high mortality, we analyzed 73 cases with brain abscess (50 chronic, 23 acute), admitted to our hospital between 1955 and 1975.

The analysis disclosed that both, the localisation of solitary abscesses in the different brain lobes, and the etiology - hematogenous, otorhigenous, posttraumatic - do not essentially influence the final prognosis. On the other hand, multiple brain abscesses located in the midbrain or pons have a mortality of nearly 100%. This is in line with previous findings (2, 3, 4).

In solitary brain abscesses, two factors are of utmost importance in determining the final outcome of the disease: a) the preoperative level of consciousness and b) the type of abscess, acute or chronic. The mortality rises directly proportional to the deterioration of the state of consciousness; alert (21%), somnolent (35%), soporous (55%), comatose (80%) (Fig. 1). In addition to this factor, our data show a significantly higher mortality in acute abscesses than in chronic abscesses. Figure 1 shows that both factors may act additively. Soporous or comatose patients with acute abscesses had the worst prognosis, whereas the best chances for survival were found in patients with chronic abscesses of grade I.

The most frequent cause of death in acute abscesses was meningoencephalitis with subsequent inflammatory brain swelling, whereas in the chronic cases a high intracranial pressure due to the space occupying mass is the factor responsible for death. This is in agreement with previous reports in the literature (1, 2).

A further important factor determining the prognosis of such patients is the selection of the antibiotic treatment. The analysis showed that antibiotic therapy, as judged from a retrospective point of view, was frequently inadequate concerning the dosage or the selection of the respective antibiotic, or both. In 23% of the patients the antibiotic therapy was delayed due to difficulties in the diagnosis and localization of a brain abscess. Prognosis was significantly worse in patients treated inadequately with antibiotics.

Since 1972, dexamethasone was used in our hospital in association with antibiotics to control brain edema in intracranial pressure. 25 patients were treated with 16 mg dexamethasone daily (Decadrom 4 x 4 mg i.m), 2-4 days preoperatively and 4-6 days postoperatively. Figure 2 demonstrates that 41% of these patients could be shifted to a better level of consciousness, 55% remained at their previous level and only

Table 1. Mortality of patients with acute or chronic brain abscess treated with antibiotics and surgery or with antibiotics, dexamethasone and surgery

	Acute Abscess		Chronic Abscess		Total	
	Number	Mortality	Number	Mortality	Number	Mortality
Operation + Antibiotics	9	87.5%	35	33%	44	43%
Operation + Antibiotics + Dexamethasone	8	50%	12	8%	20	25%

Table 2. Results of various operative techniques in patients with acute or chronic brain abscess

	Total	Dis- charged	†	Acute Abscess		Chronic Abscess	
				†	†		
Aspiration	16	6	10(62%)	4	4(100%)	12	6(50%)
Primary Excision	33	23	10(31%)	9	6(66%)	24	6(17%)
Aspiration + secondary Excision	15	11	4(27%)	4	2(50%)	11	2(18%)

one patient (multiple abscesses) deteriorated. In contrast, patients treated with antibiotics alone showed significantly less improvement and more frequently a marked deterioration. 14.5% of these patients showed improvement of their level of consciousness, 62.5% remained unchanged and 22% deteriorated. This favourable effect of dexamethasone has been observed in patients with a chronic abscess as well as in patients with an acute abscess (Fig. 2).

Beside the improvement of the neurological status the steroid diminished the mortality rate markedly. Sixty-four patients were operated on. Forty-four out of these 64 patients were pre- and postoperatively treated with systemic antibiotics, but received no steroid. The mortality rate of this group was 43%. Twenty out of these 64 patients were submitted to steroids and systemic antibiotics. Their mortality rate was 25%. The difference is even more significant, if the mortality of the acute and the chronic cases is considered separately (acute abscess: 87.4; versus 50%; chronic abscess: 33%; versus 8%) (Table 1).

Table 2 presents the results with relation to the type of surgery. Patients with an acute or chronic abscess submitted to repeated aspiration and instillation of antibiotics into the cavity have a mortality of 62% (Table 2).

In contrast, the mortality with primary excision of the abscess or with secondary excision following an initial aspiration and instillation of antibiotics was distinctly lower. This is in line with results reported by SCHIEFER and KUNZE (6). It might be assumed that there is a tendency of performing aspiration in patients in (comatose) worse condition while excision is preferably performed in patients in good condition. The analysis of our material disclosed, however, that irrespective of the level of consciousness, excision of the abscess always lead to better results than aspiration, although a lower level of consciousness always had a worse prognosis as shown in Figure 1.

Summary

The final outcome of patients with a solitary brain abscess seems to depend mainly on two factors. This is the level of consciousness and the type of the abscess, acute or chronic. Both factors may be influenced by adequate therapy. Using optimal systemic antibiotics together with dexamethasone enables improvement of the level of consciousness and may allow a delay in surgery until encapsulation has occurred. Primary and secondary excision of the abscess, both of which have their indication, should be preferred to repeated aspiration. By adequately applying all these measures, a reduction of the mortality to about 8-15% should be possible.

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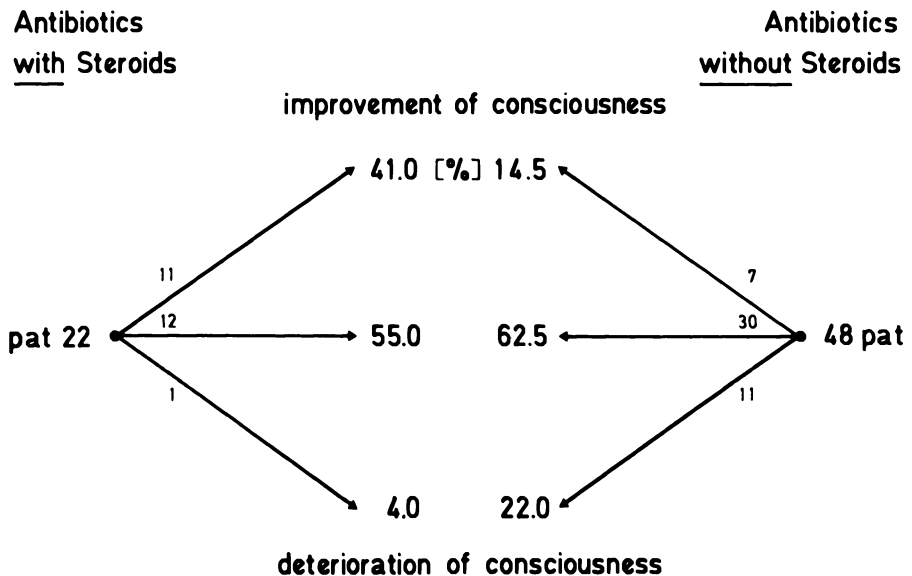




Fig. 2. Improvement and deterioration of consciousness depending on therapy of antibiotics with and without steroids

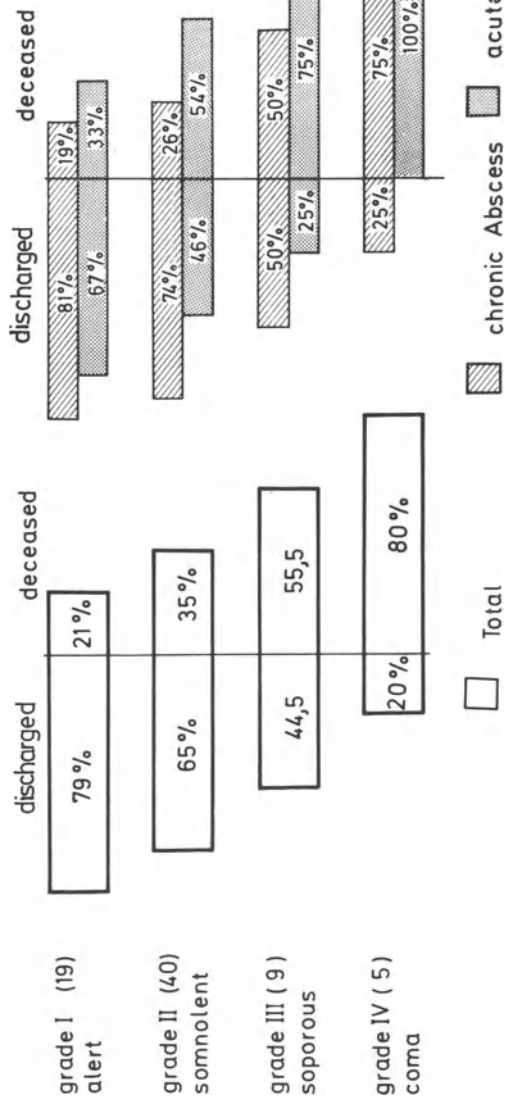


Fig. 1. Relationship between the mortality of acute and chronic brain abscesses and the level of consciousness (state I-IV) at admission

