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INSTRUCTIONS FOR AUTHORS

Any article relevant to orthopaedic surgery, orthopaedic science and the teaching of either will be considered by *The Iowa Orthopaedic Journal* for publication. Articles will be enthusiastically received from alumni, visitors to the department, members of the Iowa Orthopaedic Society, residents and friends of the University of Iowa Department of Orthopaedics. The journal will be published annually in May or June. The deadline for receipt of articles for the 1991 journal is February 1, 1991.

Articles published and their illustrations become the property of *The Journal.*

When you send an article it is *essential* that the following items be submitted:

1. The **original manuscript complete with illustrations.** The corresponding author must be clearly identified with address and telephone number. Manuscripts of accepted articles will not be returned.

2. A **bibliography,** alphabetical and double-spaced, of references made in text only. Refer to bibliographies in this copy of *The Journal* and follow style exactly.

3. **Legends** for all illustrations submitted, listed in order and typed double-spaced.

4. **Illustrations**
   a. *Black-and-white glossy prints* of photographs. Give *magnification* of photomicrographs.
   b. *Original* drawings or charts.
   c. Color illustrations cannot be used unless in the opinion of *The Journal* they convey information not available in a black-and-white print. If color is desired, please send both color and black-and-white prints.

Preparation of manuscript: Manuscripts must be typewritten, double-spaced with wide margins. Write out figures under 100 except percentages, degrees, or figures expressed in decimals. A direct quotation should include the exact page number on which it appeared in the book or article. All measurements should be given in SI metric units. In reporting results of surgery, only in rare instances can cases with less than two years' follow-up be accepted.

Preparation of illustrations: Number all illustrations and indicate *top* plainly. Write the author's name on the back of each illustration. Send prints unmounted or mounted only with rubber cement; paste or glue will damage them. Drawings, charts, and lettering on prints usually should be done in black; use white on black backgrounds. Put dates or initials in legends, not on prints. Make lettering large enough to be read when drawings are reduced in size. When submitting an illustration that has appeared elsewhere, give full information about previous publication and credit to be given, and state whether or not permission to reproduce has been obtained.

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INTRODUCTION

This Journal has as its primary purpose education. Those who participate in the production of each volume undoubtedly learn the most. It is our goal, however, for each reader to learn something new and to benefit from perusing the Journal.

This volume marks the tenth edition of *The Iowa Orthopaedic Journal.* The production of the Journal involves several tasks, including solicitation of manuscripts and advertisements, as well as editing, organizing and distributing the "final production". As in previous Journals, the residents of the Department of Orthopaedic Surgery have been given the privilege and responsibility to produce this Journal.

The Iowa Orthopaedic Journal seeks to reflect the activity of faculty members and residents in the Department of Orthopaedic Surgery, as well as serve as a forum for visitors to the department. As such, we include basic and clinical research, review articles and case reports. We also include from time to time articles such as those by Drs. Gartland and Albright on the current practice environment and cost containment in medical care.

Publication of this Journal could not be possible without the help of our faculty advisers: Dr. Reginald Cooper, Dr. Charles Clark and Dr. Ernest Found. Superb organizational and secretarial assistance was provided by Mrs. Sandra Bredman and Mrs. Kay Redlinger-Phillips. We appreciate and gratefully acknowledge the contributions of the authors and advertisers, without whose support the Journal could not be published. Finally, the wordprocessing skills of Ms. Laura Cole facilitated and expedited the publication of the Journal, and we extend grateful thanks to her. We hope that you, the reader, benefit from our efforts and we welcome your response and criticism.

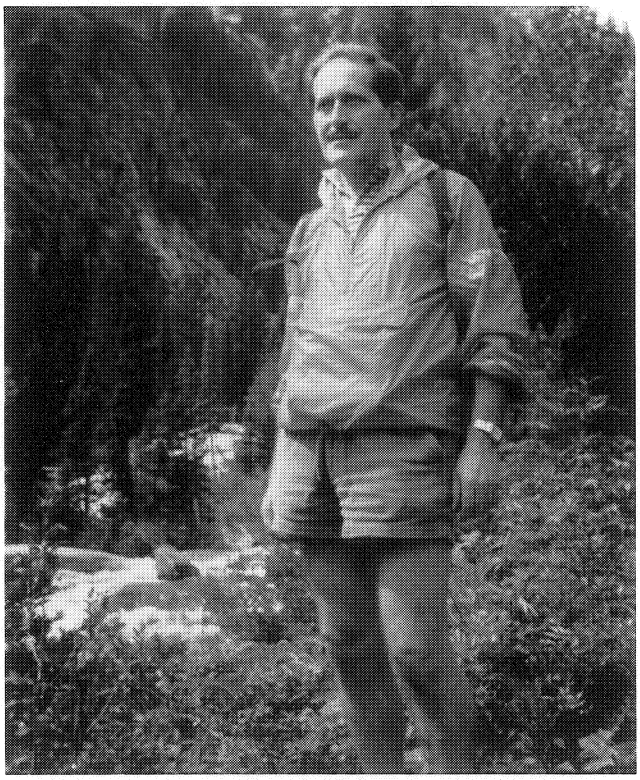
The Editors

Craig G. Mohler, M.D.

Joseph E. Mumford, M.D.

1990 IOWA ORTHOPAEDIC JOURNAL DEDICATION

Jerry Maynard, Ph.D.



Vittorio A. Pedrini
1933–1989

This 10th anniversary edition of *The Iowa Orthopaedic Journal* is dedicated to the memory of our friend and colleague Dr. Vittorio A. Pedrini. Dr. Pedrini died suddenly on Sunday morning, August 20, 1989.

Victor received his doctor of pharmacy degree from the University of Pavia, Italy, in 1955. In 1955–57, he served as an instructor of biological chemistry at the University of Pavia, Italy. In 1958, he came to the Iowa Department of Orthopaedic Surgery as a research associate for two years. He then returned to Italy to serve as a professor of biochemistry until 1963. In 1963, he returned to Iowa permanently as an assistant professor of biochemistry and orthopaedic surgery and became the director of the biochemistry research laboratories in the Department of Orthopaedic Surgery. He was promoted to associate professor in 1969 and to full professor in 1974.

Victor, a member of six professional societies, was particularly active in the Orthopaedic Research Society. He devoted the major portion of his research career to connective tissue biochemistry as it relates to musculoskeletal growth and disease. During his tenure at Iowa he published more than fifty papers in major scientific journals and had a major role in training approximately thirty graduate students and post-doctoral fellows in biochemically oriented orthopaedic research. Hence, through his research and the training of other academicians, Victor contributed extensively to the knowledge of many individuals concerned with orthopaedic disorders.

We have lost a true friend and colleague, but we have not lost the benefit of his knowledge. He was dedicated and generous. He shared his knowledge with many. We are indeed fortunate that Victor shared his life and career with the orthopaedic community at large and particularly with The University of Iowa.

ORTHOPAEDIC PATHOLOGY AT THE UNIVERSITY OF IOWA: SAGACITY AND SERENDIPITY

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Presented at the Iowa Orthopaedic Alumni Meeting,
September 28, 1989

It is my perception that in the past most physicians were more concerned with the "how" and "why" of disease than at present. The emphasis now seems to be on "What is it?" and "How do I treat it?" Many physicians are willing to accept the answer "What is it?" from consultants rather than integrating data including the pathologic anatomy to arrive at a diagnosis and a rational course of treatment. Those surgeons who say "Don't tell me why it is so, just tell me what do I do to fix it" are in my opinion "technician-surgeons" not "physician-surgeons". That attitude is not the rich tradition from which Iowa Orthopaedic Pathology developed and flourished! In fact, pathology has been an integral part of the educational program of residents and postgraduate students since the department's inception in 1927. As chairman, Dr. Steindler felt orthopaedic education should be based on clinical experience with a foundation in basic science. In this paper, I would like to share with you the evolution of orthopaedic pathology at the University of Iowa.

Dr. Weichselbaum, founder of the Vienna Institute of Pathological Anatomy and his pupil Jakob Erdheim (Fig. 1), proved to be major influences on orthopedic pathology at the University of Iowa. Erdheim joined the Vienna staff in 1900 as an assistant to Dr. Weichselbaum.[1] In his thirty-seven years at the Institute, Erdheim contributed to our knowledge on the effects of the organs of internal secretion on the skeleton. He published on the role of parathyroid glands on calcium metabolism and detected secondary parathyroid hypertrophy in rickets and osteomalacia. He also described osseous changes in acromegaly and its relationship to eosinophilic pituitary tumors. A respected teacher, he inspired and guided his students.

Rarely was the clinical staff absent from autopsies performed on their patients. Erdheim's contact with surgeons served to correlate anatomical and clinical findings. Each autopsy became a clinicopathological conference.

Figure 1
Jakob Erdheim.

The 150 years of prominence of the Vienna school (from 1788–1938) was destroyed when the Nazi Army marched into Austria in 1938. During that period more than 100 American physicians did postgraduate work at that institute including Drs. Dallas Phemister and E. Howard Hatcher.

It was during the turmoil of the early 1930's that Dr. Steindler (Fig. 2), a Vienna graduate, arranged for Erdheim's "brilliant pupil" Ernst Freund to come to Iowa to teach bone pathology and start a bone pathology laboratory.[2] Freund's arrival perpetuated Dr. Steindler's philosophy that orthopaedic progress does not occur through the pursuit of technical perfection but through the advances of the basic medical subjects of anatomy, pathology, physiology, biochemistry, and biomechanics.

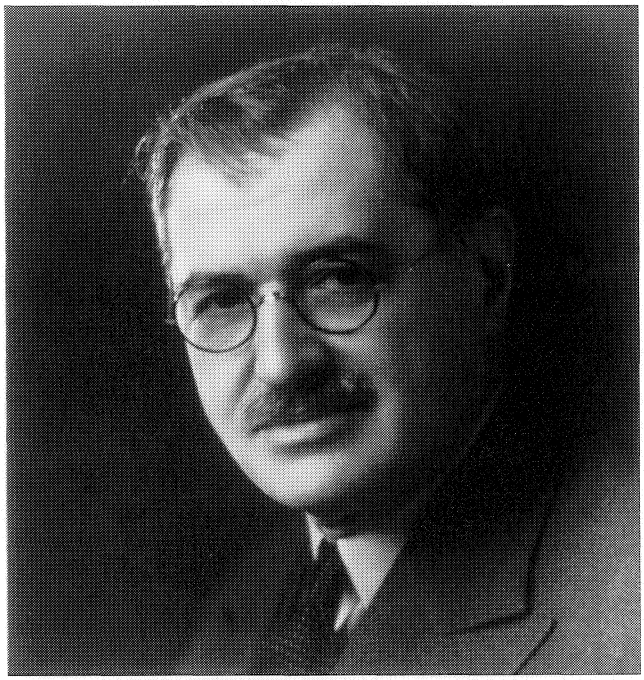

Figure 2
Arthur Steindler.

The laboratory was across from the brace shop in the Steindler building and had a small room next door for students and residents to perform laboratory tests—you could smell the formalin! (Fig. 3)

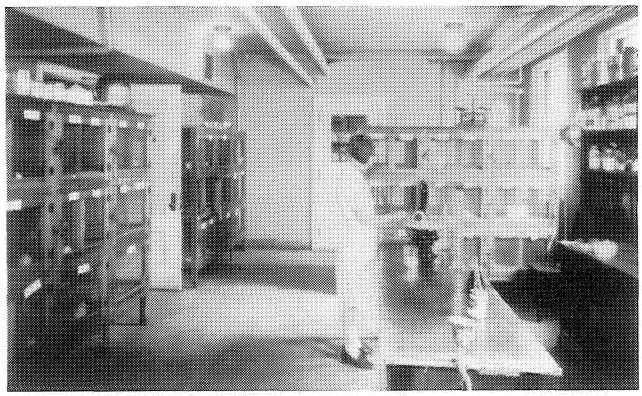

Figure 3
Rodent laboratory in the basement of Children's Hospital (Steindler Building). Room similar to the Pathology Laboratory in 1933.

As a medical student in 1926, Freund wrote his classic paper on aseptic necrosis of bone.[3] At age twenty-four, Freund graduated from medical school and began work with Dr. Erdheim, rising to the rank of first assistant (Fig. 4). His interest in orthopaedic surgery led him to spend two years with Dr. Putti at the Rizzoli Institute in Bologna. In 1931, he spent a research fellowship year with Jaffe at the Hospital for Joint Diseases.

When he came to Iowa, Dr. Freund brought with him specimens of rare untreated musculoskeletal diseases such as hyperparathyroidism, osteomalacia, and Paget's disease. Many specimens embedded in celloidin were cut, mounted, and stained to start a slide collection. Dr. Freund's collection was cataloged and partially integrated into the Iowa cases.

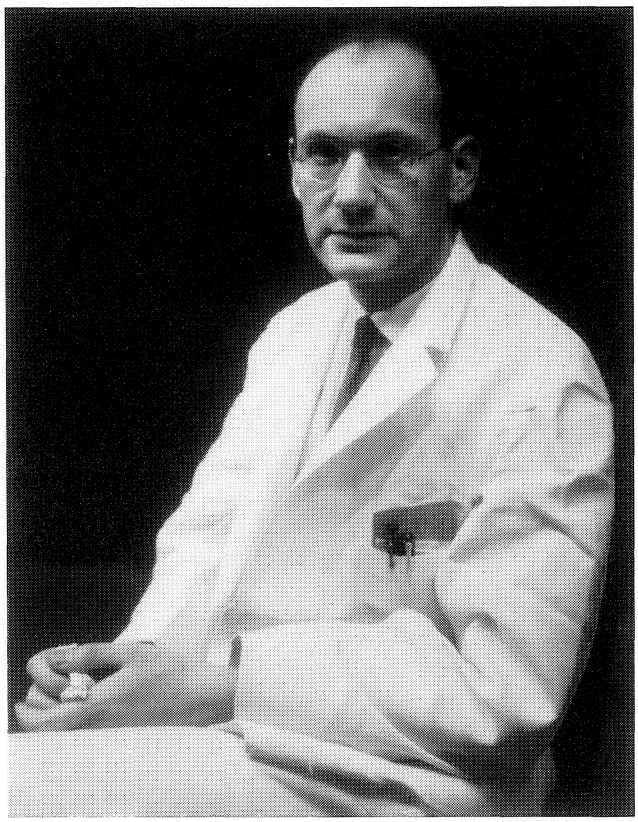

Figure 4
Ernst Freund.

A few examples follow. Figure 5 is a gross specimen of osteomalacia of the proximal tibia. Figure 6 is a histologic section of rickets of the distal femur showing a wide epiphyseal plate. The histologic pathology of primary hyperparathyroidism is illustrated in Figures 7 and 8.

Freund prided himself on his diagnostic skills and could identify musculoskeletal disease from gross anatomy alone. He rarely needed a microscope to make a diagnosis and, when challenged by an American postgraduate student, Freund missed only one in over 100 specimens.

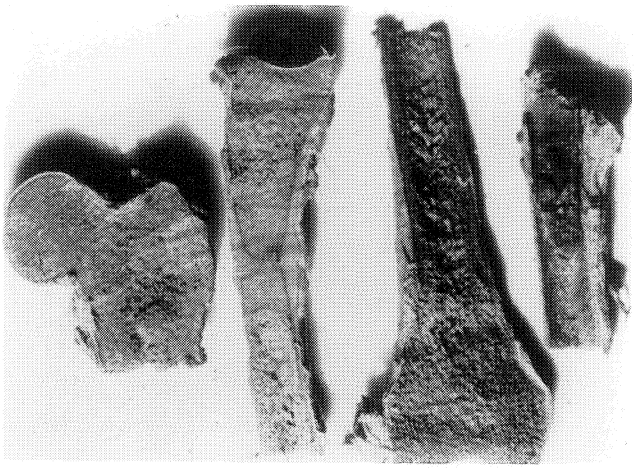

Figure 5
Gross specimens (autopsy) of tibia and proximal femur-osteomalacia.

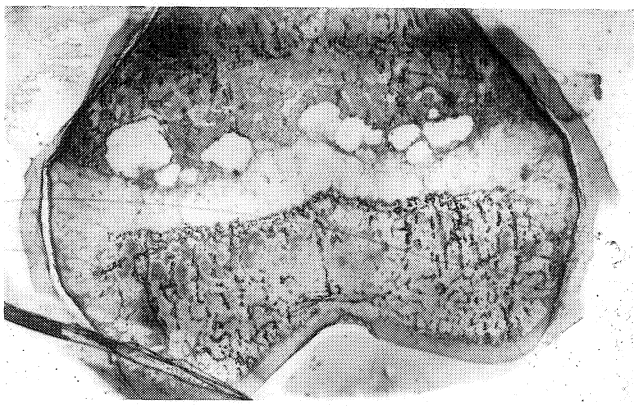

Figure 6
Photomicrograph of rickets of the distal femur.

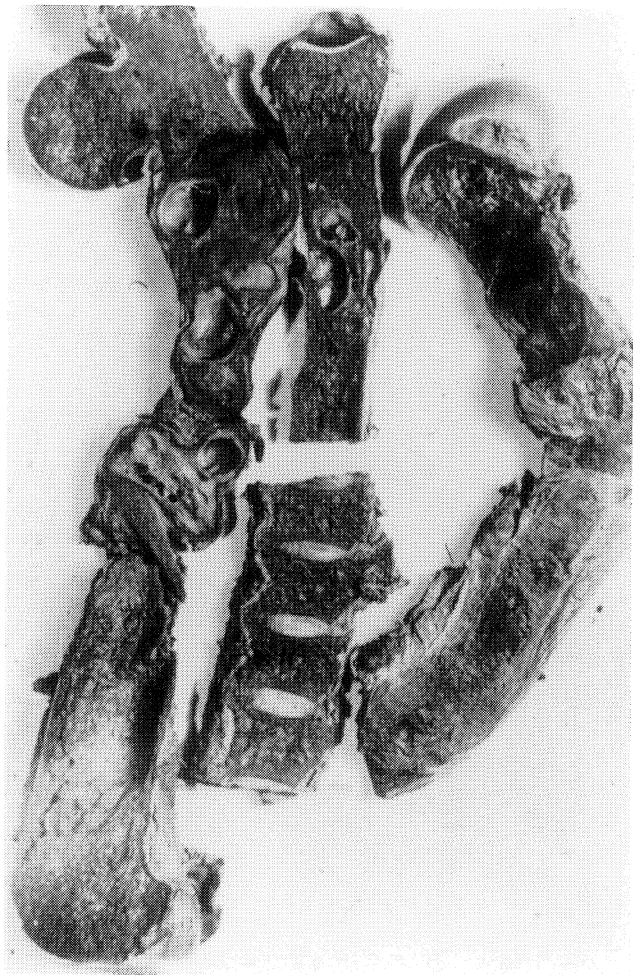

Figure 7
Autopsy specimen of femur-primary hyperparathyroidism—note large cysts in the proximal femur.

For personal reasons, Dr. Freund left Iowa in 1936 to join a private orthopaedic practice in Florida. From there, he went to Loma Linda University Medical College in Los Angeles, where he died in 1938. Prior to his death, Dr. Freund willed the Erdheim musculoskeletal pathologic collection to Dr. Henry Jaffe. In 1979, the Jaffe Collection, including part of the Erdheim Collection, was turned over by Dr. Jaffe to Dr. Crawford J. Campbell.

When Dr. Freund left Iowa in 1936 the bone pathology laboratory was run by others, including Dr. Vernon Luck from 1936–38, Dr. Robert Tidrick from 1939–40 and Dr. Seymour Albert from 1940–42, after which Dr. Ignacio Ponseti ran the laboratory and did the teaching.

One of the attractions for my coming to Iowa was the presence of the bone pathology laboratory and its large collection of material. I was encouraged and supported by our departmental chairmen, first Dr. Carroll Larson, followed by Dr. Reginald Cooper. The Iowa Orthopaedic Collection was useful in providing material for the American Academy of Orthopaedic Surgery Pathology Committee,

Figure 8
Macro section of proximal femur—primary hyperparathyroidism.

which started the pathology exhibit of unknown cases as an oral exam with immediate feedback. As Chairman of the Pathology Committee, I was responsible for preparing the exhibit at each Academy meeting. I note with pride that it continues to attract a large number of people at the annual meeting. The Academy education and sound slide programs for student and resident teaching include our material on bone tumors. The American Board of Orthopaedic Surgery draws from Iowa Orthopaedic Pathology material for questions, slides, and radiographs for the pathology oral examination later named the Interpretive Skills Examination.

The University of Iowa Department of Orthopaedics influenced resident education during the decades of the 1950's to the 1980's. During this period, multiple groups held seminars on the role of bone pathology in that education, including the American Orthopaedic Association (AOA), Orthopedic Research and Education Foundation (OREF), American Academy of Orthopaedic Surgeons (AAOS), and the American Board of Medical Specialties (ABOS).[4,5,6]

Teaching of pathology to Iowa residents was shared at first with Dr. Ponseti and later with Dr. Cooper. In the 1970's Dr. Mickelson carried on the teaching and supervision, until his departure in 1980, when Dr. Buckwalter took over.

Learning bone pathology in the 1950's involved a three month rotation by the resident on my team. The resident examined all gross tissue removed at surgery, and with the orthopaedic pathology technician, cut and radiographed each specimen which was embedded and sectioned in celloidin or stored in the gross museum (Fig. 9). The resident reviewed all the slides, first by himself, then with staff. From the surgical cases the conference cases were selected. Typically ten to fifteen residents and faculty crowded into an eight by ten foot room with a monocular scope and a swivel prism that projected the image on the wall (Fig. 10). Later, we cleared space in the basement for conferences. We also chose one or two cases for a surgical-radiology-pathology conference once a week with Drs. Warner, Gillies, Tidrick, Ehrenhaft and as many residents and students who could attend.

Orthopaedic pathology enjoyed a high level of interest from the 1940's to the 1970's. As superspecialization became more commonplace, the pressures of patient volume began eroding the academic aspects of most residency programs. A strong undercurrent of discomfort with pathology (especially with the use of the microscope) emerged during this period and the American Board of Orthopaedic Surgery chose to eliminate the microscope from the oral examination this year (a move which some of us traditionalists deplore and believe will undermine part of the foundation of a scientific orthopaedic education).

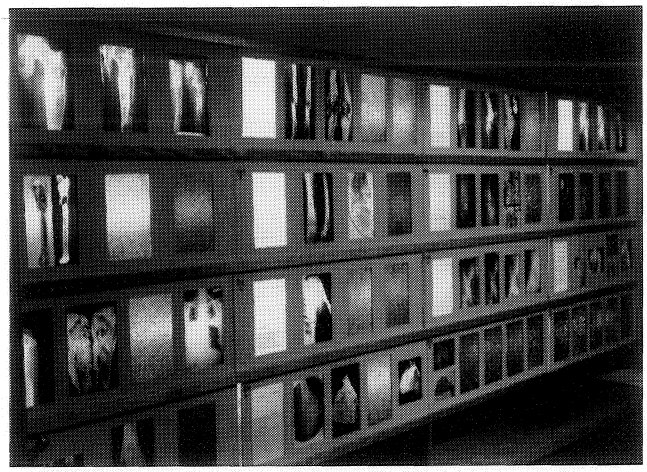

Figure 9
Gross specimen museum.

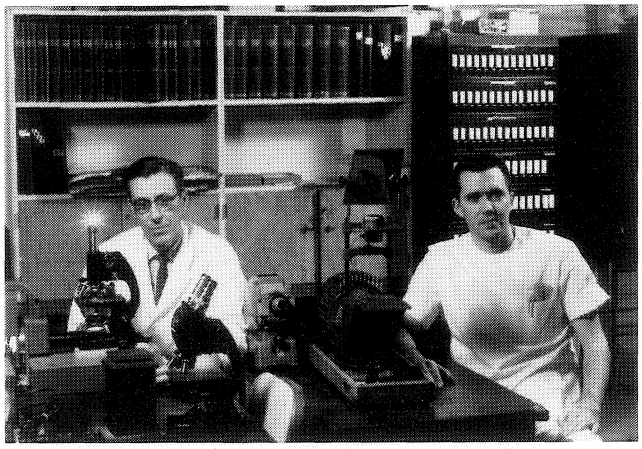

Figure 10
Microscopic and lantern slide projectors—Drs. Bonfiglio and Jerry Becker.

Freund, Erdheim, and the other leaders discussed in this paper emphasized the value of an orthopaedic education based on the essential knowledge of orthopaedic pathology. The pathophysiologic approach guides evaluation and treatment in an efficient and practical way by providing the rationale for diagnostic procedures and therapy. The clinical-pathological conference lives on in a limited form. It deserves our continued support, and should not be allowed to die.

The pathophysiologic approach helps the student and orthopaedic resident develop a set of attitudes towards correlative pathology which become a permanent part of the physician's approach to patient problems.

I trust I have been able to give you a brief view into the lives of the physicians who influenced Orthopaedic Pathology at Iowa. Not only were they wise in their pursuit of knowledge about musculoskeletal diseases, but they actively sought those who would add to the scientific base of orthopaedics to benefit our patients.

ACKNOWLEDGEMENTS

The help of Drs. Ignacio Ponseti, Hans Ehrenhaft, Vernon Luck and Mr. Earl M. Rogers of the University of Iowa Library Archives is gratefully acknowledged.

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MEDICAL RESEARCH ETHICS

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An orthopaedic surgeon suspected of scientific misconduct during a Food and Drug Administration clinical drug trial broke into his office, set fire to a file room and threw medical records into a whirlpool[1]. Despite the surgeon's efforts, an audit found falsified patient data. Although intentional falsification of clinical or basic science medical research results may be rare, episodes like this raise questions about the ethical conduct of medical researchers and the veracity of the results they report. In particular, recent reports of misconduct in medical research by young physician scientists and lax supervision of these scientists by senior investigators[2-6] have caused public concern over the integrity of all medical research. Stimulated by these reports, the Federal Government and research universities have developed regulations and guidelines for dealing with fabrication or falsification of results and plagiarism. In addition, the Public Health Service has established two new offices for dealing with scientific misconduct: the Office of Scientific Integrity Review (OSIR) and the Office of Scientific Integrity (OSI). The purposes of these regulations, guidelines, and offices include discouraging, detecting and investigating scientific misconduct and determining what sanctions will be applied if misconduct occurs.

Those who perform medical research must, however, do more than comply with institutional and governmental regulations and avoid obvious misconduct. They must accept responsibility for ethical conduct in their own scientific work and help support high standards of ethical conduct in the research community. Failing to do so may impede or delay medical progress and will damage the credibility of all medical research, thereby harming not only the medical research community but the patients whose care depends on the results of research.

IS THERE A PROBLEM?

Traditionally, research ethics have not been formally defined or taught. Ideally younger researchers learn standards of conduct from working closely with more experienced investigators and the medical research community that consistently supports these standards. Many scientists and physicians believe that this system creates the optimal research environment and ensures that well-accepted ethical principles guide the conduct of medical research. They doubt the existence of a fundamental problem in medical research ethics. They argue that commonly cited incidents of research misconduct including plagiarism, falsification of data and invention of experiments and results[1-6] involve only a few young medical researchers and that these deviations from principles of research ethics result from defects in the character of a young researcher combined with opportunities for misconduct and pressures to increase scientific productivity. Phillip Handler, president of the National Academy of Sciences, supported this view in testimony before the House of Representatives when he stated that "The matter of falsification of data, I contend, need not be a matter of general societal concern. . . . one can only judge the rare acts that have come to light as psychopathic behavior originating in the minds that made very bad judgements—ethics aside, minds which at least in this one regard may be considered deranged."[7]

An alternative view is that even though some examples of misconduct result from aberrant behavior by individuals with character defects, more important and potentially correctable problems are that medical research education does not consistently teach high ethical standards and that the medical research environment and the medical research community do not consistently express support for ethical conduct. If this view is correct it suggests that individuals who are guilty of misconduct may represent only the obvious manifestations of more common problems in the medical research community.

MEDICAL RESEARCH EDUCATION

Beginning with the selection of students for medical school, medical research education rarely emphasizes ethical standards. Medical schools tend to choose their freshman class by a process that rewards achievement of a high grade point more than achievement of exemplary character, intellectual breadth, individuality and creativity. They rarely attempt to critically assess the ethical standards and motivation of the applicants. Understandably, premedical students compete for grades, an effort that

does not necessarily promote development of intellectual curiosity and integrity. Robert Petersdorf, president of the American Association of Medical Colleges (AAMC), indicated some premedical students become "hypercompetitive, narrow-minded, greedy, and dishonest at best, and 'ferocious geeks' at worst. Nothing will stop them from earning high grades."[8] Perhaps for these reasons many medical students have learned that high grades and tests scores are valued more than other achievements, motivation and integrity.

Even if grades become less important in medical school, following graduation individuals seeking an academic career in a clinical specialty must compete aggressively to secure a desirable residency position. Once again, class rank, grades, lists of activities and publications form criteria that often make the difference between success and failure in the competition.

THE MEDICAL RESEARCH ENVIRONMENT

Like medical research education, the medical research environment rarely stresses ethical conduct. Furthermore, following residency, the individual who wishes to achieve academic success in orthopaedic surgery or in most other specialities must do so in an environment that includes constraints and stresses that do not encourage development of high ethical standards including:

1) Limited time and opportunity for research training, independent research or education in the ethics, history and philosophy of science. The constant need to develop and refine clinical skills and provide patient care makes finding uninterrupted time for research a special problem for physician-scientists.
2) Increasing sophistication and expense of research methods. As research becomes more expensive and complex, performing independent scientific work grows more difficult for individuals with limited time and access to financial support and research education.
3) Financial pressure due to acquired educational debt and often the financial needs of a family. The cost of medical education and the long duration of clinical residency education burden most young physicians with financial obligations that make it difficult for them to spend substantial time learning research methods.
4) Limited financial support for clinically related orthopaedic investigations or basic research directed towards orthopaedic problems. The limited support causes intense competition for research funding and desirable academic positions. Since success in this competition generally goes to those with the greatest number of publications and presentations, many young individuals feel great pressure to produce an impressive number of research reports and presentations rather than spend time learning a complex technique or thoroughly studying a scientific question.
5) Domination of research resources, presentations and publications by large research programs vs "research mills." At best, efficient use of resources and multiple people working in the same area can make large research programs productive and offer unique educational opportunities for young researchers. At worst "research mills" exploit younger workers by assigning multiple workers to different components of the same project. This entitles multiple individuals to recognition as authors but decreases individual responsibility, places the leader at a distance from the work, and produces the maximum number of publications and presentations from the same line of investigation, thereby generating multiple reports that describe similar or even overlapping investigations.
6) Lack of emphasis on medical research ethics by the research community including specialty societies, universities, funding agencies, journals and award committees. Until recently, few of the organizations responsible for promoting, sponsoring and disseminating medical research have attempted to define general standards of ethical conduct of medical research.

Some of these characteristics of the medical research environment are not always deleterious. Many result from social and economic forces that cannot be altered and some will probably become worse despite any efforts to change them. Awareness of the problems and efforts to correct those that can be corrected are more likely to be beneficial than uncritical acceptance.

RESPONSIBILITY FOR PROMOTING ETHICAL CONDUCT

At least some of the reported incidents of scientific misconduct and the possibly more common unreported incidents of unethical behavior may result from the lack of strong support for high standards of ethical conduct in medical research education and in the research environment. Governmental agencies can issue regulations and guidelines but only the members of the medical research community can establish and teach shared ethical principles by consistently rewarding sustained effort, integrity, and ethical behavior. They should support and encourage genuine curiosity, creativity and substantive individual contributions, not productivity alone as measured by number of publications and presentations. If they do not, the values absorbed by at least some young investigators will be those promoted by rewarding only quantitative measures of accomplishment including grades, test scores and number of publications, and by encouraging competition

more than individual intellectual development, genuine collaborative efforts, integrity and scientific curiosity.

ETHICAL CONDUCT OF MEDICAL RESEARCH

Since medical research differs from some other types of research including military and commercial research, some of the principles that apply to ethical conduct of medical research may not apply to other types of research. Concepts of ethical conduct of medical research that may help encourage discussion of principles of medical research ethics include the following:

1. The Purpose of Medical Research

Medical research should be designed and conducted to develop new knowledge that promotes health, prevents diseases and injuries and improves diagnosis and treatment of diseases and injuries.

Examples of unethical conduct: a) designing and conducting research with the primary purpose of discovering methods of causing injury, illness or suffering; b) designing or conducting research that is repetitious or redundant with the intent of advancing individuals or specific groups financially or professionally; c) designing or conducting research that is not intended to produce new information that is valid or significant; and d) designing or conducting research that is intended to promote a specific theory, investigator's opinion or the commercial success of a specific product.

2. Use of Medical Research Resources

Resources allocated by educational, governmental or philanthropic organizations for the performance of specific medical research should be used only for that purpose unless the granting agency gives specific permission for reallocation of the resources.

Example of unethical conduct: Use of resources provided by governmental or philanthropic organizations for the direct financial benefit or personal use of the investigators.

3. Use of Animals in Medical Research

Animals should be used in research only when there are no suitable alternatives. Research projects should be designed to use the minimum number of animals in a manner that avoids unnecessary discomfort for the animals and maintains appropriate standards of animal care.

Examples of unethical conduct: a) use of methods that cause animals unnecessary discomfort; b) failure to maintain appropriate standards of animal care; c) use of excessive numbers of animals to perform an experiment; d) use of inappropriate animals; and e) use of animals when other methods of conducting the research would be acceptable, for example, computer simulations, tissue culture or mathematical models.

4. Use of Human Subjects in Medical Research

Human subjects should be used in medical research only when there is no reasonable alternative. Human subjects should never be exposed to unnecessary risk, embarrassment or expense. They should understand the purpose of the research, and if their participation may benefit them (a therapeutic experiment) or is intended primarily to benefit future patients (a nontherapeutic experiment). Human subjects should provide voluntary informed consent before being included in a prospective study and should be allowed to discontinue participation in a research program at any time without compromise of their medical care. Human subjects participating in clinical research programs should receive the care and treatment that is in their best interest.

Examples of unethical conduct: a) exposure of human subjects to unnecessary risk; b) failure to obtain voluntary fully informed consent; c) causing human subjects unnecessary embarrassment; d) causing human subjects unnecessary expense; e) use of human subjects with selected medical problems or results of treatment that tend to prove an investigator's bias or promote a given treatment or medical device; and f) coercion of human subjects to participate.

5. Responsibilities of the Principle Investigator

The principle investigator of a scientific research project or clinical research project is responsible for proposing, designing and reporting the research. The principle investigator may delegate portions of the work to other individuals but this does not relieve the principle investigator of the responsibility for critically evaluating this work.

Examples of unethical conduct: a) failure to participate in and supervise the design or conduct of a research project; b) failure to adequately supervise those conducting the project; and c) failure to critically review results and verify the accuracy of reports.

6. Reporting the Results of Research

The results of research should be described in timely, objective, accurate, complete reports and potential conflicts of interest should be identified.

Examples of unethical conduct: a) failure to provide timely, accurate reports; b) providing reports that do not contain sufficient information to replicate the experiments; c) falsification of reports; d) fabrication of results; e) reporting results of uncertain or minimal significance; f) preparing multiple partial reports or duplicate reports of the same work to increase the apparent productivity of the investigator; and g) failing to identify potential conflicts of interest including possible financial benefits to the investigators from research reports.

7. Credit for Scientific Work

The principle investigator or senior author of a scientific report is responsible for insuring that appropriate credit is given for contributions to the research described. Genuine collaborative research should be encouraged and all individuals who make substantial contributions should be given appropriate credit. Individuals who do not make substantial contributions to an investigation should not be included as authors. Sources of financial and technical support and individuals who provide important materials and information should be acknowledged.

Examples of unethical conduct: a) failure to credit coworkers and individuals who provided ideas, data and interpretation; individuals or agencies that have provided resources; or individuals or groups that have previously done similar research; b) failure to credit sources of quotations; c) plagiarism; d) failure to review and credit relevant previous publications; and e) including individuals who did not make substantial contributions to the scientific work as authors.

8. Research Records

Accurate and complete records of research should be maintained until there has been sufficient time for critical review. The time will vary with the type of research, but five years after publication is sufficient for most work.

Example of unethical conduct: Failure to maintain accurate and complete records of research activity so that replication of the work or verification of the results is difficult or impossible.

9. Scientific Error, Contradictory Results and Inability to Replicate Results

If errors in the proposal, conduct or report of scientific work are identified the investigator should report the errors. If the investigator or other investigators repeat an experiment and obtain results that contradict the initial report or they are unable to replicate an experiment, the contradictions or inability to replicate an experiment should be reported. If the long term results of an experiment or a clinical study differ from the initial reported results, the differences should be reported. Scientific publications have a responsibility to publish reports of scientific errors, contradictory results and failures to replicate previously reported research.

Examples of unethical conduct: a) failure to report a significant scientific error; b) failure to report work that contradicts previously reported data or conclusions; c) failure to report difficulties replicating or verifying previous findings; and d) failure of a scientific publication to publish reports of scientific errors, contradictory results and failure to replicate previously reported research.

10. Misconduct Versus Differences in Methods, Interpretation and Judgement

Unequivocal misconduct should be reported, but members of the medical research community have a responsibility to distinguish honest error from misconduct and to respect differences in scientific methods and analysis, interpretation or judgement of data.

Examples of unethical conduct: a) verbal or written personal attacks on other investigators based on differences in methods, analysis, interpretation, judgement or opinion; b) attempts to discredit or intimidate other investigators because of differences in methods of investigation or interpretation of data; c) efforts to restrict funding of research, publication or presentation of data because of differences of interpretation; d) accusations of misconduct when honest error is as likely; e) failure to identify and report unequivocal instances or scientific misconduct.

CONCLUSION

Paul Friedman, Professor of Radiology and Dean for Academic Affairs, University of California, San Diego, noted "... the quality of scientific research is adversely affected by an unethical research environment."[9] Individuals who choose to participate in medical research should accept responsibility for ethical conduct in their scientific work and support high standards of ethical conduct in the medical research community. Governmental guidelines, regulations and offices for dealing with obvious examples of misconduct may expedite management of the most apparent instances of misconduct after they have been detected and may discourage some investigators from committing plagiarism or reporting falsified or fabricated results, but only the scientific community can establish and teach shared principles of ethical conduct. For the most part the medical research community has not formally established principles of ethical conduct and some features of medical research education and the medical research environment may contribute to misconduct in research by placing strong emphasis on competition and quantitative measures of productivity while failing to emphasize ethical conduct and individual intellectual development. For these reasons, the members of the medical research community should define shared principles of medical research ethics and promote acceptance of these principles through inclusion of research ethics as a component of medical research education and through support of ethical conduct in the research environment by governmental and private funding agencies, universities, specialty societies, award committees and journals.

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WHAT HAPPENS TO WILD ANIMALS WITH BROKEN BONES

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"It is commonly supposed that, in order to unite, a fracture must be immobilized. This cannot be so since, with few exceptions, fractures unite whether they are splinted or not; indeed, without a built-in mechanism for union, land animals could scarcely have evolved".[11] The statement appears in many forms in the orthopaedic literature but the principle remains the same. The underlying thought is that long bone fractures are not uncommon in adult wild animals and that they can heal naturally. It therefore behooves an orthopaedic surgeon to bear this fact in mind before interfering with what is a "natural process". This paper traces the origin of the statement, re-examines the original material, and combines this with information now becoming available from the first long-term observations of animals in the wild. The results suggest that long bone fractures in adult wild animals are rare and commonly fatal.

Writings early this century laid great emphasis on Darwinian natural selection. It was felt that any animal whose health fell below par from disease or injury would be killed. Animals shot for sport were commonly found to be in good health and these were felt to be the survivors of this selection.[11]

However, as early as 1904 the first paper appeared[5] which suggested that the situation was not quite as simple as might have been thought. In 1911, Duckworth[6] published a paper based on the skeletons of fourteen adult Orang Utangs which had been shot. Four (30%) of these had evidence of healed fractures. He concluded that fractures were common in adult wild primates and that on the whole they healed with relatively little deformity.

This evidence was extended by Schultz,[16] who reviewed data from many primate species (Table 1) and published a very careful study of 118 shot specimens of gibbon, an acrobatic monkey which spends its life high in the canopy of tropical rain forests (Table 2).[15] He found evidence of fractures in 36% of the skeletons, and noted that most healed with very little deformity and a mean shortening of only 4.5% (Table 3).

I have reviewed the Duckworth collection of Orang Utang skeletons in Cambridge and the Schultz collection of gibbon skeletons in Zurich and catalogued the fractures. Evidence of healed fractures of all but long bones

Table 1

Percentage Frequency of Healed Fractures Among Wild Primates

Species	Name	Behaviour	No. of skeletons	% with fractures
Leontocebus	Golden lion Marmoset	Arboreal	56	12
Aotes	Owl monkey	Arboreal	10	20
Cebus	Cebus monkey	Arboreal	22	27
Nasalis	Proboscis Monkey	Arboreal	25	28
Hylobates	Gibbon	Arboreal	260	33
Pongo	Orang Utang	Arboreal	68	34
Pan	Chimpanzee	Terrestrial	56	18
Gorilla	Gorilla	Terrestrial	19	21
Gorilla*	Gorilla	Terrestrial	127	7

Skeletons from museum specimens
*Long bones only

Table 2

Frequency of Fractures in Wild Gibbons

Bone	No. fractured	Bone	No. fractured
Humerus	11	Metatarsi	2
Radius	3	Phalanges	9
Ulna	5	Clavicle	4
Femur	12	Scapula	2
Tibia	5	Pelvis	1
Fibula	3	Sternum	1
Patella	1	Ribs	1
Wrist or ankle	3	Orbital rim	2

Total 65 fractures in 42 out of 118 animals

Table 3

Length of 14 Healed Long Bones Compared with Normal Side in Wild Gibbons

Bone	Length on each side		Difference in % of normal slide
	Fractured	Normal	
Humerus	221	224	– 1.3%
Humerus	228	228	0
Humerus	223	219	(both fractured)
Humerus	226	238	– 5.0%
Humerus	220	228	– 3.5%
Humerus	225	236	– 4.7%
Humerus	236	235	+ 0.4%
Ulna	249	250	– 0.4%
Ulna	262	266	– 1.5%
Femur	200	199	+ 0.5%
Femur	199	206	– 3.4%
Femur	197	205	– 3.9%
Femur	172	201	– 14.4%
Femur	188	205	– 8.3%

have been excluded here to allow comparison with other studies.[4] The presence of healed fractures in each skeleton was noted, and careful measurement made of the degree of angulation, length of overlap and total length change of the healed bone compared with the other side.

All the healed fractures were in bones with closed epiphyses but if the fractured bone was found to be longer than the other side it was assumed that epiphyseal overgrowth had taken place and that the fracture had occurred in a juvenile skeleton which had survived to adulthood before being shot for study.[10] If the fracture was in the epiphyseal zone and there was clearly gross growth disturbance with shortening and angulation the fracture was assumed to have occurred in a juvenile skeleton which had suffered epiphyseal damage.[13] If one or more fractures in a skeleton with multiple fractures had these features it was assumed that all the fractures had occurred at the same accident and were juvenile fractures.

The justification for assuming that the animal with multiple healed fractures received these in one accident rather than in several separate episodes comes from testing the actual incidence of multiple fractures against the expected incidence had they all occurred in separate incidents. In the fifty-six skeletons available for study in the Schultz collection, five animals had only one fracture, four had two, three animals had three, one animal had four fractures, two had five and one animal had six fractures.

If each of these fractures had occurred in a separate incident the probability of sustaining a fracture would be given by:

$$p + p^2 + p^3 + p^5 + p^6 = P_0$$

where p is the incidence of one fractured bone and p^2 gives the incidence of two fractures, etc. P_0 is the overall probability of fractures in the population.

The expected number of animals with one, two, three, etc. fractures in this hypothesis is given in the "expected" row of Table 4, while the number actually found is given in the "observed" row. Using the Kologorov-Smirnov non-parametric one sample test the probability of the observed distribution of fractures fitting the hypothesis is less than 1%.

Table 4

Probability of Multiple Fractures Occurring Individually

No. of fractures	0	1	2	3	4	5	6
Skeletons observed	40	5	4	3	1	2	1
Skeletons expected	40	13	3	0	0	0	0
Fo(0)–F16 (E)	0	0.5	0.34	0.25	0.19	0.124	0

D = 0.5 N = 16 p = 0.01

On the basis of these assumptions eleven of the fourteen skeletons in the Schultz collection with healed fractures sustained the injuries when they were juvenile. In the other three it is not possible to say with certainty whether they occurred in juveniles or adults (Table 5).

Both Schultz[16] and Bramblett[2] state that the number of fractures in skeletons increases with age. Schultz does not support this statement with any data and my study of his collection does not confirm his conclusion. Bramblett's[2] data may be confused by the addition of phalangeal and rib fractures which are liable to misdiagnosis. Exclusion of these fractures removes this trend from his data.