Intracerebellar Pneumocephalus. Case Report

A. GRIMMER

A 32-year-old patient suspected of having a space-occupying lesion in the posterior fossa underwent occipital trepanation. Before operation the patient showed symptoms of increased intracranial pressure. The angiographic examination demonstrated a tension hydrocephalus. Furthermore the patient showed a fixation of the head to the right, clinical evidence of a disturbance in swallowing without any definite sign of a lesion of the caudal cranial nerves as well as spastic tetraparesis predominantly on the right. Herniation of both cerebellar tonsils predominantly on the right was discovered at operation; inspection of the right cerebello-pontine angle showed no pathological findings; tumor growth in the right cerebellar hemisphere could not be demonstrated by surgical exploration. The only certain pathological finding was a dry fourth ventricle which indicated obliteration of the aqueduct of Sylvius. A Torkildsen ventriculo-cisternal shunt was implanted. The obliteration of the aqueduct was confirmed by postoperative pneumoencephalography. Following a short period of improvement, spontaneous decerebrate rigidity without any disturbance of consciousness appeared. The Torkildsen shunt was believed to be insufficient and an additional ventriculo-atrial Holter shunt was implanted. The neurological conditions improved and the patient was released from the hospital. One month later, however, he returned with further neurological deterioration. The computer tomographic study demonstrated pneumocephalus in the right cerebellar hemisphere. The X-ray films of the middle fossa showed both petrous bones to be intact. Expecting spontaneous remission of the pneumocephalus, we observed the patient very closely in the following weeks, until a series of acute events with nausea, vomiting and vertigo occurred, which forced us to abandon our hopes for remission. In the meantime, the patient developed vestibular disturbances and a disturbance of the right side similar to Parkinsonism in addition to the neurological symptomatology described above. The air was evacuated by an occipital retrepanation and incision of the pneumocephalus, 10 months later. A curtain-like structure made of cerebellar substance was found on the posterior wall of the pneumatocele covering a pial-arachnoid defect of the cerebellum. This defect was located just in front of a cranio-dural defect of the posterior wall of the right petrous bone. The second defect was closed. The patient's neurological condition has continuously improved since operation.

The pathophysiological mechanism of this cerebellar pneumocephalus may be the following: during the first operation, in which exploration of the right cerebello-pontine angle was performed, a cranio-dural lesion in the posterior wall of the petrous bone, i.e. one of its mastoid cells and the adjacent dura, was inadvertently produced. Subsequently air entered the posterior fossa through the cranio-dural defect via the auditory tube, the tympanum, the tympanic antrum and the mastoid cells when the pressure differential between the extracranial spaces and the intracranial cavity was reversed, induced by

sneezing, coughing or nose-blowing. Air accumulated in the right cerebellar hemisphere through a defect in the pial-arachnoid membrane of the cerebellum probably caused by the same iatrogenic mechanism. This one-way valve mechanism prevented air from escaping and, since intracerebral gas is absorbed very slowly, air accumulated in the intracerebellar substance.

In his survey of 295 cases of pneumocephalus from 1967, MARKHAM reports on 73 cases of intracerebral pneumocephalus. None of these, however, was located in the cerebellum. According to MARKHAM, the conditions under which an intracerebral pneumocephalus can develop are the following: a defect in the pial-arachnoid membrane in proximity to a cranio-dural defect, both connected by an adhesion; repeated changes in the pressure differential between the extracranial spaces (paranasal sinuses, mastoid cells) and the intracranial cavity induced by sneezing, coughing or nose-blowing, and the development of a one-way valve mechanism caused by herniated brain substance. In our case, all these conditions were fulfilled.

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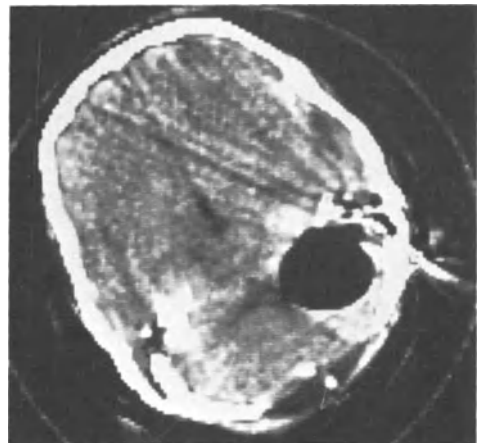


Fig. 1. Intracerebellar pneumocephalus in the computerized tomogram

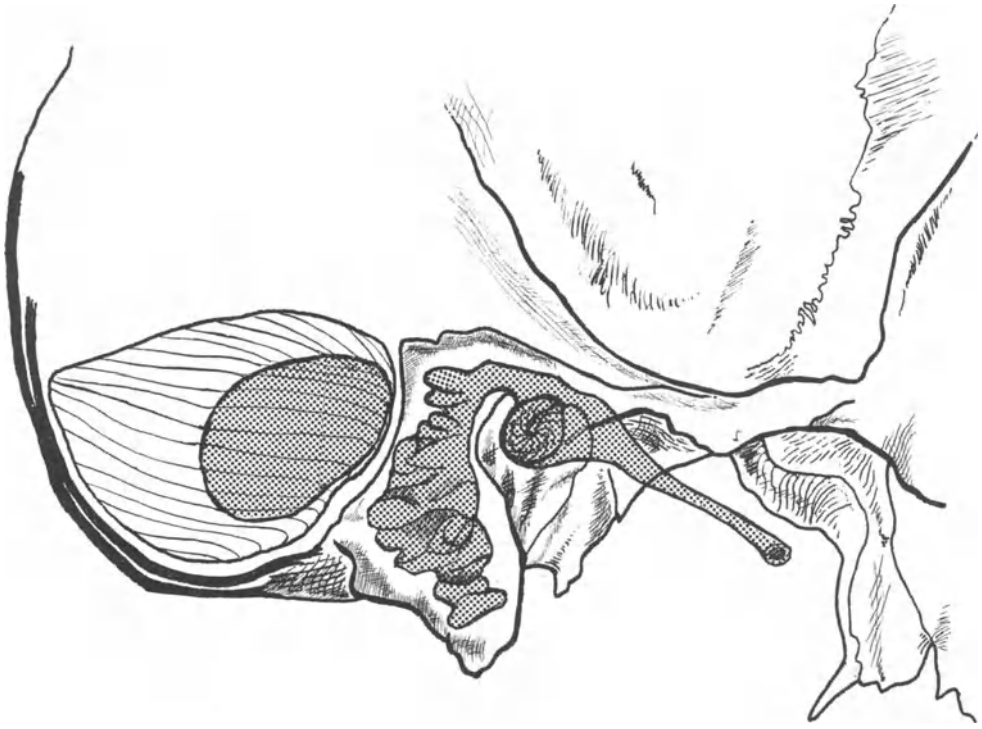


Fig. 2. Intracerebellar pneumocephalus and extracranial spaces

Malignant Lymphomas of the Brain

G. EBHARDT and W. MEESE

Malignant lymphomas (m.L.) and non Hodgkin-lymphomas were classified in the KIELER CLASSIFICATION 1974 by LENNERT, who continued the concept of LUKES.

This had become necessary, because the modern methods of experimental immunology, immunochemistry and immunomorphology had gained new knowledge. The classification differentiates malignant lymphomas of low and high malignancy.

In the central nervous system, malignant lymphomas are found in generalized lymphoproliferative disease, but also as a primary local process which comprises from 0.3% to 1.5% of all intracranial tumors. As there is no fundamental cytological difference between intracranial and extracranial m.L., they may be treated uniformly according to the KIELER CLASSIFICATION.

The neurosurgical clinic of the Klinikum Charlottenburg has observed 5 patients with m.L. in 1975 of whom 3 patients were operated. Two of these patients and the non-operated patients died. At autopsy a generalized systemic disease could not be demonstrated in a single case. The cases four and five of Table 1 are discussed in detail because they had a different clinical course and they seem extremely relevant from a morphological point of view. Only these two cases were examined by computer tomography.

Case 1

In the 54-year-old man a Waldenstroem syndrome had been known for 3 years. Two years later psychological changes were recognized which deteriorated later.

Four weeks prior to hospital admission, speech disorders occurred. There were choked discs bilaterally and a central palsy of the right facial nerve. The EEG showed moderate general disorders. Carotid angiography demonstrated a large space-occupying mass in the left temporal cerebral lobe. The brain scan was not pathological. Computer tomography (Fig. 1) showed a zone of low density in the left fronto-temporal region which was not enhanced by contrast medium. At operation, a tumor situated deep in the fronto-basal region was incompletely removed.