If fractures occurred at a constant rate throughout life then there would be an accumulation of healed fractures in older animals. This possibility can be tested statistically by comparing the observed frequency of fractures with that which would be expected from this hypothesis (Table 6). The probability of that accumulation is less than 5%, while the hypothesis that most fractures occur in juveniles fits the data very well.

Table 6

Data from Ref. 9

Age group	Juvenile	Adult	Senile
No. of skeletons	21	41	19
No. of fractures found	11	20	7
No. of fractures expected if all occurred in juveniles	9	20	9
No. of fractures expected if constant accumulation	3.5	20	14.5

χ^2 probability of accumulation being correct hypothesis = 5%
χ^2 probability of juvenile being correct hypothesis = 70%

A further problem arises from the fact that the study of shot specimens may introduce distortions in data simply because some animals may be more easily collected than others. This was originally suggested by Randall[12] but refuted by Schultz,[14] who said that if anything animals which had previously been injured were more alert and quicker to escape than those which had not previously been injured.

Buikstra[4] carried out a study of his problem comparing the incidence of healed fractures in a museum collection of skeletons with the incidence in the skeletons of a complete population which had to be destroyed for conservation. Her conclusions were that the so-called random collection of specimens for museum collections may introduce major distortions into the incidence of conditions, casting into further doubt the validity of conclusions drawn from museum collections.

In order to bypass these problems an attempt made to discover the natural history of long bone fractures from field studies was carried out by workers who have observed groups of primates in the wild.

Table 5

Observations on the Schultz Collection

Index no.	Bones fractured	Fracture type	Maturity skeleton	Age of fracture	Notes
1532	Radius and ulna	Undisplaced cross-union	Adult	Juvenile	Overgrowth of fractured bones 0.5–9%
1560	Elbow	Bony ankylosis	Adult	?Adult	No change in length of bones ?septic arthritis
1577	Humerus	Undisplaced midshaft	Adult	Juvenile	Overgrowth of 7.5%
1578	Humerus	Undisplaced midshaft	Adult	Unknown	Contralateral bone missing
1584	Tibia, fibula ribs, phalanges	Midshaft tibia angulated	Adult	Juvenile	Despite angulation 0.3% overgrowth 5% real overgrowth
1609	Humerus	Undisplaced midshaft	Adult	Juvenile	Overgrowth 0.8%
1611	Hip, digit, clavicle	Dislocation malunion oblique	Adult	Juvenile	20% reduced acetabular size on dislocated side
1612	Humerus, clavicle	Midshaft oblique	Adult	?Adult	Both bones shortened
1617	Clavicle	Midshaft	Adult	Juvenile	3% overgrowth
1622	Humerus	Supracondylar and midshaft	Adult	Juvenile	1.9 cm shortening overall but 2.2 cm fracture overlap 1.5% overgrowth
	Femur, clavicle, ribs	Upper third midshaft			
1623	Tibia, fibula digits	Midshaft	Adult	Juvenile	Angulation but no shortening overgrowth 5%
1630	Tibia, fibula	Midshaft	Adult	Juvenile	Overgrowth 1.5%
1635	Humerus	Supracondylar	Adult	Juvenile	0.3 cm shortening but 1.5 cm overlap = overgrowth 6%
1636	Radius, ulna, clavicle, tibia, fibula	Oblique midshaft undisplaced	Adult	Juvenile	2.2 cm shortening but 0.3 cm overlap = overgrowth 8%

Field observation data was gathered from eleven research workers who have led teams studying primates in the wild for long periods. During the period of observation only three adult animals were observed to sustain major long bone fractures. All these animals died within a very short period, one of his injuries and two killed by predators. It is not easy to estimate how many animal years of observation these records represent because from hour to hour each observer may have different numbers of animals under observation but a conservative estimate is 3,000 animal years (Table 7).

This gives an adult fracture and mortality incidence of one per 1,000 animal years. The incidence in juveniles and infants of fracture and mortality is one per ten animal years in the only species for which data are accurately available, the Red Colobus (Table 8). In arboreal species such as the Colobus the commonest cause of injury appears to be falls[17,9] and these are eleven times more common in young animals than adults so the higher mortality in infants is in part due to the higher incidence of accidents and not just their lower chances of survival.

Table 7

Estimated Animal Years of Observation in the Wild of Primates

Observer	Species	No. of animals	Years of observation	Animal years observed
Goodall[7]	Chimpanzee	40	20	800
Struhsaker[17]	Colobus	30	20	600
Strumm*	Baboon	50	15	750
Packer*	Baboon	50	15	750
Homewood[8]	Mangeby	15	1	15
Marsh[9]	Colobus	15	1	15
Others†‡	Baboons	20	5	100
Total		220	77	3130

*Personal communication
†S. Cobb, and ‡ P. Hamilton, personal communications

Table 8

Incidence of Falls in Two Intensive Studies of the Red Colobus (Arboreal) Both 15 Animal Years

Infants	Juveniles	Adults	Total
4	6 (1)	2	12
10 (2)	2	0	12

Numbers in brackets are fatalities

DISCUSSION

The situation with regard to major long bone fractures in wild animals seems to be complicated by the fact that museum specimens may not accurately represent the situation in the wild. Field workers, because of the difficulty observing animals in their natural state, may be missing some fractures, especially minor ones and those occurring in juveniles. They would be unlikely to miss a major fracture, however. Juvenile bones are less brittle and produce a more vigorous healing response than adult bones[10] and certainly young primates supported and protected by

their parents probably stand a better chance of surviving in the wild than an adult without such support who sustains a similar injury. It seems likely that a substantial proportion of healed fractures in museum collections occurred originally in juveniles and that the observation by Schultz that the incidence of fractures increased with age may be an artifact produced by the way in which specimens were collected.

Fractures in the long bones of modern man are almost always the result of high-energy impact caused by motor vehicles, machinery, or sport, or the osteoporosis of senility. Using the admission cards of an accident and emergency department a search was made for fractures which had occurred in adults aged over eighteen and under fifty which did not involve any of the "benefits of modern civilization" and which could be said to be a "wild fracture". The catchment was just under 100,000 and there were ten fractures per month. Calculating for the number of adults in the catchment area the incidence was found to be approximately one fracture per 1,000 man years, a similar figure to the observed incidence in primates.

It seems much more difficult to say what does happen to wild primates with broken bones. Certainly fractures in juveniles are relatively common in humans and in wild animals judging from the museum material, but the incidence of major adult long bone fractures is more difficult to estimate and major fractures may be very rare and seem to be commonly fatal.

From an evolutionary point of view it is not necessarily the case that mechanisms for repair of fracture are prerequisite for the evolution of land mammals. In fact, it is surprising that there is any mechanism at all because a long bone fracture is so rare and so universally fatal. There appears to be little or no healing mechanism for injuries to the central nervous system (CNS) in mammals. The explanation given for this had been that any animal sustaining an injury of sufficient severity to cause significant CNS damage would result in the animal inevitably dying during the period of coma because of dehydration, starvation or predation. There therefore cannot be any selection pressure to start to evolve a healing mechanism if the injury is by definition universally fatal. Only an injury affecting a significant number of individuals and in whom a significant number survive can be subject to selection pressure for improved healing mechanisms. This is because of the increased chance of procreation in those animals who are injured and have survived, a standard example of Darwinian natural selection. The fact that there is a well-developed healing mechanism for adult long bone fractures in mammals suggest that the injury is not uncommon and that a significant number of individuals do survive, a conclusion at variance with the findings of this paper. An alternative explanation is that the bone healing mechanism is simply standard bone remodeling; in other words, a physiological response which acts by chance to the benefit of injured individuals. This is simply not the case because histological studies reveal that the callus response to a fracture is completely different from the remodeling process of bone. A second explanation is that the healing response is an example of the persistence of a juvenile response into adulthood neoteny. Certainly the data presented here suggest that fractures are much more common in juveniles and that due to parental care the chances of surviving are high. This means that selection pressure can be exerted to evolve sophisticated techniques for healing of fractures.

Alexander[1] had addressed this problem in a theoretical paper on the optimum strength of bones in animals where a balance must be struck between avoiding fracture and the penalty in weight and resources in producing unnecessarily strong bones. In a second paper,[3] he measures the incidence of healed fractures in the skeletons of birds, molluscs and primates. He finds that wing bone fractures in birds, which might be expected to be fatal, are significantly rarer than primate long bone fractures which he believes are more likely to be survived. Fractures in snail shells which can easily be survived by the animal are the most common of all. His hypothesis, that the strength of the skeleton is determined in part by the severity of the penalty for skeletal failure, is confirmed. A problem with the data is that the incidence of fractures is derived from the incidence of survivors in the population. This must by definition underestimate the problem and to a certain extent invalidates the data. This is because in those animals in whom healed fractures are rarely found (such as birds) the reason could be either that fractures rarely occur because the skeleton is of adequate strength or because the fractures are uncommon but usually fatal. In the second case, the skeleton is not in fact strong enough and the injury may be common. From the data presented there is no way of distinguishing between these hypotheses. Nevertheless, it appears likely on theoretical grounds that there is far stronger selection pressure for the evolution of a skeleton of adequate strength than there is for a healing mechanism for bones to heal once broken.

CONCLUSION

It is difficult to establish how common long bone fractures are in wild primates but they may be much rarer than originally thought. It is probably that long bone fractures are rare in adult wild primates and that when they do occur, they are fatal.

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THE CONCEPTUAL DEVELOPMENT, THE SURGICAL TECHNIQUE, AND THE CLINICAL APPLICATION OF THE PERICAPSULAR INNOMINATE OSTEOTOMY

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INTRODUCTION

In the middle 1950's, Dr. Paul A. Pemberton of Salt Lake City treated a large number of North American Indians, most of them from the Navajo nation. This nation, with a population in excess of 100,000 people, has an incidence of congenital dislocation of the hip approximately five times that of the general population. Because many were untreated, he had the opportunity to treat a large number of patients of varying ages with dislocations of the hip. At that time he performed either a closed or open reduction and then returned the patients to the reservation in a hip spica cast. Many never returned for follow-up care, and they were found later to have dislocated hips, due to premature cast removal or failure of adequate acetabular remodeling. This prompted Dr. Pemberton to develop an operative procedure that could be done at the same time as open reduction, that could provide hip joint stability and thereby avoid the likelihood of redislocation.[5] He therefore developed the pericapsular innominate osteotomy that bears his name. He presented his early experience with this combined procedure at the annual meeting of the American Academy of Orthopaedic Surgeons in New York City in 1958,[6] and his early experience with the procedure subsequently was published in the Journal of Bone and Joint Surgery in 1965.[7]

During the developmental period of the operation, many problems and complications of the procedure were identified. These included femoral head osteonecrosis, cartilage necrosis and painful joint stiffness. Most of these untoward events could be traced to having performed the operation lacking well-defined indications, prerequisites, and contraindications. With the development of indications, prerequisites, and contraindications, and with better understanding of the biomechanics of the operation, these complications have become essentially eliminated. Furthermore, extensions of the clinical problems for which the procedure has valuable application have been identified. These three issues, namely, the conceptual development, the technical details, and the practical clinical application of the Pemberton osteotomy make up the essential contents of this article.

CONCEPTUAL DEVELOPMENT

I have already alluded to the issues surrounding the development of the operation. Unfortunately, as with many new procedures, enthusiasm for its versatility as a panacea for treatment for nearly all problems of untreated congenital dislocation of the hip led to some disappointing surgical adventures. Serious attention was not given to some very important issues, such as the need for concentric hip reduction as a prerequisite to performing the operation. The requirement of a good range of motion, and many of the other well established and now well-accepted prerequisites were not known nor was their value properly appreciated. Also, it was not fully understood in this early period that the operation actually could and undoubtedly did change the configuration of the acetabulum. In the proper set of circumstances, however, this latter observation proved to be beneficial, because of many sloping acetabulae encountered in hip dysplasia were returned to a much more normal configuration following the procedure. On the other hand, because of the great ability of the operation to achieve acetabular correction, over-correction of acetabular obliquity was a distinct potential pitfall, and one that is difficult to anticipate or quantitate even now by surgeons who are experienced in performing the operation.

I learned to do this procedure in 1958, shortly after it was demonstrated publicly at the Academy meeting. Since Dr. Pemberton lived in Salt Lake City it was convenient for him to perform this procedure for me on a living patient. Although the procedure demanded substantial surgical skill and attention to detail, it also accomplished correction of the acetabular roof better than any other acetabular operation yet devised. The major challenge was to develop the proper indications, a well-defined set of prerequisites, and a logical set of contraindications. In Pemberton's original publications, none of these were as clearly outlined as we currently view them. With several years of observation, glowing successes and unfortunate failures of the procedure have been objectively analyzed, ultimately leading to a well defined set of parameters that guide our decision-making.

Before reviewing these issues, it is important that one fully understands the technique of the operation, how it accomplishes the acetabular correction, and why it can be used in a variety of clinical problems when the acetabulum is the primary site of the abnormality. The original description of the operation was reasonably well outlined by Pemberton in 1965.[7] However, the illustrations were rather abbreviated, and even such master surgeons as Heinz Wagner[9] could not fully appreciate the technical subtleties of the operation (Fig. 1). Since then, several professional medical illustrators have provided graphic depictions of the operation. I am indebted to Dr. Raymond Morrissy[4] for permitting me to use illustrations which provide the reader with the best pictorial understanding of the technical details of the operation.

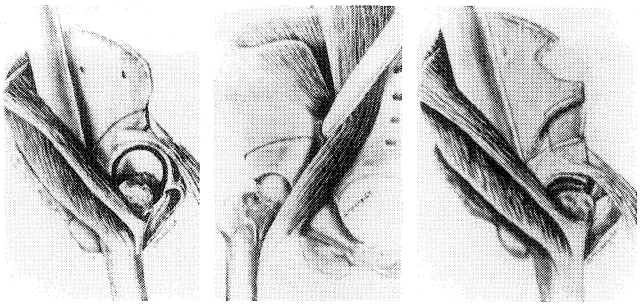
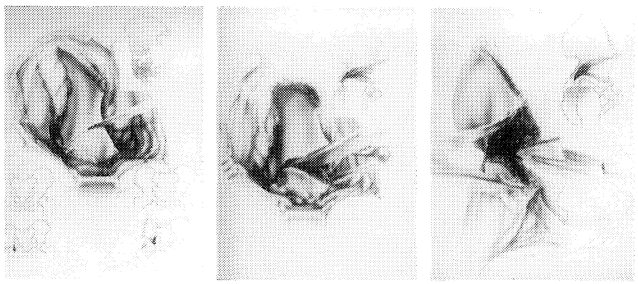


Figure 1
Pemberton's original illustration of the pericapsular osteotomy. The cuts into the inner and outer tables are well illustrated, but missing is an illustration of the location of the ilioischial area of the triradiate cartilage. Also it does not show the importance of making the outer cut more superiorly than the inner cut in the ilium. (From Journal of Bone and Joint Surgery, 47A:65-86, 1965.)

SURGICAL TECHNIQUE

The hip joint is approached through an anterior incision of the surgeon's choice. Both the inner and outer tables of the ilium are subperiosteally exposed laterally and inferiorly and as far as the capsular reflection of the hip on to the ilium, then medially over the superior ramus of the pubis, and posteriorly as far as the sciatic notch (Fig. 2). The decision whether or not to explore the hip joint can be make at this time. Clearly this will be necessary in the case of a dislocated hip, but it is not necessary in the instance of a simple dysplastic acetabulum or a reducible subluxation of a dysplastic hip wherein the femoral head can be reduced concentrically as demonstrated preoperatively by radiographic studies. It goes without saying that a dislocated or subluxated hip *must* be concentrically reduced prior to performing the acetabular procedure.

In most instances, the initial outer cut into the ilium is made just above the reflected head of the rectus femoris (Fig. 2). However, when greater lateral coverage of the head is desired, the outer cut may be made substantially



A B C

Figure 2
Illustration of the exposure of the ilium and the initial osteotomy in the pelvis. Upper insert outlines in the inner cut and its relationship to the posterior area of the triradiate cartilage (A). The pericapsular osteotomy is well illustrated in B. Note use of lamina spreader to facilitate posterior exposure. A triangular full thickness graft taken from the anterior superior spine is then impacted into the gap. Note grooves cut in the cancellous bone of the proximal and distal fragments designed to receive the graft and enhance its stability. Insert shows placement of the graft (C). (Courtesy of Dr. Raymond Morrissy, Atlanta, Georgia).

higher on the ilium. This represents one of the more versatile aspects of the operation, because this particular incision into the outer cortex of the ilium can also be carried posteriorly in a similar manner to provide increased posterior femoral head coverage. The cut in the inner pelvic wall then parallels the outer cut, except that it is lower and is of a smaller arc than the outer cut (Fig. 2). These two variations make possible both lateral and anterior femoral head coverage as the two cuts into the ilium are connected by a wider curved osteotome. Both of the cuts are extended in a curvilinear fashion posteriorly, using the capsular reflection as the guide. Retractors in the sciatic notch not only protect the sciatic nerve, but also discourage and hopefully prevent the surgeon from entering the sciatic notch. On the other hand it is equally important that this posterior inferior cut *not* enter the hip joint. There is about one to 1.5 cm of bone between the posterior aspect of the joint and the sciatic notch in the young child three to eight years of age. This segment of bone is the target, and the osteotomy ends up at the posterior superior arm of the triradiate cartilage. About one to two centimeters of the posterior osteotomy is essentially performed blind, but the maneuver can be greatly assisted by the skillful use of the lamina spreader (Fig. 2). The inferior fragment is then depressed inferiorly and laterally. Once the desired correction of the inferior fragment has been achieved, then appropriately placed "slots" are made in the cancellous bone of the superior and inferior fragments of the osteotomy so that the full thickness bone graft taken from the ilium can be impacted into these slots, thus preventing any tendency for the graft to displace medially or laterally. Following impaction, the graft should be very stable in these younger children and therefore internal fixation is unnecessary (under age seven or

eight years). The patient must be prevented from weight-bearing despite this demonstrated stability. Because of the unreliability of youngsters in this age group, a spica cast is essential. Clearly, in the rare case when an open reduction has accompanied the osteotomy, then a cast is obviously mandatory in order to protect the reduction and capsulorrhaphy. In six weeks the osteotomy is almost always solidly united, after which the patient may be placed in a removable abduction splint for four weeks, and this is gradually eliminated as the range of hip motion is regained. If an open reduction of the hip had been performed, then the patient's lower limbs are placed in "broomstick" fiberglass plaster casts for an additional six weeks in order to permit motions of flexion and extension and yet prevent rotation and adduction or abduction of the hips (Fig. 3). This is done primarily for the open reduction of the hip, and not for the pelvic osteotomy.

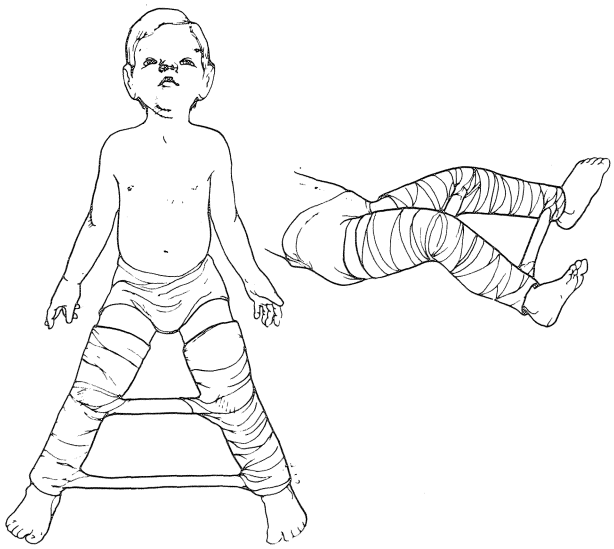


Figure 3
Illustration of the "broomstick casts" that are applied at four to six weeks following surgery. These permit flexion and extension motion of the hips but prevent abduction, adduction and rotation. These are employed only when an open reduction accompanies the pelvic osteotomy.

INDICATIONS

In congenital dislocation of the hip, the indications for the operation are few. A rare indication in our hands is its simultaneous performance at the time of open reduction (Fig. 4). We would much rather obtain a stable, concentric reduction and then observe the development of the acetabulum over a period of time, certainly in children under five years of age. On the other hand, we occasionally encounter a hip that cannot be rendered stable at the time of open reduction, and, therefore, a properly performed pericapsular osteotomy can provide stability. The second indication is an acetabulum that does not improve its slope or

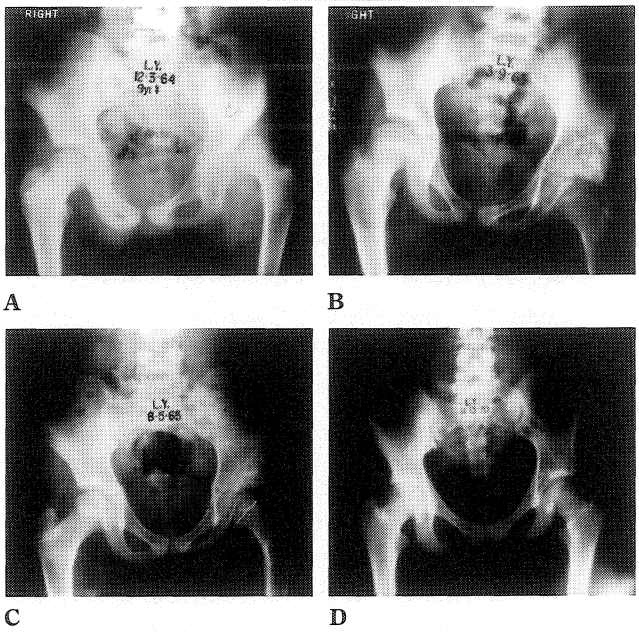


Figure 4
Pelvic radiograph of a nine-year-old girl with obvious congenital dislocation of the left hip. Note the triradiate cartilage is still open (A). An open reduction was done, and because of instability of the reduction a pericapsular (Pemberton) osteotomy was accomplished. Note comparable profiles of the obturator foramina showing that the acetabular correction has taken place only at the triradiate cartilage (B). Five months later the reduction remains stable and acetabulum has begun to remodel (C). Five years following original surgical procedure the hip is nearly normal in appearance (D).

configuration over a period of several months or a year or two of observation following either closed or open reduction (Fig. 5). If the upper femur is of acceptable configuration, then a pericapsular osteotomy can restore the acetabular roof to near normal appearance, and with the passage of time it becomes essentially normal. The third indication is the hip that shows not only an abnormal slope to the acetabulum, but also demonstrates a slow tendency of the femoral head to subluxate or shows progressive extrapelvic protrusion (Fig. 6). This hip will undoubtedly eventually become an irreducible subluxation and therefore early stabilization is indicated. It must, however, meet the prerequisite of being capable of concentric reduction, despite its subluxating tendencies. These are the only three defensible and proven indications for the procedure in congenital dislocation of the hip and its sequelae. By adhering to these indications and fulfilling the prerequisites (see below) our results have been uniformly excellent.[3]

PREREQUISITES

The prerequisites for performing the operation are just as important as the indications, for if one ignores any of these, failure is a high probability.[1] First is to select the proper skeletal age group. The triradiate cartilage must

be open and flexible. The age when the triradiate cartilage fuses varies widely with the sex of the patient (e.g. girls earlier) and the various ethnic groups (e.g. Latin Americans earlier). As a rule, the procedure is best accomplished before age six or seven years of age, although in some unusual situations it can be done in older children through age ten or eleven. Second, the femoral head must be concentrically reduced or be capable of concentric reduction. Third, the range of hip motion must be normal, or close to normal. It is especially important that the hip have good flexion, abduction and *inward* rotation, because the osteotomy tends to place the acetabulum forward and outward, and any restriction of flexion or inward rotation would be accentuated by the osteotomy. Finally, there must be a good or normal cartilage space that is free of the substantial degenerative change. One of the virtues of this operation is that it utilizes the articular cartilage of the acetabulum as the weight-bearing surface, and it stands to reason that the better the cartilage space the more long-lasting will be the result.