The histology of the tumor showed large strongly basophilic cells with large central nucleoles. The infiltrative growth and the numerous mitoses indicated the malignancy, and led to the diagnosis of an immunoblastic lymphoma of high malignancy. The patient was treated by cytostatic drugs and was radiated with telecobalt.

Case 2

This 55-year-old man had an extremely short history of only one month. After an inadequate trauma without primary loss of consciousness, a progressive psychological disturbance developed. The patient became apathetic and somnolent. 200/3 cells in the CSF, which were mainly lymphocytes, pointed to the differential diagnosis of a space-occupying lesion and encephalitis. The brain scan showed a pathological symmetrical accumulation in the supra-sellar region. Computerized tomography showed a large bifrontal region of low density without enhancement (Fig. 2). The patient died of pulmonary embolism. The brain was dissected according to the slices of the computer tomographic examination. The tumor resembled a butterfly glioma and was situated in the cortex and the white matter of both frontal lobes and in the splenium (Fig. 4). Nodular infiltrations were found in the vicinity of the frontal horns of both lateral ventricles. The histology confirmed a lymphoblastic tumor of high malignancy. There were cellular infiltrations in the meninges. Between tumor cells there was an extreme proliferation of protoplasmatic astrocytes and of few rod-like microglial cells.

Discussion

The 5 patients with malignant lymphomas who were observed in the neurosurgical clinics, Klinikum Charlottenburg in 1975, were a 72-year-old woman and four men of an age between 54 and 65 years.

The disease is usually encountered in the 6th and 7th decade. Men are more frequently affected than women. All our cases were malignant lymphomas of high malignancy. In 68 primary m.L. JELLINGER observed immunoblastomas in 58 percent. This type of tumor was found in 3 out of our 5 cases.

These tumors, in earlier times classified as reticulum cells sarcomas, develop from immunoblasts and not from reticulum cells or histiocytes (8). The B-cell lymphomas may cause paraproteinemia usually with an elevation of IGM. The macroglobulinemia Waldenstroem which was observed in the first case is therefore not a separate disease but rather a clinical syndrome. When the meninges are affected, the immunoelectrophoresis of the CSF shows pathological values.

The cytological examination of the CSF reveals pathological cells in 57 percent (KOLAR, 7). RAWLINSON and co-workers observed malignant lymphomas in 12 patients, who showed an affection of the central nervous system by clinical symptoms and were verified by autopsy. 6 of these cases (50%) had lymphoma cells in the CSF, the others presented

Table 1. Five cases with malignant lymphoma who were observed at the neurosurgery clinic in 1975

Age	Sex	History	Tumor localization	Histological diagnosis
72		3 month	right temporal region including basal ganglia	immunoblastic lymphoma of high malignancy
64		3 month	right parieto-occipital region	lymphoblastic lymphoma of high malignancy
57		4 month	bifrontal periventricular region	immunoblastic lymphoma of high malignancy
54		3 years	left frontal paraventricular	immunoblastic lymphoma of high malignancy
55		1 month	bifrontal periventricular	lymphoblastic lymphoma of high malignancy

a negative cytology. The authors believe, however, that CSF cytology is a valuable diagnostic adjunct to verify malignant lymphomas of the central nervous system.

NEW and SCOTT (11) have shown computerized tomograms of malignant lymphomas, which correspond to our observation of a blurred region of low density. The history of patients with malignant lymphomas is usually short. However, sometimes a longer history may be observed as in our first case. Lymphoblastic malignant lymphomas have a worse prognosis than immunoblastomas. If after surgery the tumor is irradiated the survival is increased from 0.9 to 25 months. The paraventricular localization of the tumor seems to be preferential. Sometimes growth resembles that of a butterfly glioma as in 2 of our 5 cases.

Both circumscribed tumors and diffuse infiltration of the cerebral white matter and cortex are found.

KEPES and co-workers report on a case which was believed to be a pseudotumor cerebri and which at autopsy presented only extreme cerebral edema. Only the histological examination was able to provide the diagnosis of a malignant lymphoma.

One reason for the increasing number of malignant lymphomas may be due to the therapy using immunosuppressive agents and irradiation.

CHO and co-workers observed primary malignant lymphomas in the brain after renal transplantation and immunosuppressive therapy. The human renal transplant registry contains 25 further cases which in 11 cases showed an isolated affection of the brain. Hitherto the pathogenesis of primary malignant lymphoma of the brain without generalization is not clear. An initial intracranial manifestation of a lymphoproliferative disease may be possible which causes death prior to generalization.

Summary

Malignant lymphomas may be localized in the brain as one manifestation of systemic disease or they are isolated in the central nervous system. About one-half of the cases had tumor cells in the CSF. Electrophoresis of serum CSF may reveal an increase of immunoglobulins. Clinical history is usually short. Operation and irradiation yield better survival results than operation alone. This is especially true for immunoblastomas. The morphology shows a nodular or diffuse tumor growth, which sometimes resembles butterfly gliomas.

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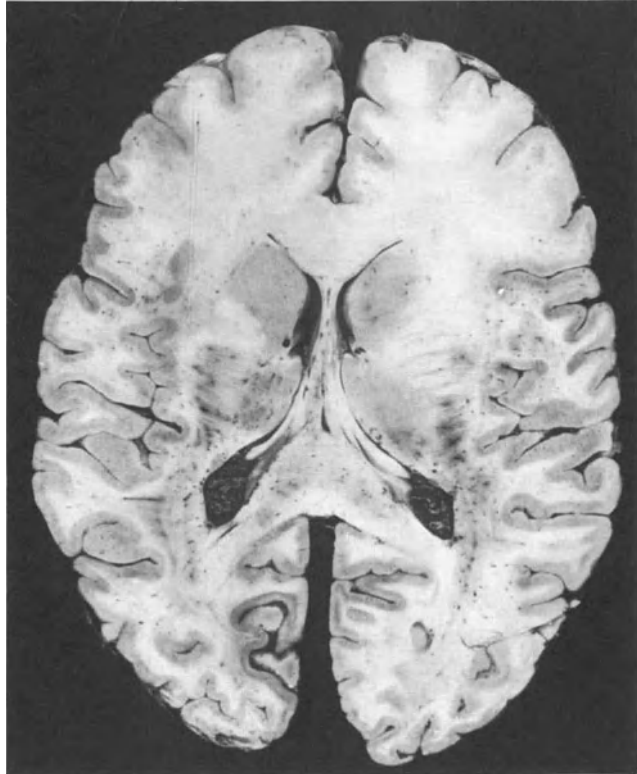
Fig. 3. Considerable swelling of the corpus callosum and of the cere- bral white matter in both frontal lobes



Fig. 1. Diffuse finger-like zone of low density in the left frontal region with considerable displacement of midline structures. No enhancement after injection of contrast medium



Fig. 2. Diffuse finger-like bifrontal region of low density. Non enhancement after injection of contrast medium



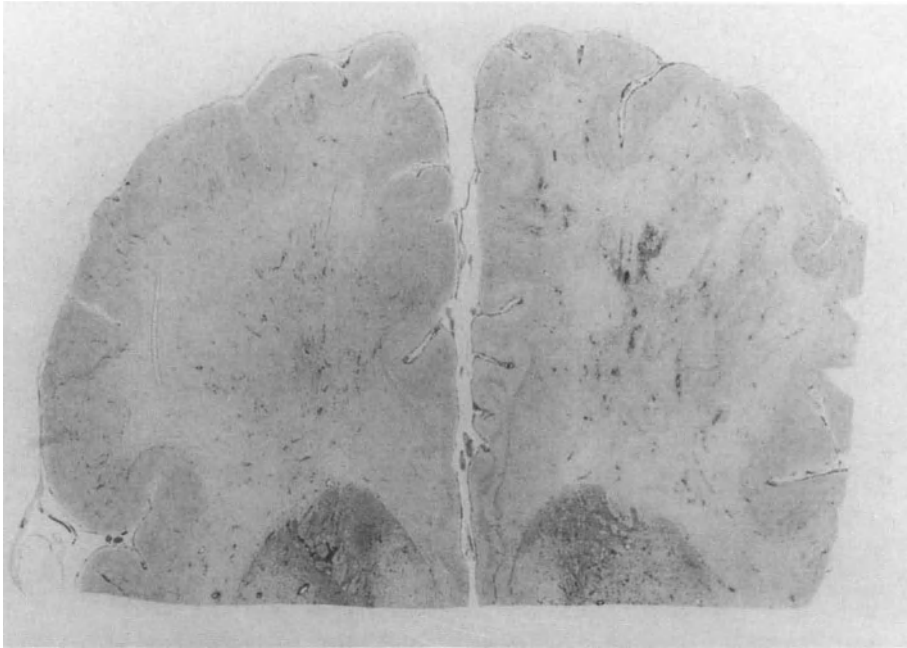


Fig. 4. Diffuse tumor cell infiltration of the cerebral white and grey matter and meninges. Nodular tumor cell infiltration in the paraventricular region

The Use of the Fogarty Catheter Method in the Treatment of Carotid-Cavernous Sinus Fistulas and Giant Basal Sack-Shaped Aneurysms

H. ALTENBURG, D. STÖWSAND, and W. WALTER

The treatment of giant basal sack-shaped aneurysms of the cerebral arteries and the carotid-cavernous sinus fistulas is a challenge for every neurosurgeon.

Encouraged by the most recent publications of French and American neurosurgeons and neuroradiologists (2, 3, 4, 5, 6, 7) concerning the successful application of the FOGARTY catheter method in the treatment of carotid-cavernous sinus fistulas as well as in experiments with animals suffering from intracranial aneurysms, we, too, have in the meantime applied this procedure with great success.

In our opinion the intraarterial occlusion of the carotid-cavernous sinus fistulas by a balloon catheter at present represents the best method of treating these fistulas. In this method the FOGARTY catheter is introduced into the internal carotid artery after appropriate pre- and intraoperative angiographic determination of the precise fistula-localization and the collateral blood supply. The catheter may be introduced after the carotid artery has been uncovered at the neck or the percutaneous SELDINGER method may be employed. During this operation the catheter is pushed forward as far as the carotid syphon. Constant X-ray control and occasional injections of contrast medium are essential. The balloon catheter is inflated at the level of the fistula and the catheter and the balloon are left there. In addition the internal carotid artery may be closed by a suture at neck level. In the meantime attempts have already been made to manipulate the inflated balloon over to the venous side of the fistula in order to maintain the blood circulation through the internal carotid artery (1). Even without this measure the clinical results are excellent. All the authors who have dealt with the subject are in agreement on this point and their views have been confirmed by our own experience.

We have successfully experimented with a further promising application of the FOGARTY catheter method in treating a giant inoperable aneurysm of the supraclinoid section of the internal carotid artery. This aneurysm had already produced symptoms similar to those normally observed in the case of a tumor of the pituitary fossa with suprasellar growth: bitemporal hemianopsia, increasing deterioration of vision and hormonal disorders. After thorough angiographic determination, the following procedure was adopted: first the catheter was inserted into the internal carotid artery and the artery was closed at the level of the aneurysm. A few days later angiography of the contralateral side showed that there was optimal collateral blood supply and that the aneurysm was no longer filling up with blood. Thereupon a second operation was carried out. After fronto-temporal osteoplastic trepanation and clipping of the internal carotid artery immediately below the point where it branches into anterior cerebral artery and middle cerebral artery, the aneurysm, which had in the meantime become completely thrombosed, was totally removed.

On the basis of our own experience we should like to advocate the more frequent use of the FOGARTY catheter method in cases like those described above.

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Histological and Radiological Results of Discography with Water-Soluble and Oily Contrast Media in Rabbits

W. ELIES and W. SPREITZER

In the diagnosis of lumbar and especially cervical degenerative disc diseases, discography is more and more in use. The knowledge about the short- and long-term effects of contrast media (c.m.) on the disc tissue is of importance. Pathological tissue changes seem to be relatively unexpected because results of clinical examinations show complications only in 0.02% and these are not only inflammations (4). In the literature, we found only two reports about animal experiments in dogs with intradiscally injected c.m. (2, 3). The authors did not find any lesions up to one year after discography. Histological examinations were made and in most cases cicatrisation of the puncture channel was seen. That was the only deviation from normal. Experimental discography in animals with modern, water-soluble or oily c.m. is unknown to us. For this reason we performed animal experiments with some often-used water-soluble and one oily c.m.

Material and Methods

For our experiments we used water-soluble c.m.¹ of different iodine content (282 - 480 mg/ml) and osmolarity (1040 - 3011 mOsmol/l) and the oily monoiodostearate¹ (320 mg/ml) (Table 1). Fifty rabbits of random sex, one year of age and with an average weight of 5 kg were used. Under sodium pentobarbital anesthesia laparotomy was made and 0.05 ml of the c.m. injected into each of three lumbar discs. Immediately after discography and before killing the animals, X-rays of the lumbar

Table 1. Osmolarities and iodine contents of the contrast media used in discography

	Osmolarity (mOsmol/l)	Iodine Content (mg/ml)
Dimethylglucamin - Iocarmate (Dimer XR)	1040	282
Methylglucamin - Iotalamate (Conray 60R)	1456	282
Methylglucamin - Iotalamate (Conray 80R)	3011	480
Methylglucamin - Ioxitalamate (Telebrix 380R)	2512	380
Monoiodostearate (DuroliopaqueR)		320

¹ Fa. Byk-Gulden, Konstanz.

spinal column were taken. 12 h, 24 h, 48 h, 2 days, 2 and 4 weeks after discography the animals were killed and the injected as well as a normal intervertebral disc removed for histological examination. After complete decalcification, sections were cut to contain the discs and the adjacent vertebral bony end plates. These were stained by the hematoxylin and eosin method, van Gieson's method and the Prussian blue method. By removing a normal disc in each animal, we could compare that tissue with the injected discs and observe pathological changes. The following factors could be the reason for tissue lesions after discography: Osmolarity, chemical structure and iodine content per ml of the c.m.. In order to separate these factors, hyper- and hypoosmolar solutions were injected. We used glucose solution (3011 mOsmol/l) and distilled water.

Results

In our experiments histological and radiological short- and long-term examinations up to 4 weeks showed no pathological changes of the intervertebral disc tissue and adjacent vertebral bony end plates. After injection of water-soluble c.m., hyperosmolar glucose solution and distilled water during the first days, we could find only irregular and insignificant changes like a swelling of the nucleus pulposus tissue or an increase of the perivascular cells situated here. These changes were never seen at the same time in the three injected lumbar intervertebral discs. In nearly all examined discs, puncture channels with the different stages of cicatrization were found (Fig. 1). X-rays of the lumbar spinal column were normal in all cases. Pathological changes like lesions of the vertebral bony end plates or a diminished distance between two vertebrae were not found corresponding to the histological findings. 12 hours after injection of the oily monoiodostearate into the nucleus pulposus there we saw fat droplets, perceptible by the empty areas in hematoxylin-eosin stainings. During the subsequent time no pathological lesions were found like in discs injected with water-soluble c.m.. The opacity of injected intervertebral discs was proportional to the iodine content of the injected c.m.. The best X-rays were obtained by use of CONRAY 80¹. After discography with monoiodostearate relatively good contrasting discs were seen. Two weeks later the well-known ways of elimination of the oily c.m. were found (1). At any time after discography, Prussian blue stainings were negative. This fact shows that no intradiscal bleeding occurred.

Discussion

Clinical studies about side effects in discography allow the presumption that no severe lesions of intervertebral disc tissue occurred after injection of the water-soluble c.m. used today. In our experiments, we could not show by histological and radiological examinations any pathological changes from 12 hours up to four weeks after discography with water-soluble c.m.. Furthermore the oily c.m. monoiodostearate, whose tissue tolerance is lower, caused no inflammable or degenerative disc lesions. Toxic side effects on the intervertebral disc tissue are to be expected from osmolarity, chemical structure and iodine content of the c.m.. For separating such factors, we injected a hyperosmolar glucose solution and distilled water. These changes in chemical structure, osmolarity and iodine content caused no tissue reactions. The findings of the experiments show a good tissue tolerance for the c.m. used. Proportional to the iodine content per milliliter of the c.m., the opacity of the injected discs increased. According to the histological and X-rays findings no pathological lesions of the intervertebral discs or adjacent vertebral bony end plates were found. A reason for the

good tissue tolerance of the c.m. used could be the fact that the intervertebral disc in rabbits is vascularised and water-soluble c.m. are eliminated in a very short time. But it seems that this fact plays only a minor part in the explanation of good tissue tolerance. In the discs examined, water-soluble c.m. were demonstrable over a period of some hours by X-rays. Furthermore, we know only a few cases of inflammation following discography in the non-vascularised human intervertebral disc. Because of the reported findings about our experiments, the use of water-soluble c.m. with a high iodine content is to be discussed for human discography. It seems, that these c.m. produce no lesions of the intervertebral disc. In contrast, the use of oily c.m. in human discography is not to be recommended because of the high viscosity and low rate of elimination. Hemosiderin tests by Prussian blue stainings were negative in all histological sections. This finding excludes the occurrence of bleeding at discography.