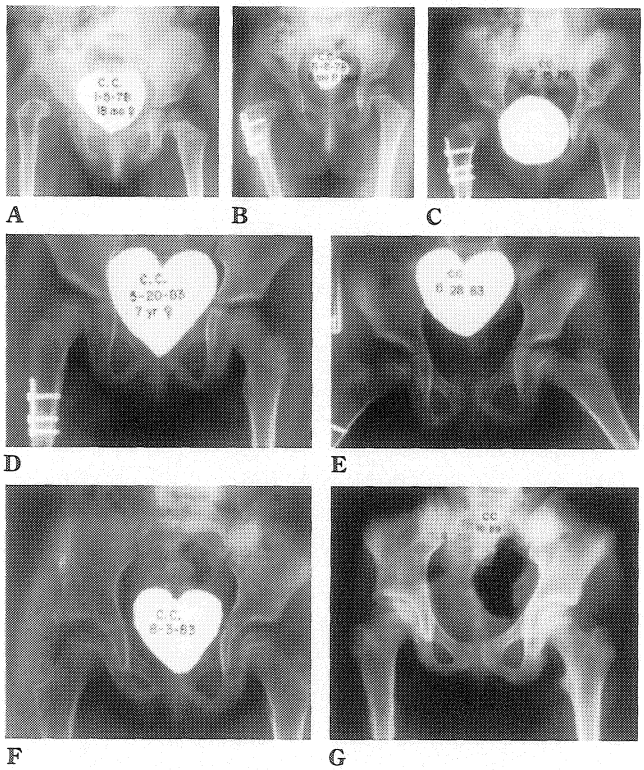


Figure 5

Pelvic radiograph of an eighteen-month-old girl with dislocation of right hip (A). Femoral shortening was required for proper, safe reduction (B). One year later the hip reduction is stable, but the acetabulum, although improved, is still dysplastic (C). Four years later, there has been no improvement in the acetabular dysplasia, although the hip is stable (D). An "abduction-inward rotation" pelvic radiograph shows that the femoral head seats well in the acetabulum (E). The hip joint three months following pericapsular osteotomy is seen in F. Six years later at age thirteen the acetabulum covers the femoral head and has shown substantial remodeling (G).

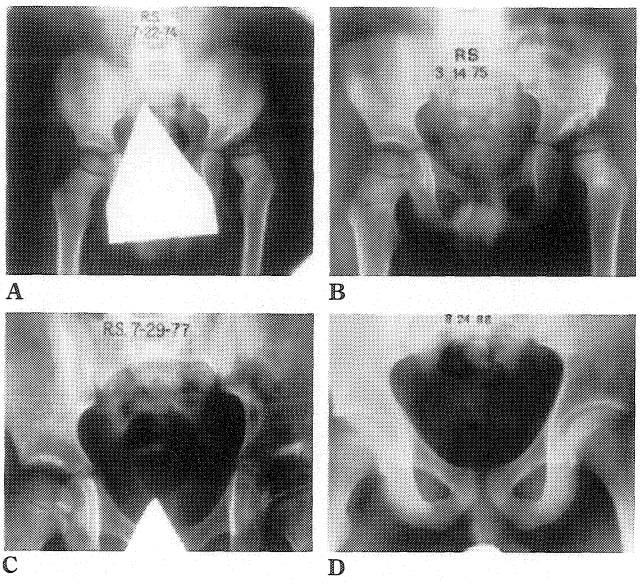


Figure 6

Pelvic radiograph of a four-year-old boy who had undergone a closed reduction two years previously. The femoral head appears to seat well, but no medial teardrop has developed (A). Eight months later the femoral head is subluxated and unstable (B). Radiograph showing the results of a pericapsular osteotomy done two years earlier (C). Eleven years later the hip is almost indistinguishable from normal (D).

CLINICAL APPLICATIONS

Although the operation has its greatest value and application in young children with residual acetabular abnormalities secondary to congenital dislocation of the hip, the pericapsular innominate osteotomy can be used for managing problems presented by paralytic hip abnormalities (Fig. 7), Ehlers-Danlos syndrome, and Downs syndrome (Fig. 8). The reason why it can be used in these unusual circumstances where most other reconstructive osteotomies are ineffective is because the Pemberton pericapsular osteotomy does not uncover the posterior acetabulum, and is capable of achieving greatly improved femoral head coverage and stability in this area. Thus, although in many loose hip joints we have created deformities in a previously normal acetabulum and upper femur, we have done so fully aware of the fact that the options in these conditions are so unattractive that creation of these deformities is justified. Therefore, we have used the pericapsular osteotomy freely in conjunction with varus rotational proximal femoral osteotomy in an effort to provide stability to a dislocating hip, either paralytic or due to excessive capsular laxity, that may otherwise become painful and arthritic. In *paralytic* problems we always accompany or follow the osteotomy with muscle balancing procedures if possible. In loose-jointed patients, we also add a capsular plication which, although temporary, does help stabilize the hip at the time of surgery.

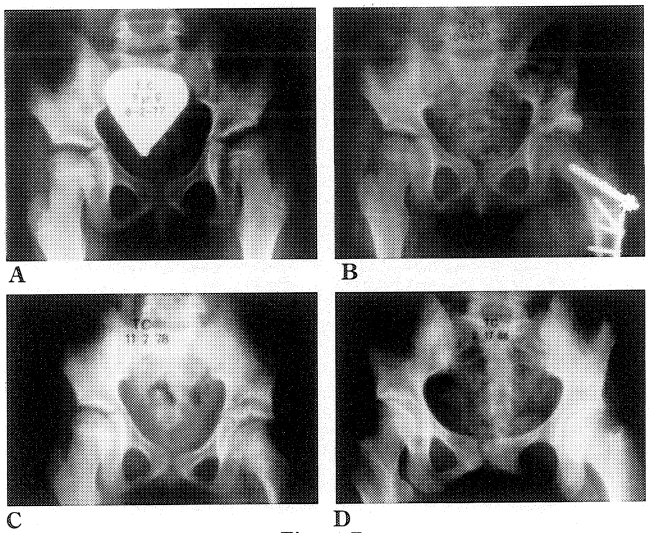


Figure 7
Pelvic radiograph of a seven-year-old girl with cerebral palsy. The left hip is subluxating as evidenced by the "V" shaped teardrop, the coxa valga deformity of the proximal femur, and the reduced coverage of the femoral head (A). A pericapsular pelvic osteotomy was done in conjunction with a proximal femoral osteotomy to correct both sides of the hip joint (B). An adductors posterior transfer was subsequently accomplished. One year later the femoral head is well covered and the acetabulum is well formed (C). Ten years following the osteotomies, the hip remains well developed and note the remodeling that has converted the teardrop to normal (D).

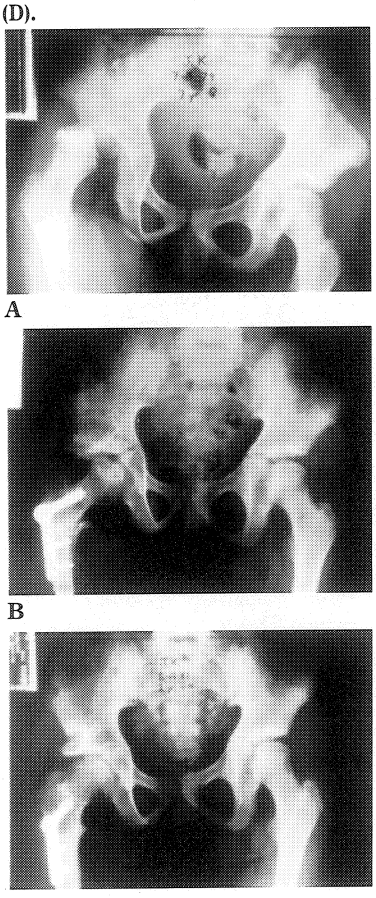


Figure 8
Pelvic radiograph of a seven-year-old girl with Down's syndrome who has had a chronically recurrent dislocation of the right hip. There is radiographic evidence of osseous necrosis and subtle collapse of the femoral head (A). It had become disabling due to pain. A pericapsular pelvic osteotomy, a varus-producing proximal femoral osteotomy and a radical capsulorrhaphy of the hip joint were accomplished (B). Two years later the hip joint has remained stable and some repair of the osseous necrosis is evident (C).

CONTRAINDICATIONS

The contraindications for the procedure are very simple to define; namely, failure to meet any of the indications or the prerequisites outlined earlier. These are the same basic contraindications that are described by Salter for the performance of the redirectional innominate osteotomy.[8] Therefore, if the child does not have an open triradiate cartilage, does not have a reducible, congruently located hip, or a good or nearly normal range of motion, then the operation should not be performed. The other indications and prerequisites have already been presented.

ADVANTAGES AND DISADVANTAGES OF THE PERICAPSULAR OSTEOTOMY

Several features of this procedure make it very attractive as compared to other pelvic osteotomies. Yet, there are some drawbacks to the operation. Over-correction of a perceived acetabular deficiency is a real and worrisome issue. No currently available technological modality can assist the surgeon to establish how much correction of the acetabular roof should be achieved at the time of operation. Yet, these same concerns also pertain to other pelvic osteotomies. The procedure is technically demanding, and it should not be done without prior experience and/or observation of one who has done the operation many times. Also, the procedure is limited to specific skeletal age groups.

On the positive side, the operation has great versatility and can be employed to enhance acetabular coverage of a poorly covered femoral head in a variety of clinical conditions. It is a stable osteotomy with the graft firmly engaged by both proximal and distal fragments, making internal fixation unnecessary. Varying degrees and directions of acetabular correction can be achieved by the procedure, provided that good planning is exercised and the operation is properly executed.[2] There is predictable universal union of the osteotomy and graft, and we have had no failures of union. We do not have a thirty year follow-up of statistical significance that takes into consideration all of the newly conceived indications, prerequisites, technical modifications and contraindications. Yet with our current understanding of what can be achieved by this procedure, we consider it one of the most valuable recent contributions to the care of children with acetabular deficiencies, especially congenital dislocation of the hip.

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MR IMAGING OF BONE MARROW PACKING DISEASES

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INTRODUCTION

A large variety of disease processes involve the bone marrow including infection, metastases, myeloproliferative disorders and storage diseases. Magnetic resonance imaging has proven to be highly sensitive to bone marrow changes and is currently the only modality which allows direct imaging of bone marrow without the use of contrast agents or radioisotopes.

On T1-weighted spin echo images cortical bone displays very low signal intensity (black) whereas yellow marrow has high signal intensity (bright) and red marrow has low signal intensity (dark-gray). While bone marrow aspirate and biopsy remain the gold standards in the diagnosis of bone marrow disease, these technics have serious drawbacks when the disease does not involve the bone marrow diffusely and tissue sampling becomes a problem. MRI offers important information as to the location and extent of disease because a large volume of marrow is scanned.

Bone marrow begins hematopoiesis in the fourth month of fetal development and is fully responsible for red cell production by birth. Hematopoietic marrow is then gradually converted to fatty marrow in a distal to proximal fashion in the skeleton as a whole, and from diaphysis to metaphysis within individual long bones. The process continues until approximately age twenty-five. At this time red marrow is found predominately in the skull, vertebrae, ribs, sternum, pelvis and proximal shafts of the femora and humeri. Variations, however, do exist and it is not unusual to find evidence of hematopoietic marrow occupying the femoral shafts[3,11] (Fig. 1).

With age the ratio between red and yellow marrow slowly changes. Within the vertebral bodies the volume of red marrow decreases from a mean of 58% in the first decade to 20% by the eighth decade. The rise in fatty marrow is attributed to the additional fat cells needed to replace trabecular bone lost due to osteoporosis[3,10,11] (Figs. 2, 3). The presence of more marrow in the younger

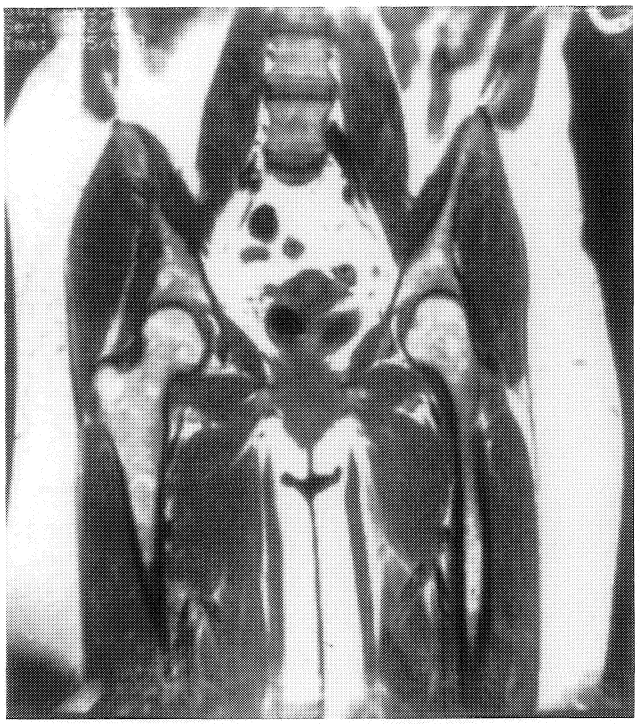


Figure 1
T1-weighted image of a healthy 43 year old female with an unusual distribution of normal red marrow extending into the midshafts of the femora. The gray areas represent red marrow and the bright areas yellow marrow.

population may make the detection of neoplastic infiltration, with T1-weighted images, more difficult. However, T2-weighted and STIR sequences as well as gadolinium enhancement readily demonstrate the neoplastic process.

Yellow marrow is very labile and quickly converts to hematopoietic red marrow when the marrow system is stressed or replaced. Reconversion occurs in the opposite order, that is from proximal to distal. Thus, in disorders, such as chronic anemia, chronic heart failure, myelofibrosis, neoplastic infiltration or marrow infarction, reconver-

Figure 2
T1-weighted image of a young, healthy, athlete demonstrating medium signal intensity from the marrow of the vertebrae, representing thick, bony, trabeculae.

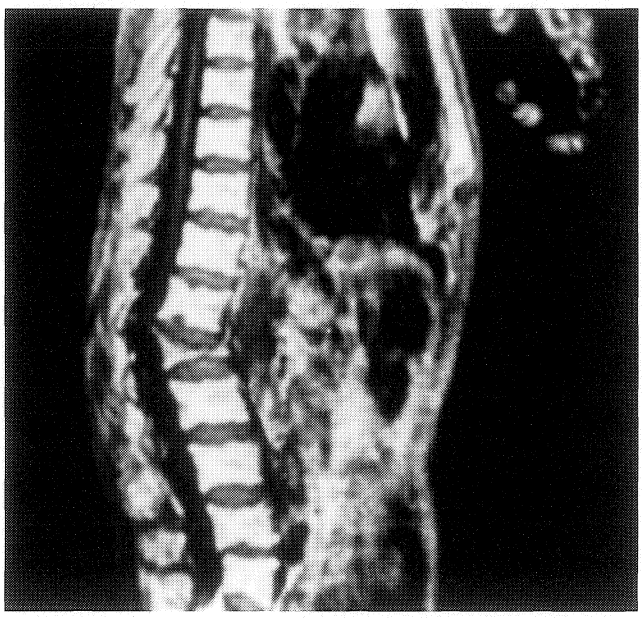


Figure 3
T1-weighted image of an elderly male with osteoporosis, demonstrating high signal intensity from the vertebrae, due to a large volume of fatty marrow.

sion occurs first in the spine and flat bones and then in the extremities, beginning proximally and extending distally.[3,11]

Keeping these principles in mind we sought to determine the characteristic MR appearances of a variety of malignant bone marrow diseases as well as the appearance of bone marrow before and after bone marrow transplantation.

MATERIALS AND METHODS

Using the 0.5T Picker MR scanner we prospectively studied the coronal and sagittal T1-weighted images of the lumbar spine, pelvis and proximal femora in twenty one patients with known bone marrow disease. This group included three with acute myelogenous leukemia, five with chronic myelogenous leukemia, five with non-Hodgkins lymphoma, one with Hodgkins lymphoma, two with metastatic breast cancer, four with multiple myeloma and one with aplastic anemia (Table 1).

Table 1

Disease Processes in Twenty-one Patients Studied with T1-weighted MR Imaging

No. of patients	Disease
3	acute myelogenous leukemia
5	chronic myelogenous leukemia
5	non-Hodgkins lymphoma
1	Hodgkins lymphoma
2	metastatic breast cancer
4	multiple myeloma
1	aplastic anemia

A subset of this group were seven patients undergoing bone marrow transplantation. These patients underwent an aggressive course of total body irradiation and/or chemotherapy beginning eight days before transplant. Leukemia patients received both chemotherapy and total body irradiation in an attempt to ablate the entire marrow. Patients with solid tumors received only chemotherapy to ablate the tumor. Studies were performed before preparative therapy, on Day −9 before transplant, and after preparative therapy on Day −1 before transplant. Two patients had follow-up studies on Day +28 after transplant. The patient group included four with acute myelogenous leukemia, two with chronic myelogenous leukemia, and one with metastatic breast cancer (Table 2).

Table 2

Day of Imaging and Disease Processes in Seven Bone Marrow Transplant Patients Studied with T1-weighted MR Imaging

Day of Imaging	Disease
Day −9, −1 and +28	acute myelogenous leukemia
Day −9 and −1	acute myelogenous leukemia
Day −9 and −1	acute myelogenous leukemia
Day −9 and −1	acute myelogenous leukemia
Day −9, −1 and +28	chronic myelogenous leukemia
Day −9 and −1	chronic myelogenous leukemia
Day −9 and −1	metastatic breast cancer

RESULTS

The five patients with chronic myelogenous leukemia and three patients with acute myelogenous leukemia all showed diffuse low signal intensity from the lumbar spine, pelvis and/or proximal femora (Figs. 4,5).

In contrast to leukemias, we found that in five patients with non-Hodgkins lymphoma and one patient with Hodgkins lymphoma, the MR appearance ranged from isolated focal defects of low signal intensity within normal appearing marrow, to a diffusely decreased marrow signal (Fig. 6).

Patients with multiple myeloma had a similar appearance to those with lymphoma. Two of these patients had diffuse low signal intensity from the bone marrow in the pelvis, lumbar spine and/or proximal femora, with patchy sparing of normal appearing marrow. One patient had a large mass of low signal intensity within the left ischium, in addition to diffuse low signal intensity, with small spared marrow areas (Figs. 7a, 7b). One patient with smoldering myeloma had a diffusely decreased marrow signal throughout the vertebrae and both femora.

Figure 4
T1-weighted image of a 48 year old woman with four year history of chronic myelogenous leukemia, showing diffusely decreased marrow signal within the vertebrae, reflecting neoplastic infiltration. Bone marrow cellularity was 100% on biopsy.

Figure 5
T1-weighted image of a 30 year old female with five month history of acute myelogenous leukemia also showing diffusely decreased marrow signal from the vertebrae caused by neoplastic infiltration. Again, bone marrow biopsy showed a marrow cellularity of 100%.

The one patient with metastatic breast cancer had discrete, isolated, focal defects of low signal intensity, within normal appearing marrow, in the lumbar vertebrae. The pelvis and proximal femora appeared normal.

The patient with aplastic anemia showed diffusely increased marrow signal intensity throughout the spine.

In the group of seven patients undergoing bone marrow transplantation we found no significant interval change in the marrow appearances between Day −9 (before preparative therapy) and Day −1 (after preparative therapy). Two patients had follow-up studies on Day +28 after transplant. One patient showed a return to normal appearing marrow while the other showed no change in marrow

Figure 6
T1-weighted image of a 60 year old male with three year history of diffuse large cell lymphoma, showing an isolated focal defects of low signal intensity (arrows), with normal appearing marrow elsewhere.

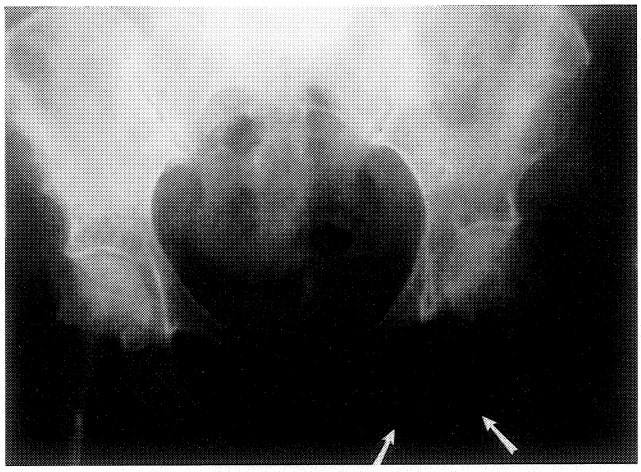


Figure 7a
Plain film obtained on a 44 year old woman with 5 week history of left hip and thigh pain, which had become progressively worse after falling. Note the destruction of the left ischium (arrows). The patient was diagnosed with multiple myeloma.