Summary

Experimental results of discography with modern water-soluble and oily contrast media in rabbits are reported. After discography and before killing the animals, the lumbar spinal column was x-rayed. Between 12 hours and 4 weeks, the animals were killed and disc removed for histological examination. Histological and radiological findings showed no disc lesions. During the first days irregular edema or an increase in perivascular cells was seen in a few discs. Cicatrisation of the puncture channel occurred in nearly all of the discs. 12 hours after injection of the oily c.m., cysts were found. Later no lesions were observed. Hyperosmolar solutions or distilled water caused no lesions.

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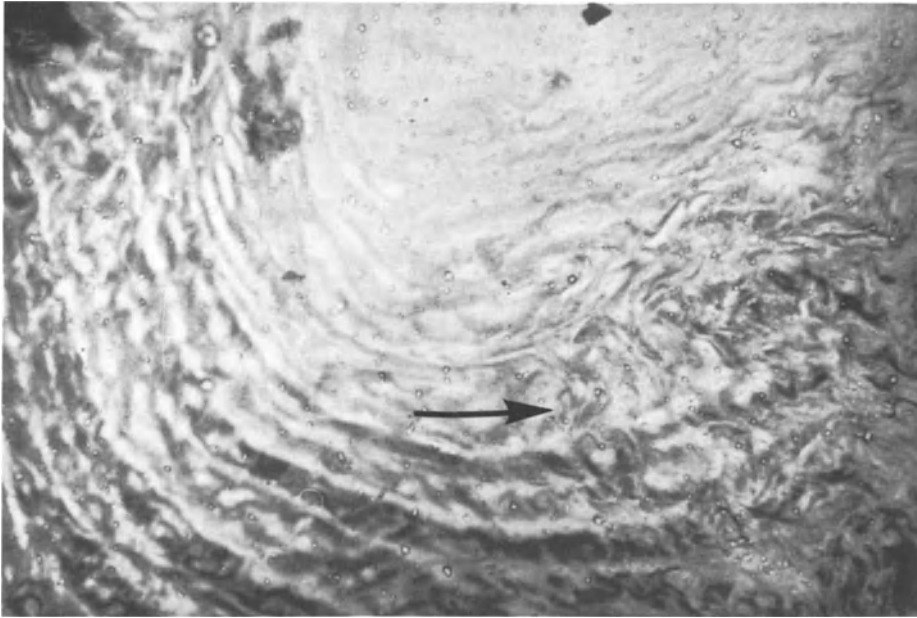


Fig. 1. Cicatrization of the puncture channel after discography

Neurotransmitter - Shifts in Cerebro - Organic Processes

F. OPPEL, G. SCHULZE, W. UMBACH, and J. BLUDAU

Summary

There is an enormous reduction in homovanillic acid (HVA) and 5-hydroxyindol-acetic acid (5-HIAA) in the spinal fluid (CSF) of Parkinson patients. L-dopa and HVA are, however, present in large quantities in the CSF of treated patients, especially when the medication contains L-dopa. This correlates well with the high yield of HVA. There is no trace of L-dopa in the CSF, when it is not administered. In the discontinuance of treatment there is no increase of CSF - HVA even during the administration of probenecid, while the 5-HIAA concentration increases continuously. If the treatment is pursued in its original form, the probenecid test shows an enormous increase of HVA and 5-HIAA with predominance of HVA particularly in those patients receiving L-dopa. The ratio HVA/5-HIAA of healthy persons (1, 5) is however not attained even after 24 hours. It follows that treatment with L-dopa produces an increase and discontinuance a decrease of the HVA/5-HIAA quotients.

Introduction

Metabolic deviations of the neurotransmitters dopamine and serotonin were described for cranial injuries (16), for diseases of the extrapyramidal motor system, e.g. chorea Huntington (7) and Parkinson disease (3, 10), for brain tumors (8) and for psychiatric diseases, particularly in cases of depression (4, 9, 13). There are also reports on the influence of 5-hydroxy-tryptophan (9) and also l-tryptophan (3), as precursors of serotonin for depressions, and on the effect of therapy with L-dopa as a precursor of dopamine. So far diagnostic and therapeutic conclusions could be drawn only to a limited extent, as some neurotransmitter deviations are only partly complex processes, and because a long-time inundation of the organism with neurotransmitter-precursors may lead to disturbances in the healthy regions of the brain. In the first place this happens as a result of a chronic excessive supply of a substrate which is normally present in considerably smaller quantities only, the second cause is the occurrence of a greater number of metabolites, particularly those with a longer duration in the organism, as for instance 3-O-methyldopa. Based on investigations of 20 Parkinson patients, i.e. of an illness with a disease-specific reduction of dopamine and serotonin, this paper presented and discussed the deviations of the dopamine-metabolite homovanillic acid (HVA) and of the serotonin-metabolite 5-hydroxy-indoleacetic acid (5-HIAA) during the chronic supply with the dopamine-precursor L-dopa.

Material and Methods

We chose 20 Parkinson patients with hypokinesia as the main symptom, they were 9 females and 11 males. Their average age was 67 years (51 - 85). For years all patients had been receiving a combined Parkinson-therapy, which in 5 cases did not contain any L-dopa. The patients were split up into 2 groups of 10 patients each. In the first group the Parkinson-therapy was suspended for 24 hrs, in the second group it was continued without any interruption. All patients had been treated in a clinically satisfactory manner, and received an additional 20 mg prodipin (1-tert.isopropyl-4,4-diphenylpiperidine hydrochloride), the effect of which is caused by the release of endogenous dopamine. As spinal taps were performed 4 times within 24 hrs, a flexible venous catheter of 1 mm outer diameter was placed intrathecally via a lumbar tap cannula and left for 24 hrs. Both groups of patients received probenecid in a dosage of 1000 mg initially, followed by 4 more oral probenecid administrations of 250 mg at intervals of 1 hr each. Dosage scheme is according to LAKKE et al., 1973 (6). The lumbar spinal taps (scheme in Table 1) were performed 1. prior to probenecid administration in the group with continued Parkinson-therapy before medication, 5 hrs. after the initial probenecid administration, 8 hrs after the initial probenecid administration, i.e. 3 hrs. after a prodipin infusion of 20 mg in all patients, 24 hrs after the first tap. The CSF was always withdrawn from the lumbar region because the CSF concentrations of HVA and 5-HIAA vary with the level of tapping (14). The individual fractions of the spinal fluid were deep-frozen immediately after withdrawing them. Determinations of L-dopa were done, of HVA and 5-HIAA. The chromatographic separation of L-dopa, HVA and 5-HIAA from the CSF was performed according to the method of ATACK (2) and LINDQUIST, 1973, and KEHR et al., 1972 (5). Their methods were used for the fluorimetric determination of L-dopa and 5-HIAA. HVA was determined according to the modifications of ANDEN, 1963 (1).

Table 1. Course of spinal taps and administration of probenecid within 24 hours

Time (h)	
0	1. CSF-sample 1000 mg Probenecid
1	250 mg Probenecid
2	250 mg Probenecid
3	250 mg Probenecid
4	250 mg Probenecid
5	2. CSF-sample 20 mg Prodipin-infusion
7	Infusion finished
8	3. CSF-sample
24	4. CSF-sample

Results

1. L-Dopa

In patients who did not receive any L-dopa, neither briefly nor long-term, there was no L-dopa detectable in the CSF. With L-dopa therapy (with decarboxylase inhibitor), we measured values of 76.5 ng/ml. At the time of the initial spinal tap, the mean values was 11.0 ng/ml, and after 12 hrs it was 12.2 ng/ml. The increase in L-dopa due to probenecid up to 60.3 ng/ml after 5 hrs, and up to 76.5 ng/ml after 8 hrs, which correlates highly ($r = 0.97$) with the occurrence of HVA (Table 2).

Table 2. L-Dopa-values in the spinal fluid of the 1. - 4. tap with interrupted (n=9) and continuous (n=6) therapy. Mentioned are only those values of the patients whose medication contained L-Dopa. Without the administration of L-Dopa, there was no L-Dopa detectable in the spinal fluid

CSF-sample (h)	Therapy	
	Intermittent n = 9	Continuous n = 6
1. (0)	0	11.0 ± 7.8
2. (5)	0	60.3 ± 16.9
3. (8)	0	76.5 ± 23.4
4. (24)	0	12.2 ± 8.7

L-Dopa in CSF/means ± SEM

2. HVA

Even with probenecid, there was no increase in HVA in those patients to whom the interrupted Parkinson-therapy had been applied. The initial values of both groups of patients and the values after 24 hrs are reduced up to 75% when comparing them with the values of healthy persons (e.g. 12) (Table 3). With probenecid plus the usual therapy, the HVA-level after 5 hrs rose from 18.4 ng/ml to 39.0 ng/ml, after 8 hrs to 55.9 ng/ml. If, from the group with uninterrupted Parkinson-therapy, only those patients are taken into consideration whose medication did contain L-Dopa (n = 6), the HVA-value increased under probenecid to an average of 80.2 ng/ml which is a physiological value (Table 4). The normal value for healthy persons is approx. 86.0 ng/ml (12).

Table 3. HVA- and 5-HIAA-values of that group of patients where Parkinson-therapy was interrupted for 24 hours. While the HVA-level is primarily reduced with only slight variations, the 5-HIAA-level increased over 24 hours

CSF-sample (h)	HVA	5-HIAA
1. (0)	11.5 ± 3.6	9.7 ± 1.8
2. (5)	8.5 ± 4.0	17.0 ± 3.1
3. (8)	11.5 ± 4.0	15.2 ± 2.6
4. (24)	10.4 ± 3.1	22.9 ± 2.9

Mean ± SEM, n = 10.

Table 4. HVA- and 5-HIAA-values of that group of patients with uninterrupted Parkinson-therapy. HVA- and 5-HIAA-levels increase after administration of probenecid. The HVA-level, however, increases absolutely

CSF-sample (h)	HVA	5-HIAA
1. (0)	18.4 ± 6.3	13.5 ± 2.0
2. (5)	39.0 ± 17.0	29.6 ± 4.9
3. (8)	55.9 ± 20.5	38.5 ± 6.6
4. (24)	23.3 ± 6.7	31.2 ± 5.9

Means ± SEM, n = 10.

3. 5-HIAA

In both groups, the initial values for 5-HIAA are more than 50% below those of healthy persons. However, in contrast to HVA, after 24 hrs the values are considerably higher than the initial values (Table 3). In those patients where the therapy had been interrupted, 5-HIAA even reached its maximum (mean value 22.9 ng/ml). Following probenecid administration, the values in this group rose to 17.0 ng/ml after 5hrs, and reached 19.2 ng/ml after 8 hrs. In the group with continuous Parkinson-therapy, probenecid led to a 5-HIAA-increase which is still below the normal (46.0 ng/ml) value (29.6/38.5 ng/ml, Table 4); after further subdividing that group which received L-Dopa (n = 6), one finds a more rapid increase (34.5 ng/ml) after 5 hrs. Even after 8 hrs, physiological values (39.3 ng/ml) will not be reached.

4. Ratio HVA/5-HIAA

The ratio HVA/5-HIAA, which is 1.5 for healthy persons, is 1.2 for the group with interrupted therapy. With probenecid it is reduced to 0.5 in contrast to an increase to 1.9 in healthy persons. For the group with the continued therapy, the initial value is 1.4. Under probenecid treatment it almost remains at this level (1.31/1.45). If the L-Dopa-group is again investigated (n = 6), it is found that with 2.1 the quotient is far above that of healthy persons (Fig. 1).

Discussion

The initial values of both groups of patients (n = 20) were obtained under identical conditions, so that for these values the total number of patients could be used as a basis. With an average value of 15.0 ng/ml, the initial value of HVA is considerably lower than the normal value (44.0 ng/ml) of the CSF. This value agrees with other authors' statements (11) and can be explained from the duration and severity of the disease. Whether the chronic administration of antiparkinson-drugs contributes to this reduction, is still open to question. 5-HIAA also has a reduced initial value (n = 20) of 11.6 ng/ml compared with the normal value (29.0 ng/ml) (12), but substantially less than HVA. The 24-hour values of 5-HIAA are opposite to the HVA values. In the group with interrupted Parkinson therapy, they increase to 22.9 ng/ml and in the group with continued Parkinson-therapy to 31.2 ng/ml, i.e. to about those of the normal values. The HVA-24-hour values, however, were almost similar to the initial values (10.3/23.3 ng/ml).

With probenecid, which according to LAKKE et al., 1973 (6) sufficiently inhibits the HVA and 5-HIAA exchange from CSF into the blood at a dosage of 2 g, the HVA- and 5-HIAA-values of the group with continued therapy both increased to three times as much after 8 hrs. In the 6 patients who received a Parkinson medication containing L-Dopa, HVA increased a lot more. There is a dependency of HVA- and 5-HIAA-values on the quantities of L-Dopa administered. If L-Dopa was not given, the 5-HIAA-values increase continuously, this corresponds with the low HVA-values. If L-Dopa was given in high doses, the HVA predominated although 5-HIAA also increased distinctly. This is seen in a HVA/5-HIAA quotient of 2.1, compared with a general value of 1.4 (normal 1.5), and 0.5 during interrupted L-Dopa administration. These results confirm the findings of TAMARKIN et al., 1970 (15), who also observed a pronounced HVA-increase following L-dopa with a relatively small 5-HIAA-increase under probenecid medication.

Not mentioned so far was the influence of prodipin on HVA- and 5-HIAA-levels. Though there was a continuous metabolic increase in both groups of patients, in that group where L-Dopa had not been administered briefly, the HVA increase was not above the normal dispersion rate. The same applied for that part of the continuously treated group which did not receive any exogenous L-Dopa (n = 4). The HVA-increase registered for patients with continuous L-Dopa-therapy following prodipin, can only be specified in comparison with a L-Dopa-treated group which did not receive prodipin.

It must be emphasized that all patients were well adjusted clinically, showing no signs of psychic alterations; BIRKMAYER 1972 (3), however, reported the same CSF-findings for a group of patients suffering from psychoses and delirious symptoms after administration of L-Dopa.

It is evident that when Parkinson-therapy was interrupted, HVA remained on the same extraordinarily low level, even with probenecid, and that there was at the same time an increase of 5-HIAA. If a combined Parkinson therapy is applied, particularly with L-Dopa (containing decarboxylase-inhibitor), HVA and 5-HIAA increased rapidly; the main emphasis, however, was on HVA. These findings show the problem of a therapy with precursors of neurotransmitters. Most likely, a disturbed serotonin- and dopamine-balance is responsible for undesired side-effects. This physiological balance must be reached in cases of illness. This can occur either by target controls of CSF during therapy, or else by an additional and improved combination of L-Dopa and the so-called dopamine-liberators.

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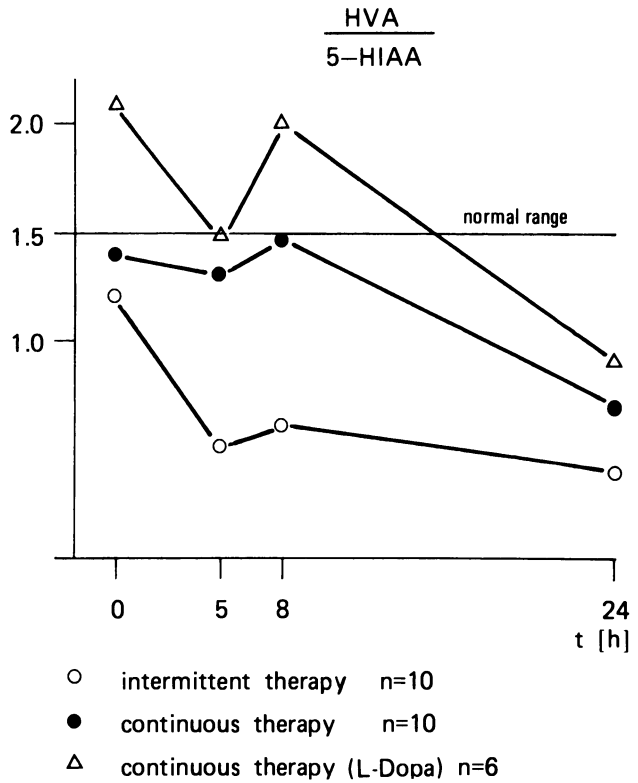


Fig. 1. The quotient HVA/5-HIAA in the course of 24 hours. The balance of both metabolites even with probenecid is normal, reaching approx. 1.5. The group with interrupted therapy was by far below this value. The group with continued therapy reached it after 8 hours. For the 6 patients from this group whose therapy contained L-Dopa (n = 6), the value is distinctly higher. An imbalance is reached again

The Diagnostic Accuracy of Imprint Cytology for Neurosurgical Biopsies

L. GERSTNER, G. WÖBER, and K. JELLINGER

Cytological techniques are used in many centers and besides frozen section techniques have been found valuable for a rapid histological diagnosis of neurosurgical biopsies (6-8). The principal advantages of the cytological methods are their technical simplicity and the rapidity of their preparation, the ease with which small portions of tissue are to be screened where the preparation by cryostat may be difficult, and the clarity of the cytology on which the neuropathologist is dependent for establishing the diagnosis. However, the accuracy of the cytological methods is still under discussion. While in some series a correct diagnosis was made in 70 to 80% of the smear preparations compared with a 94 to 95% accuracy of cryostat and paraffin section (1, 3), MARSHALL et al. (6) have shown that the smear technique has a diagnostic accuracy of 93 to 94% whether the specimen came from burr-hole biopsies or from open craniotomy. In an attempt to define the accuracy of the imprint technique and its clinical usefulness, the diagnoses made by cytology and the parallel paraffin sections were compared in 311 consecutive neurosurgical biopsies performed during the last 15 months. The sources of the biopsy specimens are summarized in Table 1. The conditions encountered were representative for those seen in any neurosurgical unit, the majority being primary and secondary tumors (Table 2).