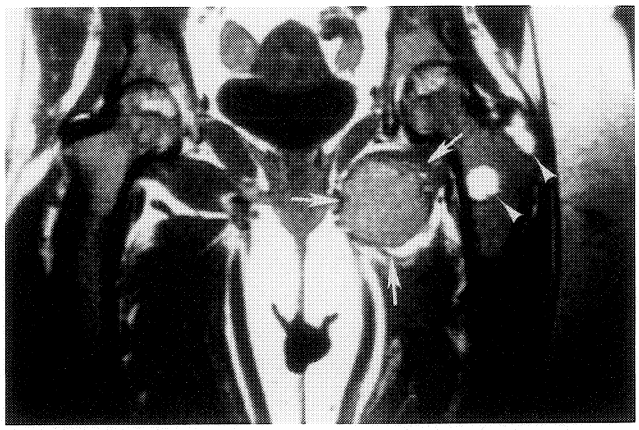


Figure 7b
T1-weighted image of the same patient showing a large mass in the left ischium (arrows) in addition to a diffusely decreased marrow signal from the proximal femora and pelvis as a result of neoplastic infiltration. The bright areas represent uninfiltrated yellow marrow (arrow heads).

appearance when compared to pre-transplant studies. Selected case studies will be presented.

CASE STUDIES

Case 1

B.J. is a 44 year old female who presented to her local physician in October of 1983 with gingivitis, lightheadedness and fatigue. A CBC was obtained which revealed a white cell count of 3.0K and a hemoglobin of 5. Bone marrow aspirate and biopsy were performed which showed a hypercellular marrow of 80 to 90% (normal 30–70%) with normal marrow elements replaced by blast cells. She was diagnosed with acute undifferentiated leukemia.

She then underwent a course of allopurinol, thioguanine, Ara-C, daunorubicin and vincristine without remission. She was switched to high dose Ara-C and remission was obtained. She did well and was felt to be a good candidate for bone marrow transplantation.

In May of 1984 allogeneic bone marrow transplantation was performed at The University of Iowa Hospitals and partial engraftment was obtained. She did well although she continued to require constant blood product support of two units of packed red blood cells at two to three month intervals.

In May of 1988 she presented with periodontal problems, diarrhea and an upper respiratory infection. A CBC revealed white cell count of 1.9K and a hemoglobin of 9.2. Bone marrow aspirate and biopsy were obtained which showed a 40% cellular marrow with 60–70% blasts, indicative of recurrent leukemia. She was admitted to The University of Iowa Hospitals for a second allogeneic bone marrow transplantation.

During this hospitalization she was given a preparative course of Busulfan and Cytoxan in addition to 900 cGy of total body irradiation. MR imaging was performed on Day −9 (before preparative therapy) on Day −1 (after preparative therapy) and on Day +28 after bone marrow transplantation.

MR imaging obtained on Day −9 showed mildly decreased signal intensity throughout the lumbar spine with normal appearing pelvis and proximal femora (Fig. 8a). This correlated well with a bone marrow biopsy, obtained on the same day, which showed the marrow to be mildly hypocellular (30% cellularity) although blast cells comprised 74% of the total (normal < 5%). This example illustrates that while T1-weighted MR imaging is sensitive to marrow cellularity it is unable to distinguish cell types which are important in diagnosis.

Figure 8a
T1-weighted image of a 44 year old woman with acute myelogenous leukemia, undergoing bone marrow transplantation. Image obtained on Day −9 before transplant and before preparative therapy. There is diffuse mild decrease in signal intensity throughout the vertebrae. CBC showed 1.3K white cells. Bone marrow biopsy showed a mildly hypocellular marrow of 30% although 74% of the cells were blast cells.

There was no significant interval change in marrow appearances between Day −9 and Day −1 (Fig. 8b). By Day −1 it is assumed that all marrow has been ablated. Biopsies were not obtained at this time, however, a CBC revealed a white cell count of .1K. The difficulty in interpreting these studies lies in the inability of MRI to differentiate viable from ablated tumor cells. While the MR study showed no significant interval change the CBC clearly reflected marrow ablation.

Figure 8b
The same patient after preparative therapy on Day −1 before transplantation. There is no significant interval change in the marrow appearances on T1-weighted imaging. All marrow is assumed to have been ablated. The patients peripheral white cell count was .1K.

The study obtained on Day +28 again showed diffuse mildly decreased signal intensity throughout the lumbar vertebral bodies with no significant change from the pretransplant studies (Fig. 8c). Again, there was good correlation with a bone marrow biopsy showing 20% cellularity and a white cell count of 4.6K, representing marrow engraftment.

Figure 8c
The same patient on Day +28 after transplantation. Again there is no interval change in the marrow appearances in comparison to pre-transplant studies. However the patients white cell count had risen to 4.6K and bone marrow biopsy showed a marrow cellularity of 20% with regenerating erythrocytic and granulocytic precursors indicating marrow engraftment.

A full engraftment was obtained within four months of transplantation. She continues to be in remission and is doing well.

Case 2

B.K. is a 62 year old female who was in good health until December of 1989 when she presented to her local physician with a one month history of increasing shortness of breath, palpatations, lower extremity edema, and easy bruisability. She also reported a one year history of increasing malaise. A CBC revealed a hemoglobin of 4.9, a white cell count of 3.4K and platelet count of 11.0K. She denied any recent viral or bacterial infection. She had no history of chemical exposure or past blood transfusions, and was on no medications.

A bone marrow biopsy was performed which showed a marrow cellularity of less than 5%, with few scattered erythropoietic and granulopoietic elements. No megakaryocytes were identified. No lymphomatous or carcinomatous infiltrates were seen. She was subsequently diagnosed with idiopathic aplastic anemia.

T1-weighted MR images were obtained, at the time of diagnosis, which showed a diffuse, markedly increased signal from the marrow of the lumbar spine (Fig. 9). The contrast between this study, and those shown in Figures 4 and 5, shows how signal intensity increases on T1-weighted images as bone marrow cellularity decreases and vice versa.

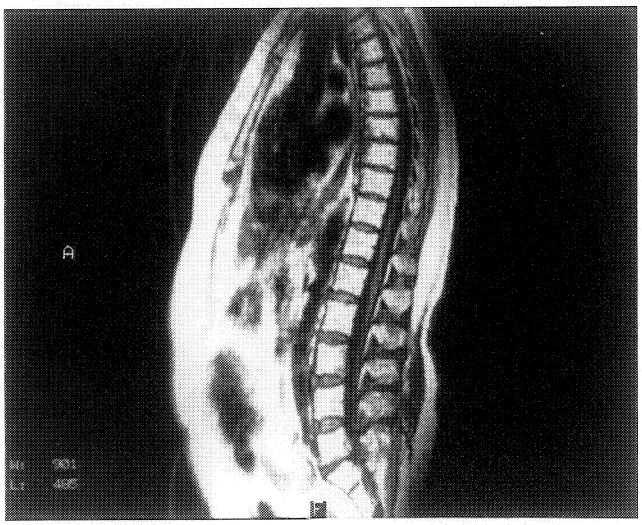


Figure 9
T1-weighted image of a 62 year old female with aplastic anemia. There is diffuse, markedly increased signal intensity from the marrow of the vertebral bodies. Bone marrow biopsy showed a cellularity of less than 5%.

The patient was treated with anti-thymocyte globulin (ATG) with poor response. She continues to be hospitalized and requires frequent platelet and RBC transfusions.

Case 3

E.G. is a 48 year old female who presented to her local physician in March of 1984 with an ankle injury and was subsequently found to have a white cell count of 30.0K and platelet count of 503.0K. Bone marrow aspirate and biopsy were consistent with chronic myelogenous leukemia. She was started on hydroxyurea and remained asymptomatic without progression of disease for three and half years.

In January of 1988 a routine CBC revealed an elevated platelet count of 460.0K and bone marrow biopsy revealed a 95% cellular marrow representing an accelerated phase of her disease. A search was begun for an unrelated bone marrow donor.

In April of 1988 she was admitted to the University of Iowa Hospitals for an allogeneic bone marrow transplantation. She underwent a preparative course of high dose Ara-C and Cytoxan in addition to 1200 cGy total body irradiation. MR imaging was obtained on Day −9, Day −1 and Day +28.

T1-weighted images obtained on Day −9 showed diffusely decreased marrow signal from the lumbar spine, pelvis and proximal femora (Fig. 10a). This correlated with a bone marrow biopsy which revealed a 100% cellular marrow and a CBC showing a white cell count of 14.7K and platelet count of 413.0K.

Post-transplant studies showed a return to normal appearing marrow by Day +28 (Fig. 10b). There was positive correlation with a bone marrow biopsy showing a 20–30% cellular marrow with all stages of erythropoiesis and granulopoiesis present, representing marrow engraftment and repopulation.

Figure 10a
T1-weighted image of a 48 year old woman with chronic myelogenous leukemia obtained on Day −9 before bone marrow transplantation. There is a diffusely decreased marrow signal throughout the vertebrae indicating a marrow totally infiltrated by tumor and consistent with a bone marrow biopsy revealing 100% cellularity.

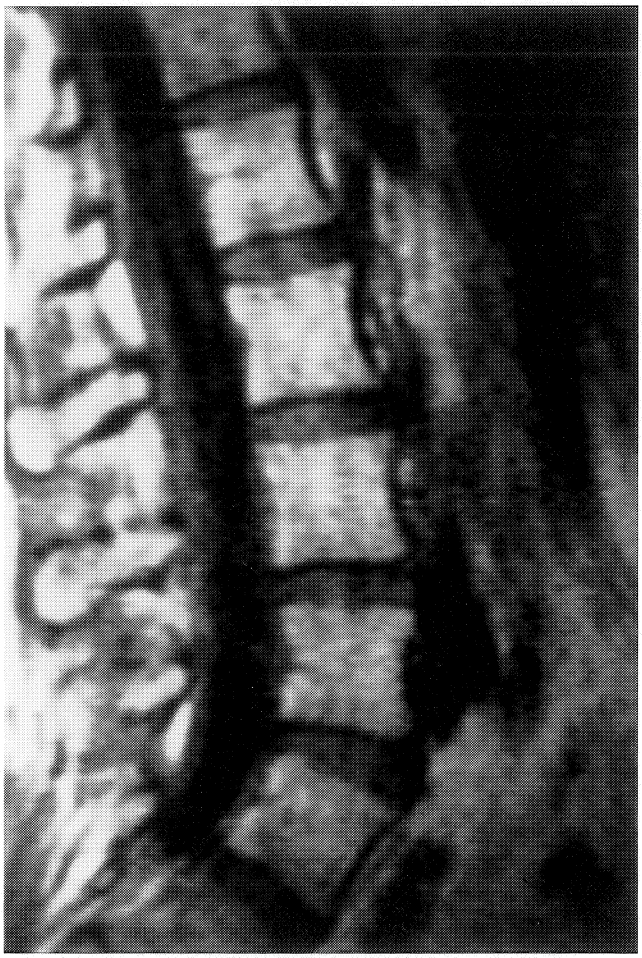


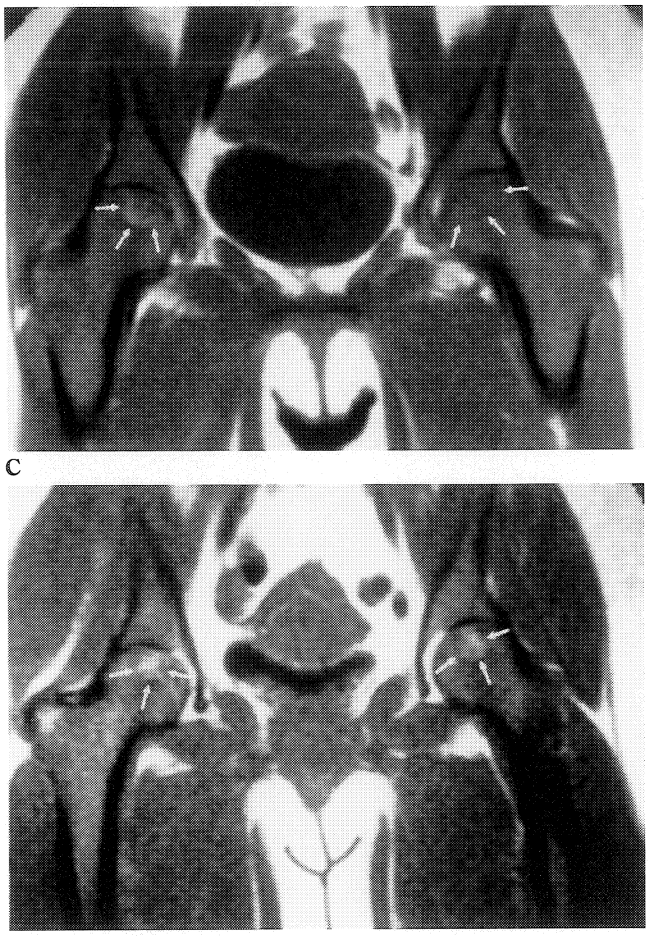
Figure 10b
The same patient on Day +28 after transplantation. There is a return to normal appearing marrow suggesting marrow engraftment. This correlates well with a bone marrow biopsy obtained on the same day showing marrow cellularity to be 20–30% (normal 30–70%) with all stages of erythropoiesis and granulopoiesis present. CBC showed a white cell count of 2.7K.

Of note is the presence of avascular necrosis in both femoral heads, on T1-weighted and T2-weighted imaging (Figs. 10c, 10d). This has been found to occur in patients with chronic myelogenous leukemia and is secondary to hypercoaguability caused by elevated platelet counts.

Two months after transplantation this patient developed an idiopathic interstitial pneumonia and died.

DISCUSSION

This study shows that both acute myelogenous leukemia and chronic myelogenous leukemia have diffusely decreased marrow signals from the vertebrae, pelvis and/or proximal femora. Other studies supporting these findings have also shown that chronic myelogenous leukemia,



C

D

Figure 10c and 10d
T1-weighted (10c) and T2-weighted (10d) images of the same patient obtained prior to bone marrow transplantation. There is diffusely decreased marrow signal throughout the pelvis representing marrow packed with tumor. Note focal areas of high signal intensity in both hips (arrows) representing avascular necrosis secondary to hypercoagulability caused by high platelet counts. The patient had a CBC showing a platelet count of 413K. Bone marrow biopsy showed a markedly hypercellular marrow of 100%.

in the chronic phase, has a tendency towards patchy sparing of yellow marrow, with the vertebrae being involved first, followed by the pelvis and femora as the disease progresses.[1,5,6,8]

The MR appearance of patients with lymphoma is variable, ranging from isolated focal defects of low signal intensity, within normal appearing marrow, to a diffusely decreased marrow signal. The difficulty in diagnosing lymphoma lies in its tendency to form focal nodules of tumor and therefore, it is not infrequent for bone marrow biopsy to be negative due to sampling error. MRI offers a sensitive method for detecting focal lesions, however, tissue characterization is lacking and often lymphoma may be mimicked by marrow infarct, infection, fibrosis, primary tumors or metastasis.[1,4,7,8,9] It is concluded that MRI is useful in following biopsy-proven lymphoma when it is carefully correlated with clinical information and other imaging methods.[2,8,11]

In multiple myeloma, the radionuclide scan is notoriously negative. In addition, myeloma often has a normal appearance on plain radiographs. Osteopenia, a common subtle finding, is non-specific and often normally seen in elderly patients, the population suspect for myeloma. Multiple myeloma is a multifocal disease and, as with lymphoma, sampling error by bone marrow biopsy makes diagnosis difficult.[1,2,10]

Because other diagnostic methods are often unreliable, we feel that MRI may be the most sensitive method of following patients with myeloma, especially patients with untreated myeloma and patients with assumed solitary myeloma.

In the group of seven patients undergoing bone marrow transplantation, we found no significant interval change in the marrow appearances before and after preparative therapy. The difficulty in interpreting these images lies in our inability to distinguish viable from ablated tumor. We are also unable to differentiate cell types, i.e. blast cells, which is an essential element of diagnosis. Perhaps with spectroscopy it will become possible to distinguish benign marrow elements from neoplasm as well as measure the metabolic activity within the tumor.[1,10] It is hoped that MR spectroscopy will provide a non-invasive and innocuous method of diagnosing marrow disease and detecting residual neoplasm.

Two patients had follow-up studies, on Day +28 after transplantation. One patient showed a return to normal appearing marrow and the other showed no change in marrow appearance from pre-transplant imaging. Both studies correlated well with results of bone marrow aspirates and biopsies, as well as complete blood counts, which had been obtained at the same time points. These preliminary findings suggest that MRI is a sensitive and valuable method of following bone marrow engraftment and repopulation after bone marrow transplant.

CONCLUSION

We have found that some malignant bone marrow diseases have characteristic MR appearances, however, a great deal of variability exists. MRI lacks tissue characterization and often it is difficult to distinguish one malignant process from another, as well as benign from malignant processes. On the other hand, MRI offers a sensitive and valuable method of following biopsy-proven bone marrow disease as well as repopulation of bone marrow following bone marrow transplantation. MR spectroscopy may become the future solution for most of the current problems.

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SPONTANEOUS FOREFOOT DEFORMITY IN RHEUMATOID ARTHRITIS OF THE FOOT

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This paper discusses an unusual presentation of forefoot deformity in rheumatoid arthritis.

A 70-year-old women developed symptoms of rheumatoid arthritis several years before. She had painful swelling, erythema, and warmth in both her wrists, in her right knee, and in both forefeet. After Plaquenil was started, her major symptoms abated.

One year later she abruptly felt an abnormal sensation in her left foot. Her left great toe had drifted laterally and her second toe had drifted medially, overlapping her great toe. There was no associated pain or swelling. She was wearing shoes with a fairly high toe box that did not cause undue pressure on the deformed toes of her left foot.

On physical examination the left great toe was laterally deviated. The second toe was riding high and was abruptly deviated medially at the metatarsophalangeal joint, overlapping the great toe (Fig. 1). The second metatarsophalangeal joint was not dislocated and could not be further subluxated from this position in a dorsal or plantar manner. There was no local soft tissue swelling or tenderness around the metatarsophalangeal joint itself.

Radiographs of the left foot showed no evidence of arthritic change in the forefoot but did show a deep erosion of the lateral side of the second metatarsal head in the region of the collateral ligament insertion (Fig. 2).

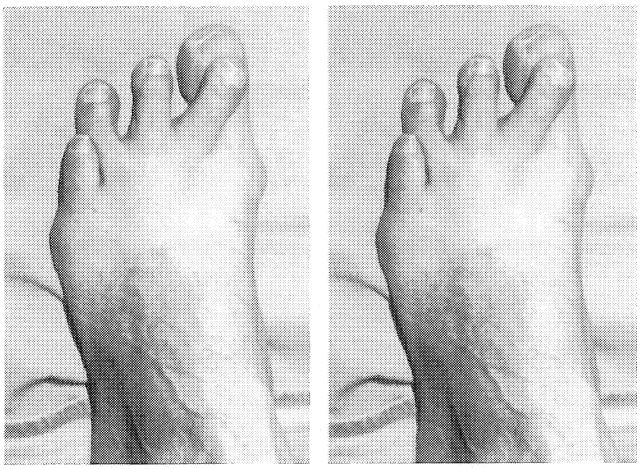

Figure 1
Acute onset of medial deviation of the second toe.

Figure 2
Erosion of the lateral side of the second metatarsal head with subluxation of the second metatarsophalangeal joint. AP view.

We hypothesize that during the initial flare of her rheumatoid arthritis, she sustained erosion of the metatarsal head as well as some attenuation of the deeper layers of the collateral ligament. At the time of the abrupt onset of her physical findings, the collateral ligament ruptured. This rupture, along with the pull of the toe flexors and extensors, caused the deformity.

The patient had no complaints regarding pain, functional impairment or cosmesis. She was merely interested in why she had developed this foot deformity.

The possibilities of surgery, ranging from attempts at simple local repair of the ligament to proximal phalangectomy, were discussed. Because there was no pain or impairment of function, no surgery was performed.

DISCUSSION

This paper demonstrates the relationship between rheumatoid arthritis and subsequent joint involvement. Clayton[1] described two clinical types of rheumatoid arthritis: a type which develops eventual fibrous or bony ankylosis,

and a type characterized by destruction of bone and laxity of soft tissues. We believe our example is of the latter type. This women had findings of rheumatoid arthritis several years before, only later to have acute problems with her second toe.

In 1953 Lippmann[2] showed the dramatic speed with which joint ligaments may weaken in response to a neighboring inflammation. This occurs before skeletal decalcification reaches a level detectable by roentgenograms. In Lippmann's study, ligaments adjacent to inflammation seemed to fray and tear close to the point of attachment. We speculate that during the time of acute synovitis this woman sustained a sharp decline in breaking strength of the involved collateral ligament. At the time of the abrupt onset of physical findings, this collateral ligament ruptured. The physical findings described are a result of this spontaneous ligament rupture.

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THE NEUROPATHIC FOOT

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Studies estimate at least 8.5% of the population will develop diabetes mellitus by age 70,[7] approximately one-third of all diabetics will develop some degree of neuropathy,[5] and one in 680 diabetics will be afflicted with Charcot joints.[8] We contend that the problem is actually much more common, but often misdiagnosed or underdiagnosed. This paper will briefly discuss the recognition of neuropathic changes in the foot.

HISTORY

Neuropathy in diabetics was first observed by Rollo in 1790. In 1868, Charcot described neuropathic arthropathy in patients with tertiary lues.[1,5] He felt that multiple fractures and dislocations in this patient population was due to the loss of a poorly-understood trophic neural influence.[1,6] Equally well-known German physicians Virchow and von Volkman claimed this hypothesis was "errant nonsense" and the true cause was simply single or repeated trauma to insensitive tissue.[1] Many insults were exchanged in print and one can almost develop a sense of acquaintance with the protagonists by reviewing the literature of the era! The Germans were probably closer to the truth, but the matter is not settled to this day.

In 1936, Jordan described neuropathic arthropathy in diabetics.[5] This was fifteen years after the discovery of insulin by Banting and Beast[3]; before this era large numbers of diabetics did not survive. Currently, more than twenty causes of neuropathy with associated arthropathy have been described.[6] Diabetes is by far the most common, followed by neurosyphilis and syringomyelia. Sensory loss with retention of motor function is a common thread. The resulting arthropathy is the same regardless of the source of the neuropathy.[4]

CLINICAL ASPECTS

Loss of protective pain sensation can be variable in degree. One diabetic may be insensate to the level of the knee; amputation of the grossly injured or infected foot could literally be performed painlessly without anesthetic agents. Another diabetic may be unaware of neuropathy and retain almost full sensation. Therefore, some diabetics will develop deformity with complete and "diagnostic" lack of pain, while others *will* complain of appreciable pain, although it will almost certainly not be proportional to the degree of injury. Charcot joints are not necessarily painless!