Material and Methods

From the tissue obtained at biopsy small portions were used to produce multiple touch preparations on glass slides preventing smearing movements and other artefacts. Usually, several imprints were prepared from representative portions of each specimen. After air drying the imprints were stained with the May-Grünwald-Giemsa technique. If necessary, cytochemical techniques were used. The remainder of the specimen was processed for the preparation of paraffin sections stained by routine methods. In a number of cases parallel cryostat sections were made. The results of intraoperative examination of touch preparations and the final diagnoses made on paraffin sections were compared.

Results

Correct diagnosis. While the diagnostic accuracy of the paraffin preparations was 98.4%, a correct diagnosis was made in 292 of the 311 imprint preparations (93.9%). The latter usually allowed a correct grading of gliomas and often a correct classification of metastatic carcinomas.

Incorrect and inconclusive diagnoses were made in 19 cases (6.1%) in which no exact classification of the condition was possible. There were 10 cases in which the wrong diagnosis was made on the imprints

Table 1. Sources of 311 neurosurgical biopsies

Craniotomy - supratentorial	: 224
infratentorial	: 35 - total : 259
Laminectomy	40
Orbital surgery	5
Skull surgery	3
Burr-hole biopsy (brain)	2
Cysternoscopy of posterior fossa	1
Vertebral puncture	1

Table 2. Final histological diagnoses in 311 neurosurgical biopsies¹

Diagnosis	No of cases
Meningioma	74
Anaplastic astrocytoma (III and IV)	68 ²
Metastatic carcinoma	60
Isomorphic astrocytoma (I and II)	37
Neurinoma/schwannoma	13
Pituitary adenoma	6
Oligodendroglioma	5
Malignant lymphoma	5
Medulloblastoma	5
Ependynoma	4
Angioblastoma (Lindau tumor)	3
Hemangioma	2
Lipoma	2
Hemangiopericytoma (meningeal)	2
Malignant neurinoma (neurosarcoma)	2
Craniopharyngioma	2
Sympathoblastoma	2
Brain abscess	2
"Normal" brain tissue	2 ³
Choroid plexus papilloma	1
Malignant chordoma	1
Ganglioneuroblastoma	1
Eosinophilic granuloma	1
Chloroma (myeloid leukemia)	1
Plasmocytoma	1
Tuberculoma	1
Old hemorrhage	1
Cerebral infarction	1
Subacute encephalitis	1
Glial scar	1

¹ In 5 cases (= 1.65%) no definite diagnosis was made on paraffin sections.

² One case with incorrect diagnosis from biopsy material, corrected at autopsy.

³ Two cases with insufficient material; abnormal material obtained on a repeat biopsy.

(Table 3), while in 9 further cases either an inconclusive cytological diagnosis was made or no accurate classification of the condition was possible either from the imprints or paraffin sections, or both (Table 4).

The errors in imprint biopsies (Table 3) stemmed from the failure to distinguish between primary and secondary anaplastic tumors (5 cases), between isomorphic astrocytomas and neurinomas or non-neoplastic le-

Table 3. Errors of diagnosis by imprint cytology

Cytology diagnosis (No of cases)	Paraffin Section Diagnosis
Metastatic carcinoma (4)	Glioblastoma (1) Malignant lymphoma (1) Malignant meningioma (1) Neurosarcoma (1)
Fibrillary astrocytoma (2) (grade I)	Neurinoma (1) Glial scar (1)
Astrocytoma grade II (1)	Subacute encephalitis
Meningioma, fibrous (1)	Neurinoma (1)
Meningioma, endothel. (1)	Astrocytoma grade III (1)
Malignant lymphoma (1)	Astrocytoma grade III-IV (1)

Table 4. In conclusive cytological diagnoses

Cytology diagnosis	Paraffin section diagnosis	Comment
Glioma(?)	Ependynoma grade II	Insuff. material
Melanoma metastasis	Melanoma metastasis(?)	Insuff. paraffin material
Neurinoma/meningioma(?)	Neurinoma	Cervical spinal root
Malignant meningioma(?)	Hemangiopericytoma	4th recurrence
Glioblastoma/metastasis?	Glioblastoma(?)	Autopsy diagnosis
Cerebellar astrocytoma(?)	Cerebellar cortex neurinoma	Cysternoscopa Craniotomy
Normal brain tissue (?)	Glial scar	Burr-hole biopsy
Lymphoma/chloroma(?)	Chloroma, epidural	Cytochemistry
Specific granuloma	Tuberculoma	Z.-N. stain

sions - (glial scar or encephalitis - 3 cases) and between neurinoma and fibrous meningioma. In four cases anaplastic carcinoma was not correctly separated from glioblastoma, malignant lymphoma, malignant meningioma or neurosarcoma in Recklinghausen's disease, respectively. One glioblastoma was confused with a malignant lymphoma, while the commoner error was to diagnose as malignant glioma a tumor subsequently shown to be carcinoma (6) was not made in this series. These errors emphasize the problem that may be encountered in correctly identifying undifferentiated anaplastic tumors in imprints; this differentiation is, however, often difficult even in paraffin section (5). Failures to distinguish between a well differentiated fibrillary astrocytoma and neurinoma or glial scars, and between neurinoma and fibroplastic meningioma in another case illustrate yet other well-recognized difficulties. In another case, a cytological diagnosis of meningioma was made on a superficial parietal lobe tumor that paraffin sections showed to be a highly vascularized anaplastic astrocytoma invading the meninges. Such errors known in neuroradiology and gross neurosurgery are to be considered by the neurosurgeon who will not miss the opportunity of operating on a potentially removable tumor. On the other hand, in no case in the present series was a meningioma missed on the imprints.

Difficulties in accurate classification were due to insufficient biopsy material (4 cases); there were difficulties in correct classification of a malignant tumor (2 cases) or in a distinction between neurinoma and meningioma (one case), while in two cases the final diagnosis of

chordoma and tuberculoma was only possible after performing additional stains. Occasionally the biopsy specimen was so small that most of the abnormal tissue might have been utilized in the touch preparation so that the small portions left for paraffin sections contained only normal or gliosed brain. Thus, in one case in which paraffin sections did not demonstrate any neoplasm, the imprint had shown unequivocal secondary melanoma. In another patient with a tumor of the posterior fossa in whom the cytological diagnosis of cerebellar astrocytoma was made, the paraffin sections showed only normal cerebellar cortex, while the final diagnosis of neurinoma was made on a repeat biopsy. In two other patients in whom no abnormal or questionable tissue was obtained at burr-hole biopsy, the diagnosis of ependymoma and glial scar, respectively, was made on a repeat biopsy by open craniotomy. In one case of glioblastoma confirmed at autopsy, the correct cytological diagnosis disagreed with the incorrect biopsy diagnosis of metastatic carcinoma made from paraffin sections, while the fourth recurrence of a meningeal hemangiopericytoma was recognized as a "malignant meningioma" only from the imprints.