Several typical case presentations follow:

CASE I—An adult diabetic male noticed heel swelling of several weeks duration and, more recently, a minor degree of deep, aching pain. Although he continued his work as a manual laborer he limped and "had no strength" in his right foot and leg. His family doctor empirically diagnosed soft tissue infection and started a broad spectrum oral antibiotic. The swelling and pain did not respond, and further evaluation revealed no generalized malaise, fever or portal of entry for infection. Sedimentation rate and white count were not elevated. A more painstaking physical examination revealed marked diminution of light touch sensation and proprioception in the foot and toes. Roentgenograms of the foot revealed a fracture of the os calcis (Fig. 1). The soft tissue swelling and the pain subsided after prolonged immobilization in a well-padded plaster cast. There is nothing mysterious about the diabetic foot; the injury and repair reaction will subside when the extremity is protected. Without protection, healing would not have occurred. The calcaneus was in effect osteotomized and would probably have displaced proximally resulting in a "banana" or rockerbottom foot. After initial healing of this injury, an ankle-foot orthosis was advised for continued protection.

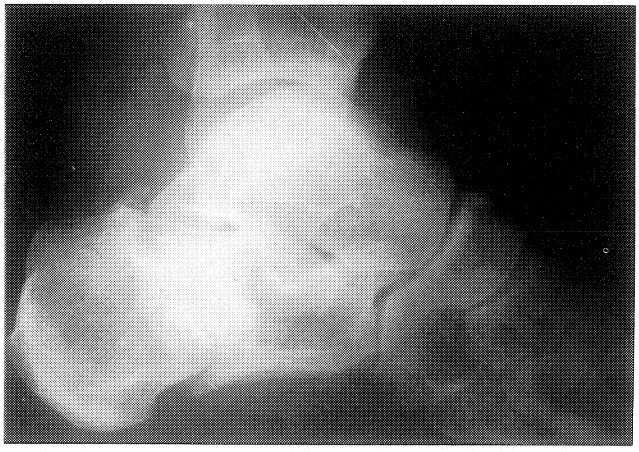


Figure 1
A minimally displaced fracture of the os calcis was initially misdiagnosed as infection. Plain films revealed the true cause of the erythema and swelling.

CASE II—Another patient presented with a similar clinical problem (Fig. 2). In this instance, the patient was hospitalized, placed at bedrest, and started on intravenous antibiotics despite the lack of systemic findings of infection. Soft tissue swelling, moderate pain, and local heat rapidly disappeared. The problem recurred when the patient started walking again. Deformity was noted for the first time and roentgenograms demonstrated dislocation of the talonavicular joint. An ankle-foot orthosis provided continued relief.

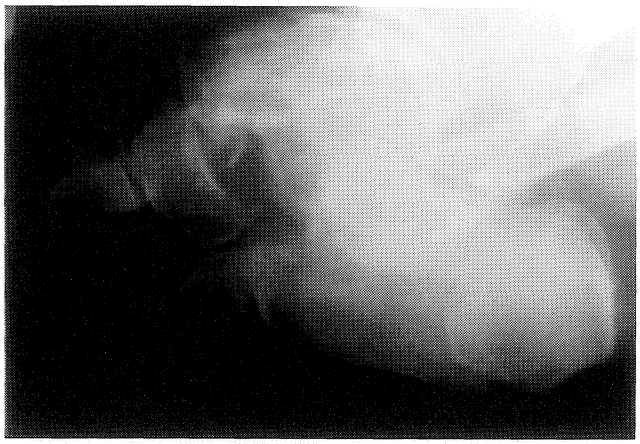


Figure 2
Fracture-dislocation of the talonavicular joint, originally misdiagnosed as infection. Bedrest and immobility will ameliorate many of the acute physical findings; antibiotics have no effect!

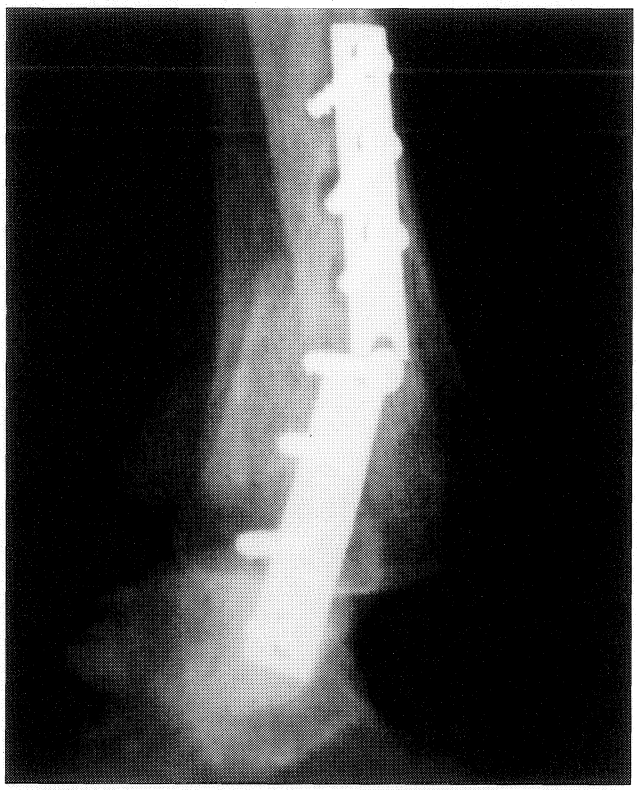
CASE III—An elderly diabetic women fractured her ankle. Her orthopedist performed open reduction and internal fixation and immobilized the ankle in a cast for several weeks post-operatively. Figures 3 and 4 confirm cast protection should have continued until union was observed radiographically, a process which may take two or three times longer than in the non-diabetic population.

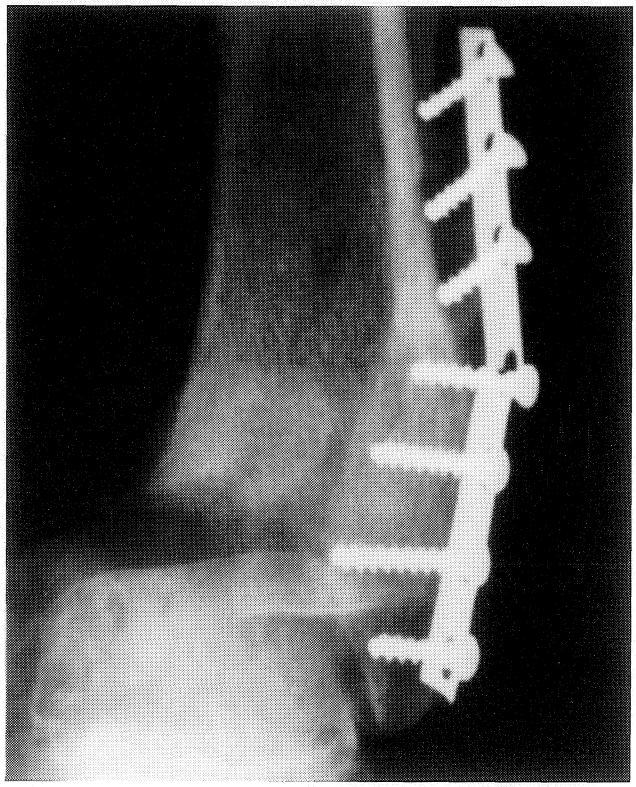
COMMENTS ON RADIOGRAPHY

Many Charcot joint problems are the result of multiple small injuries combined, rather that one major injury. In such cases, the first roentgenogram may appear negative, or demonstrate only soft tissue swelling. Later, there is usually no problem diagnosing fractures and/or dislocations.

Such injuries can be classified as atrophic or hypertrophic.[1,2,6] Both forms coexist.

The atrophic form shows a pattern of bone resorption and is sometimes mistaken for infection or an aggressive bone tumor.[1] The atrophic Charcot joint has an extremely sharp transition zone (edge of resorption) unlike the ragged, ill-defined transition zone seen in infection.[2] The resorption pattern may well be seen on both sides of the joint, a rare pattern for bone tumor.





Figures 3 and 4
Late displacement of a fractured ankle in a woman with rather severe neuropathy. Much longer post-operative immobilization may have led to a better result. Salvage is still possible.

The hypertrophic form shows appreciable proliferation of new bone as nature tries to repair the damage.[1,2,6] Some radiologists characterize the hypertrophic form as "osteoarthritis with a vengeance[1]"!

Bone scans are not indicated when there is frank bone injury by plain films. They may be useful when the diagnosis is suspected though plain films appear normal.

DISCUSSION

We treat a large diabetic population, and many of these patients have sensory neuropathy. This may lead to neuroarthropathy with secondary deformity, instability of the extremity, soft tissue injury, infection and even loss of the limb. Early recognition can help prevent this unfortunate sequence. Patient education is important and should stress daily self-examination for injury.

Any injury involving bone or joint, once diagnosed, can benefit from immobilization. With protection, swelling and local heat subside, indicating improvement. This may take many weeks in a protective plaster cast, followed by an ankle foot orthosis. In minor injury, an orthosis may not be necessary. An orthosis is mandatory following moderate or major injury.

SUMMARY

Diabetic neuropathy leads to a form of arthropathy which is an injury and repair reaction. Several typical cases of this often misdiagnosed problem are presented. Early recognition and proper protection are paramount to successful treatment of this injury.

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LIMB SPARING TECHNOLOGY IN THE MANAGEMENT OF PRIMARY BONE SARCOMAS OF THE EXTREMITIES

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1989 Michael Bonfiglio Lecture
Presented at the University of Iowa Orthopaedic
Alumni Conference, September, 1989

Prior to 1970, patients with high grade sarcomas of the extremity had very few options in regard to their treatment program. Most patients were offered a high-level amputation with grim outlook of only 25 percent chance of surviving because of pulmonary metastases. Two major breakthroughs occurred after 1970 that dramatically expanded our options for the management of these unfortunate patients. First was the development of the total joint replacement procedure which was adapted to the field of orthopaedic oncology. This provided a means of performing limb sparing procedures for patients with primary tumors of the extremity, thus avoiding amputation. Second was the application of multi-drug systemic chemotherapy for these same patients which improved their five-year survival rate from a dismal 25 percent to the present day figure of 75 percent.

Before the advent of total joint replacement, pioneers in the field of limb salvage technology relied on the excisional arthrodesis as a means of removing the tumor and its adjacent joint. The surgical void was then bridged with a large bone graft and stabilized with internal fixation devices. Healing was slow and complications were significant. Patient acceptance was poor because of the disability from a stiff joint. Presently, our mainstay for limb sparing procedures are the prosthetic implant, large bone allografts, or combinations of these methods with an "alloprothesis".

INDICATIONS AND CONTRAINDICATIONS

In order to consider a patient for limb sparing surgery, the surgeon must achieve tumor resection with a sufficiently wide margin as so to reduce the chance of local recurrence to the same level as a similar patient treated by traditional amputation. At the same time, the patient should be left with a functional capacity equal to or better than the same patient with an amputation and prosthetic limb. None of these surgical manipulations should in any way adversely affect the ultimate survival of our patient.

The contraindications for a limb sparing are several. If the tumor is large and involves a significant neurovascular structure, it is usually best to proceed with an amputation. Iatrogenic contamination of major vessels and nerves can result from poor biopsy technique performed by inexperienced surgeons unfamiliar with limb salvage protocol. In our experience, a pathologic fracture through the tumor frequently results in extensive contamination of multiple compartments around the involved bone, making it virtually impossible to obtain safe margins during an attempt at wide resection without amputation. A rare but serious contraindication is the occurrence of infection at the tumor site which is usually related to poor biopsy technique.

SURGICAL TECHNIQUE BY REGION

The Knee

By far the most common location of primary sarcomas of the extremity is about the knee joint. The distal femur is the most common site for occurrence of osteogenic sarcoma. The following is a typical example of a limb sparing procedure performed on a seventeen-year-old boy who presented with an osteosarcoma of the distal femoral diaphysis seen radiographically in Fig. 1A. A well placed biopsy confirmed the diagnosis. Metastatic workup including CT lung scan and a bone scan was negative. An MRI defined the medullary and extra-cortical extent of the tumor. Fig. 1B is a photograph of the resected specimen including the biopsy site. An "off-the-shelf" modular prosthesis, illustrated in Fig. 1C, was employed in reconstruction. This system consists of varying lengths of titanium alloy spacers with twelve and fourteen millimeter × six inch stems that are linked to a right or left rotating hinge total knee device by morse taper locks. This eliminates the delay and added expense of a custom device that might not fit.

The assembled device is cemented in place and cancellous bone from the proximal tibial plateau is placed about the porous pads located on the periphery of the prosthetic shoulder for biologic ingrowth stability. The patient's postoperative course is quite similar to that of a routine total

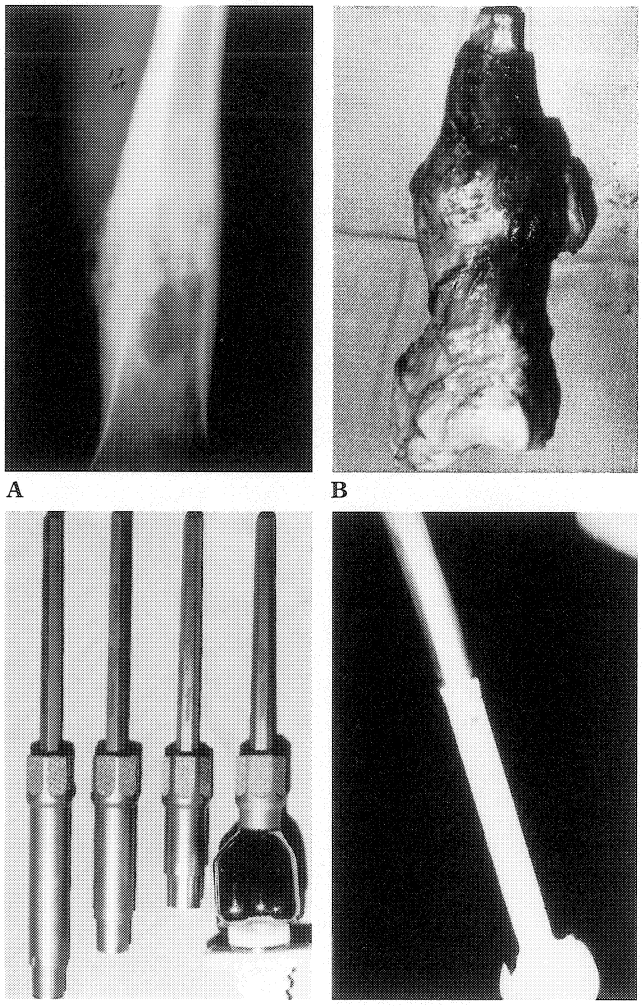

Figure 1 A–D
(A) Preoperative radiographic appearance of an osteosarcoma in a seventeen-year-old female.
(B) Surgical specimen after wide resection including biopsy site.
(C) Modular system with rotating hinge device for segmented knee replacement.
(D) Radiographic appearance seven years post-operatively.

knee replacement, except for the adjuvant chemotherapy that starts two weeks post-operatively and continues for a period of six months.

At seven years, this young man was free of disease and led a normal life with minimal disability related to avoidance of running or jumping activities. Radiographs at seven years, seen in Fig. 1D, reveal no evidence of stem loosening. Loosening, which occurs in 12 percent of our cases, is usually managed by re-cementing and more extensive bone grafting procedures at a time when chemotherapy will not inhibit osteogenesis.

The Shoulder

In the upper extremity, the proximal humerus is the most common location for primary sarcoma. This particular location lends itself very well to limb salvage surgery because it is a nonweight-bearing structure and the local recurrence rate is less than in the lower extremity. The following example demonstrates the use of an "alloprosthesis", a popular trend in limb salvage technology combining the advantages of immediate prosthetic stability with the biologic ingrowth potential of the bony allograft.

Fig. 2A demonstrates the radiographic appearance of a high grade dedifferentiated chondrosarcoma involving the proximal half of the humerus in a forty-year-old female. The resected surgical specimen, including the biopsy site, is seen in Fig. 2B. An allograft spacer has been cemented over a long stem Neer prosthesis to produce a composite alloprosthesis seen in Fig. 2C. The customized biologic prosthesis is then cemented into the distal humerus. Four years later, she is still working as a hair dresser and her

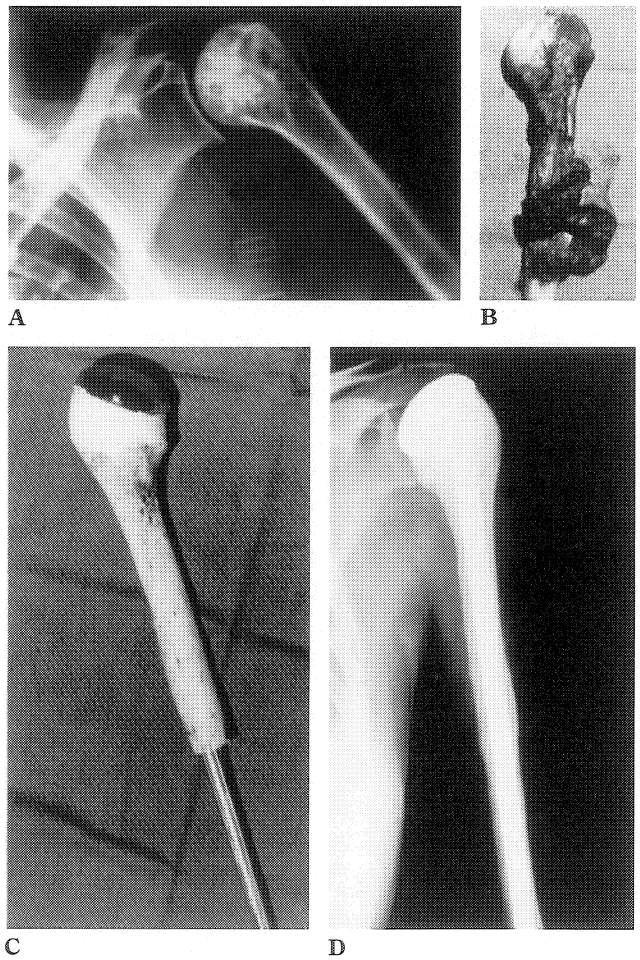

Figure 2 A–D
(A) Preoperative radiographic appearance of a dedifferentiated chondrosarcoma of the proximal humerus in a forty-year-old female.
(B) Surgical specimen after wide resection.
(C) Composite "alloprosthesis" composed of proximal humeral allograft cemented over a long stem Neer prosthesis.
(D) Radiographic appearance four years post-operatively with good bone healing.

radiograph (Fig. 2D) shows healing of the allograft to the distal humerus with no evidence of tumor recurrence.

The Pelvis

Perhaps the most challenging limb sparing procedure for the orthopaedic oncologist is the internal hemipelvectomy for peri-acetabular sarcomas. The classic ablative hemipelvectomy is a mutilating and severely disabling procedure that usually results in a lifetime dependence on two crutches. The most common reconstruction following an internal hemipelvectomy is iliofemoral arthrodesis, which is technically hard to achieve and has problems related to shortening, instability, and weakness.

A new reconstructive technique following the internal hemipelvectomy is the composite alloprosthesis utilizing an autoclaved autograft combined with a conventional cemented total hip implant. An example of this advanced technology is seen in Fig. 3A–D. This twenty-five year old patient presented with a stage II-B osteosarcoma of the ilium illustrated in Fig. 3A. A large intrapelvic mass is seen arising from the ilium and pressing against the sacral promontory. A wide resection was performed following preoperative chemotherapy. The surgical specimen, including cuff of normal muscle, is seen in Fig. 3B. At a separate table, the tumor mass was separated from the hemipelvis and sent to pathology. The skeletal remains were then autoclaved for five minutes to kill residual tumor. The autoclaved specimen was then replaced and fixed with 6.5 mm cancellous screws at the S-I joint and heavy threaded Steinman pins at the pubis. A standard total hip prosthesis was cemented into position as seen in Fig. 3C. The remaining gluteal muscles were closed over the ilium and the patient was allowed early ambulation with crutches and an abduction brace. At two months, she was allowed full weight bearing with a cane for community ambulation. Fig. 3D shows her radiographic appearance at one year. At three years she is still free of tumor and enjoys excellent function.

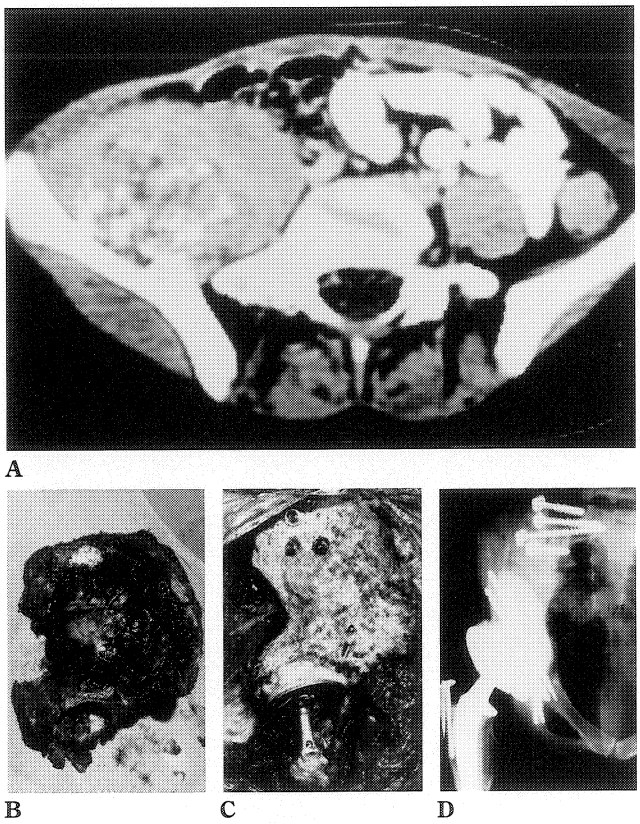

Figure 3 A–D
(A) CT scan of pelvis in a twenty-five-year-old female with osteosarcoma.
(B) Resected specimen resulting from internal hemipelvectomy with wide margins.
(C) Intraoperative appearance after replacement of autoclaved specimen with total hip replacement.
(D) Radiographic appearance one year post-operatively with no tumor recurrence and good pelvic stability.

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CHORDOMA OF THE LUMBAR SPINE: SURGICAL MANAGEMENT

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INTRODUCTION

Chordomas are rare primary neoplasms; left untreated they are uniformly fatal. These tumors arise from vestigial collections of the notochord along the axial skeleton. Chordomas comprise 3–4% of all primary bone tumors, and more than 1000 cases have been reported in the medical literature[2]. Tumor origin occurs in an axial distribution in which 50% arise from the sacrum, 35% from the clivus, and the remaining 15% from the vertebral bodies. Vertebral involvement most commonly occurs within the cervical spine; the lumbar spine is least frequently affected[3,9]. Herndon noted the presence of only twenty-four previously reported cases of chordomas involving the lumbar spine[5].