Comment

Cytological techniques used for the examination of neurosurgical biopsies for at least 40 years (2, 9) have not gained as wide acceptance in neurosurgery as in general oncology because of some doubts about their diagnostic reliability (3). The present and other investigations showing that this technique has a diagnostic accuracy of 93 to 94% in representative neurosurgical biopsy materials, however, suggest that smear and imprint techniques are most valuable for rapid neurosurgical diagnosis. The method used by the present investigators to obtain touch preparations has been found to be superior to the common smear technique (1-3, 6, 7, 9). Comparative evaluation of imprint and cryostat preparations demonstrated that the former technique was often more suitable for small and soft tissues or very hard specimens, and that the clarity of cytology was often superior to the quality of frozen section. Although the advantages and disadvantages of cytologic techniques have been discussed in detail (3, 4, 6, 8), certain diagnostic problems still arise. The major problems are the distinction between different types of primary and secondary malignancies of the CNS (anaplastic gliomas vs. metastatic carcinomas and malignant lymphomas), between isomorphic tumors showing similar patterns, e.g. neurinomas and fibrous meningiomas, and between isomorphic fibrillary astrocytomas and glial scars or normal brain tissue. These well recognized differential diagnostic difficulties, however, may also occur in paraffin histology particularly of small specimens (5).

The grading of gliomas, suggested to be impracticable from cytological preparations (4, 7) was performed with a high degree of reliability in the present material. In general, the comparison between the results of the touch and paraffin sections did not show any significant deviation in the grading of gliomas. Accuracy was less good in the correct classification of primary type of tumor in several metastatic neoplasms, reflecting the difficulty not infrequently encountered even on paraffin sections.

Although the 94% accuracy in the present study is probably due to the fact that all the imprint and paraffin specimens were uniformly examined by an experienced neuropathologist, almost similar degrees of diagnostic accuracy were attained on the present material when examined by a general cytologist and neurosurgeons with no full training in neuropathology. These data and the results of other groups show that a high degree of diagnostic accuracy with the cytological techniques can be attained as a result of several months of intense

study (6). Indeed, McMENEY (7) has pointed out that these methods are particularly useful in centers with training responsibilities. In some centers including ours, it has become routine to send a specimen from all exploratory neurosurgical procedures, even when the diagnosis seems obvious. Even experienced neurosurgeons are sometimes surprised by the neuropathologist's report. The rapid availability of imprint biopsies during neurosurgical procedures may enable the surgeon to modify his strategy on the basis of information received from the neuropathologist. The diagnostic accuracy of cytological techniques can be improved by careful selection of the tissue examined, avoidance of smear and other preparation artefacts and increasing experience of the investigators. Under these circumstances cytological methods are almost comparable in their diagnostic reliability with the paraffin techniques generally used in neurosurgical diagnosis.

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Reconstructive Surgery of Spinal Cord Vessels. An Experimental Study

G. KLETTNER, R. MEYERMANN, H. P. AMMERER, and A. WITZMANN

Both in degenerative and traumatic spinal vasculopathies, surgery is generally confined to decompression of the spinal cord and operative interventions on the aorta and its branches. Recent experience in microvascular surgery, particularly in anastomosing small-caliber vessels with a patent diameter of no more than 0.6 mm has paved the way for attempts at revascularizing the spinal cord by local microvascular procedures. A vascular approach appears to be well justified, since investigations by TÖNNIS and more recent studies indicated that slight to moderate trauma predominantly affected the blood supply of the spinal cord, while lesions of the spinal cord itself were only found to occur as a consequence of severe injuries. These findings prompted us to conduct the experiments reported here.

Methods and Operative Techniques

1. End-to-Side Anastomosis between an Intercostal Artery Branch and a Dorsal Spinal Artery

Our initial experiments aimed at revascularizing the spinal cord by way of microvascular anastomoses in the thoracic spinal region. Sheep appeared to be well suited as experimental animals for this purpose, since their vascular system and spinal canal structure are comparable to those of humans.

A branch of the intercostal artery was chosen as the afferent vessel. In the area of the autochthonous dorsal muscles this is the only vessel which shows a relatively constant course and is present in each thoracic segment. In addition, it courses in the immediate vicinity of the spinal canal. Consequently, dissection of the vessel can be limited to a length of 5 to 6 cm. End-to-side anastomosis was attempted after laminectomy and the selection of a suitable spinal vessel. As expected, anastomosis proved to be quite problematic, since the diameter of arterial vessels in this area lies usually between 0.4 to 0.6 mm.

The technique was employed in 5 sheep and 1 dog. In view of the small size of the vessels, satisfactory anastomoses were only obtainable in 3 cases. In 2 of these, appreciable hemorrhagic malacia of the spinal cord developed in the anastomosal area after removal of the clip from the afferent vessel. In one case the anastomosis originally performed well, but 24 hours after surgery a complete hemiplegic syndrome developed and the animal had to be sacrificed. Histologically, there was again appreciable hemorrhagic malacia.

2. Pedicled Muscle Grafting onto the Spinal Cord

There have been many successful attempts at revascularizing ischemic structures with the help of pedicled muscle grafts. In 1944 HENSCHEN convincingly demonstrated the revascularization of ischemic brain areas by temporal muscle transplants. The concept was later adopted in cardiac surgery (BLALOG) and in 1974 YASARGIL et al. showed in dog brains that the transplantation of abundantly vascularized tissues, such as the greater omentum and muscle tissue, produced an ingrowth of blood vessels into the central nervous system, if meticulously adapted to neural structures.

To our knowledge, there have not been any attempts at transplanting muscle tissue onto the spinal cord so far, although the autochthonous muscles in this area appear to be ideally suited for this purpose:

At the thoracic level selected for the experiment, a longitudinal skin incision was made. This was continued towards lateral curving along the costal arch in an obtuse angle. The skin flap thus obtained can readily be reflected towards cranial so that both muscles and spinal cord are well visualized. Laminectomy was performed in the usual way. Then muscle was detached from its fascia and part of it dissected cranially with a pedicle towards caudal. After incising the dura, the muscle graft was pressed onto the spinal cord and adapted. The technique was used in 10 dogs and 10 rats. In 3 dogs, hemiplegic symptoms developed immediately after surgery. Since these failed to improve, the animals were sacrificed 6 hours after surgery. This complication can, in our view, be accounted for by a faulty technique: either the muscle tissue implanted intradurally was excessively thick with resultant dural compression or dural sutures overlying the muscle graft were excessively tight. In the remaining 7 dogs no neurologic deficits whatever were observed. The animals were killed after 3 months. The histologic examination showed noticeable ingrowth of small vessels into the spinal cord.

Of the 10 rats treated one showed hemiplegic symptoms immediately after surgery. It was, however, kept alive for another week, since nursing proved to be unproblematic. Subsequently, 2 animals were sacrificed at intervals of 1 week, so that the histologic developments were recorded over a period of 5 weeks. As in the non-symptomatic dogs, there was evidence of an ingrowth of small capillaries into the spinal cord.

Discussion

In diseases and traumatic lesions of spinal cord vessels both conservative and surgical treatment have hardly made any appreciable advances in the last decades. As microsurgical techniques have become more sophisticated in recent years, delicate structures, particularly small-caliber vessels, have become accessible to surgery. Yet, microvascular surgery has failed to produce truly satisfactory microvascular anastomoses in the spinal area. While microanastomoses of vessels with a caliber down to 0.6 mm have repeatedly been shown to be functional (PIZA-KATZER), they have invariably been attempted in regions which are less susceptible to hypoxia than the spinal cord. Problems encountered in attempts at a direct local anastomosis of spinal vessels include in our view:

1. Extremely small caliber of the vessels to be anastomosed (0.4 to 0.6 mm),
2. Clipping time,

3. Flow direction at the anastomosal site (potential steal effect),
4. Inadequate venous drainage (venous anastomosis).

Microanastomoses in the caliber range 0.4 to 0.6 mm are technically possible, provided a suitable technique is used and the operator has sufficient experience. Clipping time appears to be a crucial problem. We believe it to be the primary factor underlying the development of malacia, which was present in virtually all cases treated.

While these 2 factors may be eliminated, the direction of blood flow would continue to be a problem, since a reverse flow may produce a steal effect above or below the anastomosis with resultant undesirable hypoxemia in another segment.

Venous drainage is, in our view, the cardinal factor. Experience in transplantation surgery had repeatedly shown that an increased blood flow through an arterial anastomosis is but poorly tolerated by damaged tissue, as long as venous drainage is inadequate. Consequently, we believe that for spinal microanastomoses to function properly both arterial and venous anastomoses are required. Although a venous pathway would theoretically be available for anastomosis in the vicinity of the artery described, the technique used by us was inadequate for producing a venous anastomosis in the caliber range encountered in this area.

We have found the transplantation of a pedicled muscle flap to be the more promising technique for a successful revascularization of the spinal cord. In virtually all cases treated, a more or less extensive ingrowth of small capillaries was found to have occurred in the central nervous system from the adjacent muscle. Even so, there are still some unsolved problems: The timing of surgery on what is essentially damaged tissue is one of them. And long-term effects are as yet unknown.

Nevertheless, we hope that our work may trigger further studies along these lines.

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