Clinically, symptom presentation is directly related to tumor location. Tumors in the clivus present with sequelae of increased intracranial pressure, including headache and visual disturbances. Cranial nerve palsies and pituitary dysfunctions have also been reported[3]. Tumors in this location present at an earlier age (thirty to sixty years) due to bony constraints on tumor growth.

Tumors in the sacrum usually present with perianal pain and numbness. As the tumor enlarges and compresses pelvic structures, patients often complain of constipation, urinary frequency and urgency. Due to the relatively large area for tumor growth, patients often do not report symptoms until later in life (forty to seventy years of age). Sacral chordomas can often be detected on digital rectal exam.

Chordomas of the spine arise from the vertebral body and patients can present with vague complaints of back pain. Further growth and local spread can cause vertebral body collapse, as well as compression of the thecal sac and selected nerve roots[3]. This may lead to radicular symptoms of numbness, weakness, and pain. In general, these patients also present earlier than patients with sacral chordomas.

Chordomas can cause lytic radiographic changes secondary to bone destruction. Lysis of the end plates and body substance in addition to disc space narrowing has been described[1]. Sclerotic changes frequently are seen in the periphery of the tumor and occasional complete sclerosis of the vertebral body has been reported[11]. Chordomas are radiologically sclerotic in 64% of cases; the remainder are primarily lytic[4]. Increased radiodensities within the soft tissue are caused by intralesional calcifications. The vertebral body is more likely to be invaded by the tumor than the posterior elements.

Historically, CT with myelography has been considered the diagnostic modality of choice, providing an accurate picture of bony destruction, thecal sac compression, and soft tissue spread[8]. MRI is extremely sensitive in detecting soft tissue spread and tumor recurrence. Bone scans have also been utilized in diagnosis of chordomas, however, they can be normal. Angiography appears to be useful for vertebral artery localization prior to surgical resection in the cervical spine. These tumors are relatively avascular and are not usually embolized.

The histologic and gross features of chordomas are well described in the literature. Grossly, tumor consistency varies from gelatinous to firm with lobulations of grayish tissue. The tumor is usually surrounded by a pseudocapsule; however, extension into surrounding bone and soft tissue can be seen. The tumor has the ability to spread beyond the posterior longitudinal ligament, nerve root sleeves, and paravertebral soft tissues[3].

Histologically, chordomas consist of three cell types separated by fibrous septa. Undifferentiated stellate stromal cells are intermixed with vacuolated cells with intracytoplasmic mucin storage. These vacuolated cells, or physaliferous cells, are intermingled with a third cell type of intermediate size. Nuclear pleomorphism, cellular aplasia, and mitotic figures are not usually characteristic of this tumor, but have been reported[3,9]. These tumors frequently contain areas of cartilage. Thus, the differential diagnosis includes chondrosarcoma, in addition to mucinous adenocarcinoma, ependymoma, and giant cell tumor.

Staging is accomplished by a thorough history and physical examination, followed by a combination of diagnostic

tests including pelvic, abdominal and chest CT scans, and a technitium bone scan (Fig. 1). Chambers and Schwinn[2] found that 3–48% of chordomas metastasize. Their review of seventy patients with metastatic chordomas revealed that metastases were predominately found in the lung (58%), lymph system (33%), liver (22%) and bone (17%). Eight of twenty-seven patients (30%) under their direct care developed metastases.

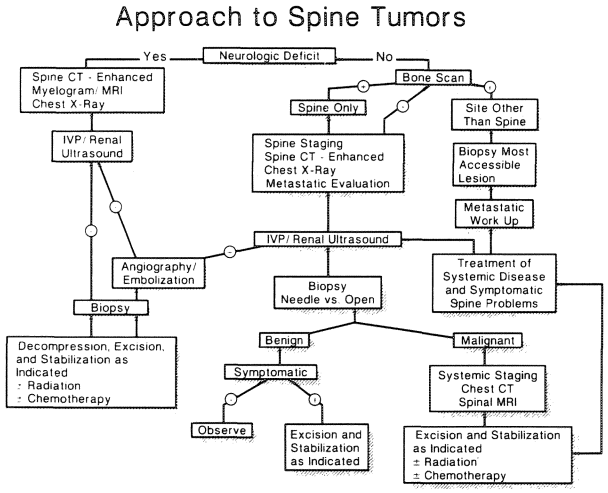


Figure 1
Algorithm for the recommended approach to primary tumors of the spine[16,17].

The prognosis depends on the location and degree of tumor spread. Tumors in the sacrum tend to present later and have a greater potential for metastatic spread. Yet, a sacral location is more amenable to radical surgical resection. Cummings[3] stated that the median survival for cranial and vertebral chordomas is thirty-three to fifty-six months, with seventy-five months being the mean survival with sacral involvement.

This article reviews two cases of lumbar spine chordomas and their treatment. The surgical approach to the lumbar spine will be examined. The anatomic extent of the tumor, and how this relates to subsequent surgical and adjunctive modes of therapy will be reviewed.

Case #1

H.S., a seventy-seven year old white female, initially presented to an outside institution with a five month history of lower back and bilateral thigh pain. She denied bowel or bladder changes, muscle weakness, paresthesias or numbness. Her physical examination was unremarkable. Although her symptoms transiently improved following epidural steroid injections, they quickly recurred with worsening intensity.

Radiographic findings upon subsequent evaluation at the University of Iowa demonstrated a lytic lesion at L2. A technitium bone scan showed increased uptake at this location alone. A CT scan following myelography, in addition to an MRI study (Fig. 2-A), demonstrated vertebral body destruction with thecal sac impingement. A metastatic workup was negative. In the anatomic zoning classification of Weinstein[17], the lesion occupied Zones III A and IV A and B. A fluoroscopic Craig needle biopsy was consistent with chordoma (Fig. 2-B).

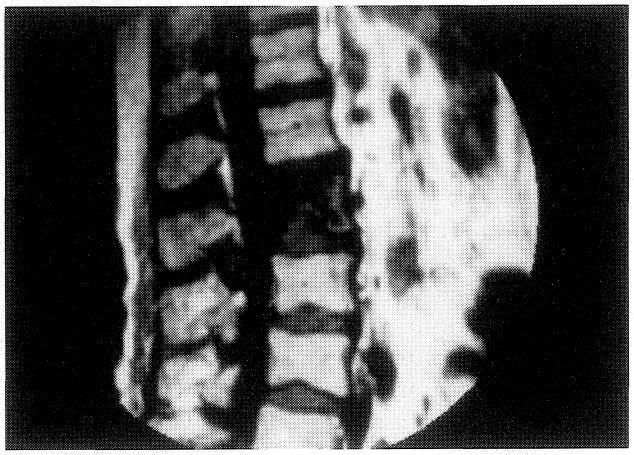


Figure 2-A
MRI (T1 weighted image) of the thoracolumbar spine demonstrating tumor involvement within the L2 vertebral body and spinal canal.

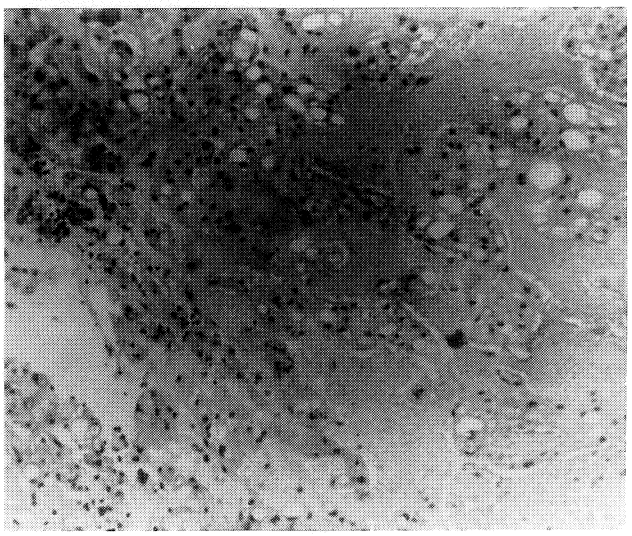


Figure 2-B
Histopathology at L2. This lesion was consistent with chordoma.

Following the diagnostic workup, the patient underwent an L2 partial vertebrectomy through a tenth rib thoracoabdominal approach. The tumor had invaded the epidural space and incompletely penetrated the posterior longitudinal ligament. There was no evidence of nerve root or intrathecal involvement. The spine was stabilized with a Keene compression rod with reversed sacral alar hooks and methylmethacrylate augmentation (Fig. 2-C). The procedure was performed in just under five hours, with an estimated blood loss of approximately one liter. There were no perioperative complications.

Preoperatively, the patient received 900 rads of external radiotherapy. Two months following the surgical procedure, 5,900 additional rads of external radiation therapy was administered.

The patient experienced significant relief of pain immediately following her surgical procedure. External immobilization included the use of a rigid thoraco-lumbar-sacral orthosis for approximately six months. A cane was used to assist in ambulation. Although she redeveloped mild, nonprogressive right lower back, buttock and thigh pain twenty-four months following her surgical procedure, there was no evidence of tumor recurrence based on CT (Fig. 2-D) and technitium bone scan. Thirty-six months post operatively she was functioning well without evidence of tumor recurrence. She takes no pain medication other than occasional use of acetaminophen.

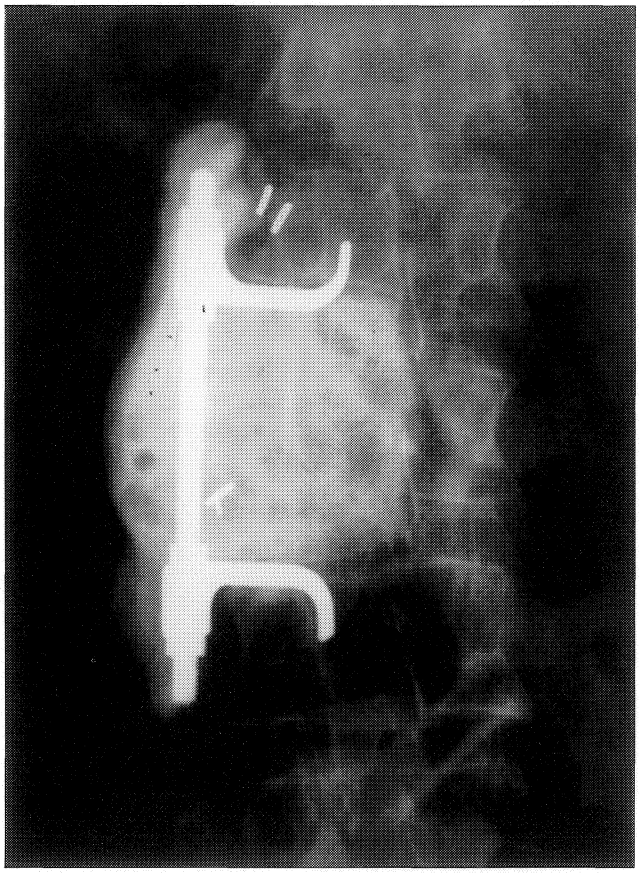


Figure 2-C
Radiograph twenty-four months following an anterior approach and intralesional resection, followed by internal fixation with methylmethacrylate and a Keene compression rod with reversed sacral alar hooks.

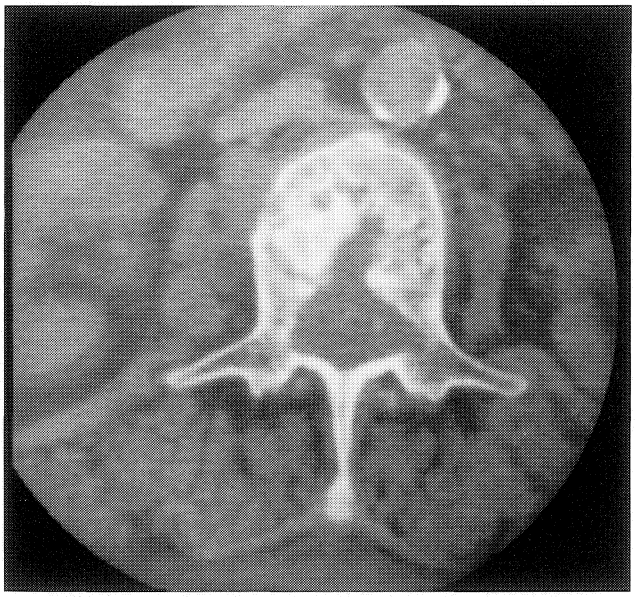


Figure 2-D
CT scan twenty-four months postoperatively without evidence of tumor recurrence.

Case #2

G.S., a fifty-two year old white male, presented with a six month history of progressive bilateral leg pain and back discomfort unresponsive to conservative treatment. Physical examination demonstrated full range of motion of the lumbar spine, no motor or sensory deficits, and bilateral straight leg raises at 60° producing posterior thigh and calf pain.

Radiographs demonstrated a lytic lesion at L3 (Fig. 3-A); a myelogram showed a high grade block at this level (Fig. 3-B). CT and MRI studies (Figs. 3-C and 3-D) revealed a destructive, lytic process involving the entire L3 vertebral body with soft tissue extension into the spinal canal and posterior elements. The metastatic work up was unremarkable. The lesion anatomically involved Zone III A and Zones IV A and B (Weinstein). Needle biopsy of the L3 vertebral body was consistent with a chordoma (Fig. 3-E).

The patient underwent "en bloc" resection of the L3 posterior elements with placement of the Variable Spinal

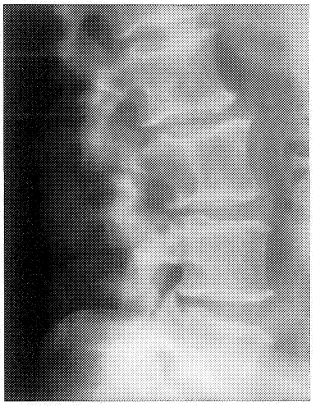


Figure 3-A
Lateral radiograph of the lumbar spine demonstrating a lytic lesion at L3.

Figure 3-B
Myelography showing a high-grade block at the L3-L4 disc space level.

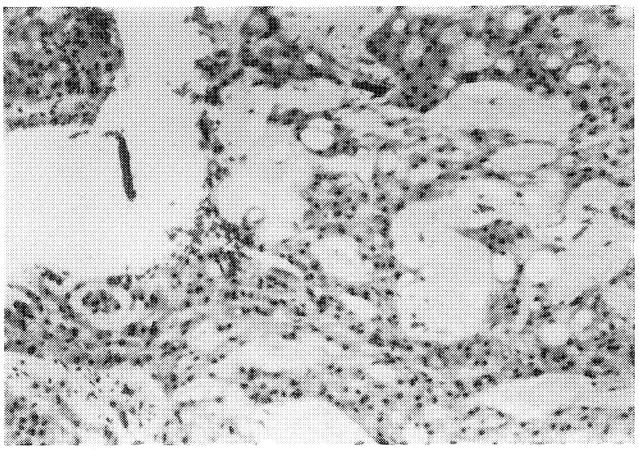


Figure 3-E
Histopathology at L3. This lesion was consistent with chordoma.

Figure 3-C
CT scan through the L3 vertebral level demonstrating tumor within Zones III A and IV A and B.

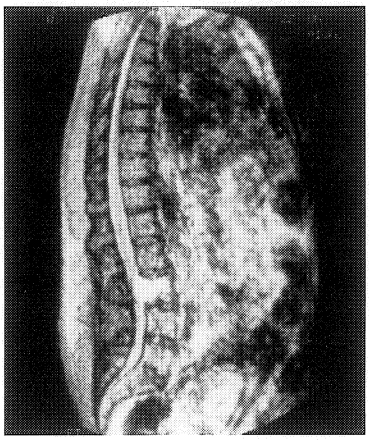
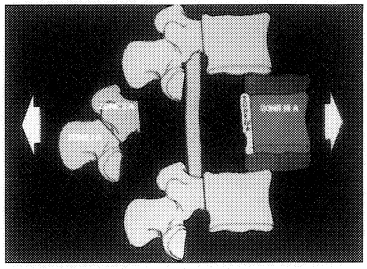


Figure 3-D
MRI (T2 weighted image).

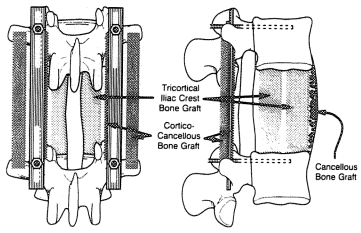
Plate pedicle screw fixation system and posterolateral autogenous graft. Under the same anesthetic, anterior corpectomy and tricorticate iliac crest strut grafting were performed via a retroperitoneal approach (Figs. 4-A and 4-B). Tumor within the epidural space and a portion of the anterior dura was excised. The combined procedure was performed in just over ten hours, with an estimated blood loss of two liters. There were no perioperative complications.

Postoperative external immobilization included use of a thoraco-lumbar-sacral orthosis for one year, with restriction of the patient's activities to sitting at no more than sixty degrees for the first eight weeks.

Thirty-five months after surgery, there was no radiographic or physical examination evidence of tumor recurrence (Fig. 4-C and 4-D). The patient could walk more

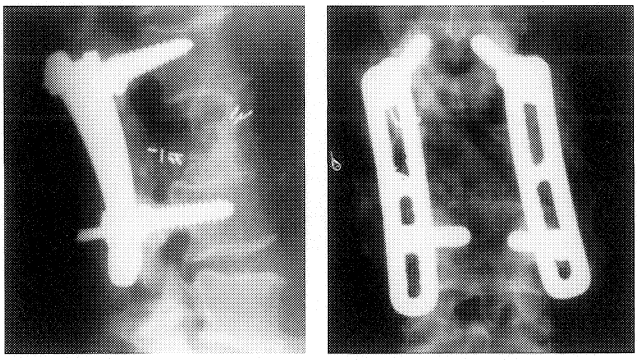


A



B

Figure 4-A and 4-B
Illustrations of the anterior and posterior resection and reconstruction. Instrumentation included use of the Variable Spinal Plating system.



C D

Figure 4-C and 4-D
Lateral and AP radiographs thirty-five months postoperatively without evidence of tumor recurrence. Both anterior and posterior grafts are solidly fused.

than eight blocks without difficulty. He had no back or leg pain, paresthesias, weakness, or bowel or bladder complaints. Physical examination demonstrated no focal deficits or tension signs.

DISCUSSION

Treatment of vertebral chordomas is limited by its location, extent of spread, and the presence of metastases.

Chordomas are relatively resistant to radiotherapy. Although it may be used for palliative treatment of tumor spread, and as an adjunct to surgery, radiotherapy offers no real potential for cure. The use of radiotherapy preoperatively and postoperatively is hypothesized to decrease tumor bulk and eradicate microscopic remnants. When used as an adjunct to surgery, it is recommended that high doses of radiotherapy not be administered in the perioperative period due to the high rate of wound dehiscence and infection. Radiotherapy can rarely increase the aggressiveness of the tumor, as well as promote the development of secondary sarcomatous changes[2].

Due to the relative avascularity of this tumor and the low percentage of clinical responses[3], chemotherapy is infrequently used. Most patients who have received chemotherapy have done so only after surgical decompression and radiation therapy have failed, or after the development of metastases.

Mindell[9] has stated that chordomas involving the vertebral column cannot be cured, and that surgery (i.e., laminectomy) is helpful only in relieving cord, nerve root, and associated soft tissue compression. Decompression, along with radiation therapy (usually in doses greater than 6,000 rads) helps diminish pain and delay the onset of paraplegia. Repeated decompressions with tumor debulkment may be of benefit.

Cummings[3] has stated that complete surgical resection, the treatment of choice for chordomas, is technically feasible only in the sacrococcygeal region, and that only very rarely can the tumor be completely excised in the vertebral region. Sundaresen[15] reported that all of his patients treated with limited tumor resection had evidence of recurrence within two years. Murali[10] suggested that the limiting factor with attempted resection was dissemination of the tumor into the epidural space and along the nerve root sheaths, rather than involvement of the vertebral bodies and intervertebral disc spaces.

Nevertheless, it is evident that the surgical approach to the spine tumor can affect prognosis[7,16,17] (i.e., longevity and quality of life). The most important factor in improving the prognosis and possibly enabling a cure in those afflicted with vertebral chordomas is complete excision. This is true of other primary tumors of the spine, including giant cell tumor[13] and chondrosarcoma.[14]

The anatomic zoning classification of Weinstein[17] aids in delineating the approach and surgical methods required for successful tumor extirpation. The anatomical extent of Zones I to IV are demonstrated in Fig. 5-A, 5-B, and 5-C. Intraosseous lesions are by definition confined within the boundaries of the cortical spine (Zones IA to IVA). Zone IA includes the spinous process, the pars interarticularis and the inferior facet. Zone IIA includes the transverse process, superior articular facet, and the pedicle to its junction with the vertebral body. Zone IIIA includes the anterior three-fourths of the vertebral body; Zone IVA includes the posterior one-fourth of the vertebral body. Zones IB to IVB are the extraosseous extensions beyond the boundaries of cortical bone. Zones IC to IVC constitute regional or distant metastatic involvement.

Surgical outcome, and thus prognosis, is ultimately affected by tumor grade and zones of involvement. Lesions involving Zone IA through IVA can be completely

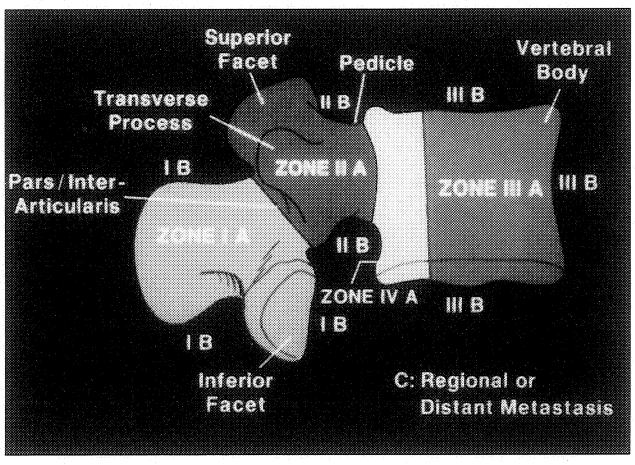


Figure 5-A
Staging of spine tumors by zones. Interosseous lesions (A) are confined within the boundaries of the cortical spine. Extraosseous lesions (B) extend beyond the cortical spine. (C) represents regional or distant metastasis. Lateral view of a lumbar vertebra.

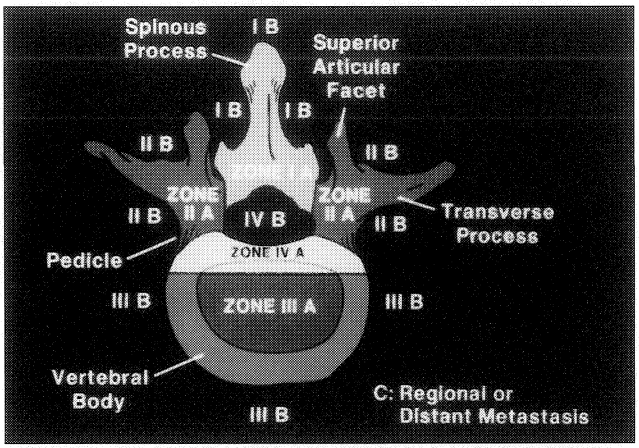


Figure 5-B

Axial view.

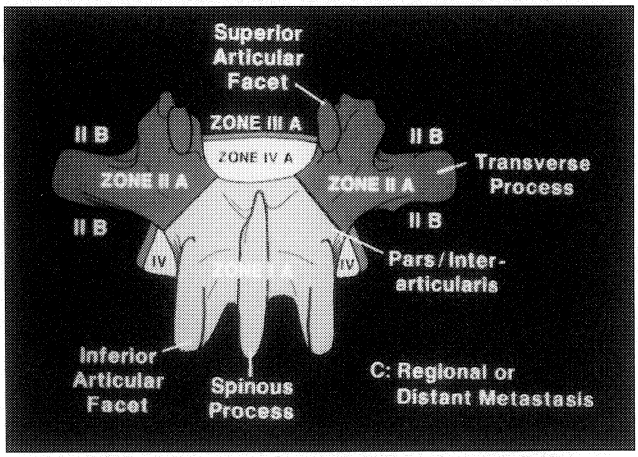


Figure 5-C

Posterior view.

excised through a wide resection. Extraosseous lesions are difficult to resect while retaining adequate surgical margins and neurologic function. Surgery is frequently intralesional.

Although other primary tumors (i.e., osteoblastomas) may exist in only one zone, chordomas most frequently have extraosseous, multiple zone involvement, possibly accounting for the poor historical outcome with surgical treatment.

Isolated lesions involving Zones I and/or II(A,B,C) are best approached posteriorly. Stabilization by posterior instrumentation and autogenous posterolateral grafting is recommended[6]. Bilateral pedicle screw fixation provides rigid posterior stabilization without spanning two or three levels above or below the lesion, as is frequently required with other forms of instrumentation (i.e., Harrington and Luque).

Zone III lesions should be approached anteriorly. Resection and reconstruction with either tricorticate iliac crest graft, rib graft, or methylmethacrylate, with or without the use of internal fixation is recommended. The use of methylmethacrylate vs. autogenous graft is determined by a number of variables including the patient's age, expected longevity, underlying health, expected functional outcome, and the need for postoperative radiotherapy.

Zone IV lesions are the most difficult to approach and reconstruct. Both an anterior and posterior approach with combined stabilization is required for maximizing the probability of obtaining tumor extirpation while maintaining a stable spinal construct.

Following a complete vertebrectomy, posterior instrumentation alone with pedicle screws and autogenous graft provides insufficient stabilization. Under these circumstances, both rigid anterior and posterior stabilization is required.

Case #1 was approached anteriorly, though it was known that the tumor invaded Zones IV A and B (the epidural space), in addition to Zone III A. This single approach was chosen to decrease the potential morbidity of a more extensive surgical procedure. It was felt that the patient would likely succumb to her underlying medical illnesses before becoming incapacitated from tumor recurrence. Although a careful and meticulous intralesional tumor resection was performed, adjunctive radiotherapy was also provided to help eliminate remaining microscopic remnants. Nevertheless, using this single approach over a combined approach decreased the probability of obtaining complete tumor extirpation. Methylmethacrylate achieved immediate spinal stability, allowed for early ambulation, and eliminated the risk of graft incorporation failure following radiotherapy.

Neither case #1 or #2 have been followed long enough (thirty-six and thirty-five months, respectively) to substantiate the presence of cure. However, both have shown no evidence of recurrence. Although there are no direct controls available for comparison, this method of treatment appears to provide for improved long term function and pain control when compared with historical controls[9,15].

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CEMENTED TOTAL HIP ARTHROPLASTY

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The purpose of this paper is to present our outlook on the current state of the art in cemented hip arthroplasty. During the 1970's, cemented total hip arthroplasty was the standard for hip arthroplasty. The two most common prostheses used in the early 1970's were the Charnley prosthesis and the Müller prosthesis, each differing significantly in design. Toward the end of that decade and in the early 1980's, long-term results became available showing variation in total hip revision rates, from 1.5% to 25%.[24,42,43,46] Subsequent observations show that long-term results with the Charnley prosthesis were better than those with the Müller prosthesis. At the turn of the decade, investigational work focused in two different directions; 1) improvement in cementing techniques, and 2) abandonment of cement. Both avenues provided an improvement over the poor results seen with the Müller prosthesis.[21,46] The senior author's favorable experience with the Charnley prosthesis led to investigations in improvement in cementing techniques. While porous ingrowth prostheses have shown remarkable short-term success, these results must be compared to the long-term success achieved with modern cement techniques.

We are extremely satisfied with our long-term results of a cemented femoral prosthesis. Variables affecting long-term results and under some control of the surgeon fall into five categories: 1) Cement physical properties, 2) Stress distribution to cement from the prosthesis, 3) Bone-cement interface : mechanical, 4) Bone-cement interface : biologic, and 5) Load to prosthesis.

1) Cement Physical Properties

Those factors known to affect the strength of the cement include mixing time and technique, pressurization, contamination with blood, laminations, and containment.

Maximal compressive strength is decreased by 10% with rapid beating, by 11% with mixing time greater than two-and-a-half minutes, and by 43% with laminations created by insertion in a "doughy" state.[28] Blood mixed with cement, which can be controlled to some extent with jet lavage and hypotensive agents[28], decreases strength up to 77% in tension. Full containment of cement by bone creates a better bone-cement composite, and improves the cement's strength.

Controversial areas include porosity[1], viscosity[27,34,40] and composition.[31,40] We feel that porosity reduces cement strength. Low viscosity cement has significantly less fracture toughness than plain methylmethacrylate.[40] The choice of ideal viscosity is not at the extremes of high and low, but in our opinion lies somewhere in between. We feel that appropriate intrusion characteristics are obtained with Simplex P cement mixed at 67 degrees for one minute, centrifuged for two minutes, and inserted at approximately six to seven minutes. The cement viscosity at time of insertion is still low enough to prevent laminations yet can be handled and pressurized more easily than lower viscosity cement. The intrusion characteristics of cement that we attempt to obtain will be discussed in the "bone-cement interface: mechanical" section.

Experimental work to improve cement mechanical properties continues[31,40], but at present no clinical data exists with sufficient controls showing superiority of other products over Simplex cement. The goal in manipulating the variables listed above is to create cement with fatigue properties that fall into the indicated range, and to create a prosthesis that generates peak cement stresses in the indicated area[21] (Fig. 1). The next section discusses the design features that decrease cement stresses.

2) Stress Distribution to Cement from the Prosthesis

The factors known to reduce peak stress include: 1) increasing stem length (increasing stem length from 100 mm to 130 mm results in 26% decrease in predicted maximum compressive strength in cement)[9], 2) altering cross-sectional shape to include rounded edges with wide lateral diameter[8], 3) tapering the stem, and 4) bonding of the proximal cement to prosthesis.[12] The prosthesis that

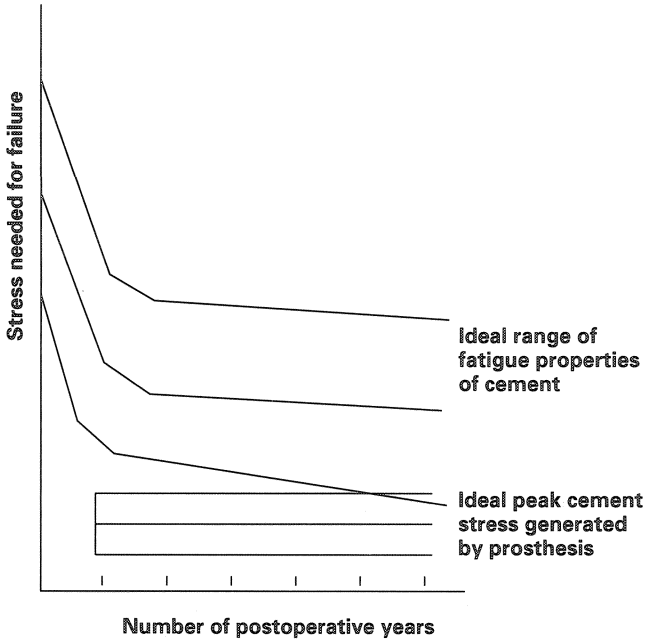

Figure 1

we currently use is a proximally pre-coated, 140 mm length stem with rounded edges and a wide lateral diameter.

Controversial variables include the modulus of elasticity and use of a collar. Controversy regarding the modulus of elasticity centers around the use of cobalt chrome versus titanium prosthesis. Proponents of cobalt chrome prostheses argue that the best way to reduce proximal cement stresses is to distribute the stress distally using a stiffer prosthesis.[10] Supporters of titanium argue that using a less-stiff prosthesis with a collar restores the proximal femur stresses to a more normal level. Maintaining proximal stress retains bone and provides cement containment. Allowing the prosthesis to stress bone through collar contact further decreases proximal cement stress and, in addition, potentially decreases micromotion at the bone-cement interface. Studies indicate that a significant amount of bone resorption must occur to adversely affect the proximal cement stresses.[15] Laboratory[36] and clinical data[26] support the concept of stress transference from collar to bone and the maintenance of bone by this stress. However, collar-bone contact is obtained only 50–75% of the time.[26,47] When achieved, collar contact usually occurs at a few localized areas on the cortical bone leaving a gap between the metal and bone which in the clinical situation would be filled with acrylic extruding beneath the flange.[32] Under the most ideal circumstances, the collar loads a composite of cement and bone. A recent prospective randomized study of collared versus collarless prostheses found that when collar-bone contact was achieved, the femoral neck was maintained, presumably through stress.[26] At five year follow-up, resorption of the femoral neck in the collarless population did not result in a significant increase in loosening rates. In addition, there was no increase in the proximal cement fracture rate for collared versus collarless prostheses. Statistically significant increase in the frequency and thickness of radiolucent lines in the proximal zone for the collarless prosthesis was observed. Whether this increase in proximal radiolucency was secondary to increased micromotion with the collarless prosthesis as predicted in laboratory studies[32] can only be hypothesized.

We use a cobalt chrome prosthesis because we feel the best way to decrease proximal cement stress is through more even stress distribution throughout the cement column obtained with stiffer prosthesis.

3) Bone-Cement Interface : Mechanical

We have seen how two components of the prosthetic-cement-bone composite can be altered to improve the composite. The third category of variables that can be controlled by the surgeon is preparation of the bony bed. We think the best bone-cement interface is achieved by first reaming the intermedullary canal with side-cutting reamers to remove all but the most firm trabecular bone. The rasp is then used to ensure that there will be adequate room for the prosthesis. Minimal rasping is required because aggressive rasping fractures and compresses trabeculae against the side walls. The bone surfaces are then cleaned by lavage, and an epinephrine-soaked tampon is placed in the canal with suction then applied to this tampon. Pressurization and intrusion of the cement are obtained by the use of an injection device, closed cavity technique, and a plug in the canal distally.[35] The viscosity that we have arbitrarily chosen is intermediate, i.e., more towards the "doughy" cement end of the spectrum. The viscosity should be low enough to prevent laminations. Our goal is to obtain 2–3 mm of cement interdigitation into trabeculae.

4) Bone-Cement Interface : Biologic

Many surgeons advocate cementless arthroplasty, citing the adverse biological effects of methylmethacrylate. The two areas that should be addressed are the effect of monomer toxicity, specifically in regard to its effect on leukocyte function, and the macrophage response to cement.[19] These two areas can be modified by the surgeon.

Operating room sterility has evolved along with many other aspects of total hip arthroplasty. Laminar flow, the use of body exhaust systems and preoperative antibiotics have dramatically decreased the infection rate with total hip arthroplasty well below 1%. Therefore, the effect of methylmethacrylate on leukocyte function does not seem to be an important variable.

Macrophage response to a well-fixed, cemented prosthesis is minimal to nonexistent[4,5], as opposed to macrophage response to particulate cement created by a loose total joint replacement. The key to reducing macrophage response is creating a stable construct such that micromotion cannot generate the debris resulting in the macrophage response.

Initial primary necrosis of bone adjacent to cement does occur with cellular damage to a 500 micron depth.[4,5,13] Monomer toxicity, heat of polymerization and surgical trauma all cause damage to bone. While surgical trauma has an obvious role in injuring bone, the evidence is less clear for contribution from heat of polymerization[20,33] and monomer toxicity.[29] Regardless of what caused this initial injury to bone, however, gap healing and remodeling of dead trabeculae proceeds in a fashion similar in cemented and uncemented techniques.[13] Studies now show a process of osteointegration at a microscopic level with well-fixed prostheses.[30] Examination of cemented prostheses obtained from cadavers show osteointegration that would be considered ideal for a custom-designed, uncemented prosthesis.

5) Load to Prosthesis

The next variable under the surgeon's control involves reducing the force transferred to the entire composite. The most important factor affecting hip reaction force is surgical placement of the hip center, ideally medial, inferior and anterior (with medial placement most important).[23] Other variables include activity level and weight. Controversial areas include femoral neck angle and ligamentous constraint. As far as increasing force across the hip joint, weight is a less important variable than activity level. A patient 25% over ideal weight increases hip reaction forces by a proportional amount. Doubling the velocity of gait, however, increases peak hip reaction forces by 50%.[7] If a patient is overweight and quite active, obviously the effects of increased activity multiplies the effect of the increased weight. However, most obese people have a lower daily activity level, and therefore, obesity has not been a contraindication for total hip arthroplasty in our experience.

The femoral component that we are currently using has a 132 degree femoral neck stem angle. Our reasons for selecting this angle are based on our experience with the Charnley prosthesis.[9]

Mechanical analysis of the hip joint has shown that a surgically altered or diseased joint capsule can limit hip motion and increase prosthetic component loading during activity.[11] This evidence suggests that maintaining the hip capsule to reduce total hip component dislocation may restrict joint motion and increase joint contact force. Although we do not advocate that routine total capsulectomy is absolutely essential, the surgeon should be prepared to remove or release part if not all of the capsule should motion be restricted at the end of the procedure.

CLINICAL RESULTS

For many surgeons, the magnitude of failure with inferior cement techniques overshadows the good results with modern cement techniques. This leads in some instances to complete abandonment of cement. The three general areas that merit the most significant consideration when comparing cemented techniques to other forms of fixation are:

1) Primary total hip arthroplasty in the physiologically older patient (greater than sixty years).
2) Total hip arthroplasty in the physiologically younger patient (less than sixty years).
3) Revision of a cemented total hip. This category is divided into two parts.
   a) Prostheses with no cortical defects below the lesser trochanter that can be revised to a short-stem cemented component.
   b) Prostheses with significant bony defects below the lesser trochanter requiring long-stem revision.

PRIMARY TOTAL HIP ARTHROPLASTY IN THE POPULATION PHYSIOLOGICALLY OLDER THAN SIXTY

The ten-year follow-up study of the senior author's experience with the Charnley prosthesis found a 1.5% revision rate and 2.1% femoral component loosening rate.[22,24] Femoral component loosening was defined as radiolucency greater than one mm wide at any point, cement fracture or component migration. By this definition, the rate of femoral loosening was 9%. Ten-year revision rates in other studies (using the Charnley prosthesis) were less than 10%. Using modern cement techniques, there are now two studies available with minimum of five-year follow-up showing less than 2% rate of definite loosening.[17,18,41] The excellent long-term results using the Charnley prosthesis combined with even better short-term results using modern cement techniques provides a very optimistic outlook for the use of cement on the femoral side.

We found a 7.9% incidence of acetabular component loosening, defined by radiolucency about 80–100% of the circumference of cement mass (with some portion of this lucency area wider than two mm) or implant migration.[22,24] Acetabular cement-bone lucency was very common; 61% of the implants had lucency along one-third or more of this interface at ten years. We are in the process

of obtaining longer follow-up on these patients and have no data regarding the long-term consequences of these radiolucent lines. The clinical impression of the senior author is that many of these cases have progressed to loosening requiring revision.

Why these differences in results on the femoral side compared to the acetabular side exist is unknown, but they are probably related to a better quality of cement technique achieved on the femoral side, different trabecular:cortical bone ratio, and vascularity of the bone. These differences have prompted us to explore other forms of fixation on the acetabular side.

TOTAL HIP ARTHROPLASTY IN THE YOUNGER PATIENT

Results reported in the literature of total joint replacement in the younger patient vary considerably. Revision rates range from 8–21%[3,6,14,39] and quality of results seem to be technique-sensitive.[14] One consistent feature, however, is that the results in the younger patient are not as good as the older patient, presumably secondary to their respective activity levels. The results with the cemented acetabulum have not been as good as the results with the cemented femoral component. A wide range in results on the femoral side exists, the best seen with the Charnley prosthesis. A retrospective review of eighty-nine cemented total hip replacements performed in patients under the age of fifty by the senior author, with an average follow-up of 12.7 years, found a 2.4% revision rate for aseptic loosening of the femoral component. 3.6% of the femoral components demonstrated radiographic evidence of definite loosening for a combined femoral component failure rate of 6%.[43] The failure rate on the acetabular side was 21%. These results, however, were obtained with older cement techniques.

REVISION TOTAL HIP ARTHROPLASTY

Results in the literature of revision arthroplasty have been uniformly poor. The mechanical failure rate at minimum two-year follow-up is around 14–15%.[2,37] Progressive radiolucent lines seen in 25–30% at two years[2] are an indicator of a poor prognosis for longevity of the prosthesis. At average follow-up of 8.1 years, the mechanical failure rate increased to 29%.[38] One study, with a mean follow-up of 4.5 years, found that clinically 90% of the patients improved. 43.6% of the patients, however, had probable loosening of the femoral component.[25] In only one of these studies were modern cement techniques utilized.[2] The type of prosthesis used in these studies was not identified.

We reviewed forty-nine hips revised for aseptic loosening with average follow-up of 4.8 years and found the mechanical failure rate (defined by definite or probable radiographic loosening) for the femoral component was approximately 2%.[44] The revision rate for the femoral component was 2%. In all of these patients, modern cement techniques and a modified Charnley prosthesis were used. The patients in this study exhibited the full spectrum of bone quality from minimal to significant cortical defects below the lesser trochanter. As with the other populations of patients we have studied, the acetabulum did poorly with a failure rate of 8% and revision rate of 4%.

With severe cortical defects below the lesser trochanter, cement fixation is less than ideal. In these situations, bone grafting and uncemented total hip arthroplasty to regain bone stock may be advantageous. With minimal cortical defects below the lesser trochanter, proper preparation of the canal can often achieve results similar to primary arthroplasty. In one study, two patients out of sixty-six with good quality bone had mechanical failure of their prostheses.[2] In these patients, a distal cement plug can be used with modern cement techniques and a short-stem prosthesis. We anticipate that long-term results in this category of patients will be better than previously reported results of revision arthroplasty in the literature.

SUMMARY

A wide spectrum of outcomes is observed in cemented total hip arthroplasty. We have concluded from our clinical experience that the long-term results on the acetabular side merit investigation into other forms of fixation. For several reasons, including use of a Charnley or modified Charnley prosthesis, we are extremely satisfied with our results on the femoral side. With use of modern cement techniques, we are optimistic that even better results will be obtained in the future.

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THE WRIST IN PERSPECTIVE

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INTRODUCTION

The last two decades have seen a marked increase in interest in the wrist. The Hunterian lecture of Geoffrey Fisk[6] pointed out the mechanical collapse of the scaphoid fracture, and brought renewed interest in the previous works of Lambrinudi[7] and Destot[3]. A modest synthesis of these ideas resulted in the concept of mechanical instabilities of the wrist based on the Landsmeer's intercalated segment model.[13] Several new terms entered the literature including scapholunate dissociation (SLD) and dorsal intercalated segment instability (DISI).[16] When the opposite term, volar intercalated segment instability (VISI) was introduced, Taleisnik[32] pointed out that this instability pattern was previously described by Navarro[23], who noted a relationship with changes at the lunatotriquetral ligament. This by extension has been described as lunatotriquetral dissociation. It was apparent that the DISI problem occurred most frequently with a scaphoid fracture or a disruption of the scapholunate intrinsic ligament complex, and that a VISI pattern was more apt to be associated with a lunatotriquetral disruption. Additionally, a variety of VISI-type collapse patterns of various degrees of presentation were often noted in patients with a lax ligamentous habitus.[4,5]

A renewed interest in the ligamentous anatomy of the wrist led many, including Taleisnik[30,31,33], Mayfield and Johnson[20], and others[14,18] to review previous descriptions (such as those of Poirier[27]) and equate the function of the ligaments with specific functional problems. This still remains a fertile area for further study.

Interest in biomechanical properties of the wrist was a natural extension of digit biomechanics.[10,12,13,16,17,19,29] This interest was in large part fueled by the desire to understand the seemingly inexorable progression of changes that occur in rheumatoid arthritis. Indeed, it became more apparent that the changes at the wrist affected those in the hand and vice versa. Standards of measurement for the extent of collapse and angulatory changes were described which aided evaluation of deformity.[21,36]

The distal radioulnar joint also drew renewed interest both as a distinct entity with definable problems as well as an aid in understanding the pathomechanics of the radiocarpal joint.[10,12,25]

Increased activity in attempting to understand the problems at the wrist led to numerous attempts to classify the problems. It is safe to say that no universally acceptable classification has yet been proposed.[5,33] While it was rather easy to recognize more advanced static features of wrist disorganization on standard x-rays, subtle features, especially those enhanced by increased compressive forces within the joint, require special techniques. Static and dynamic carpal instabilities, distinctions that present a more subtle spectrum for our inspection, have now been described using these techniques.

Rather than presenting a comprehensive review of the clinical problems, this paper examines the anatomic and biomechanical factors involved in several regions of the wrist from a pathophysiologic perspective.

STABILITY OF THE WRIST

The stability of the wrist may be viewed in the context of an unstable proximal carpal row in which the scaphoid induces flexion and the triquetrum induces extension. This provides torsion in opposite direction to the three linked bones.[10] (Fig. 1) Stability may also be viewed in Navarro's concept[23,33] of a three-column structure in which the central column of lunate and distal row is the highly unstable flexion-extension column. The radial column is the support column which is represented by the scaphoid. The ulnar column, consisting of the triquetrum articulating with the distal row, is the rotation column as it is in a direct line with the axis of rotation of the forearm.

THE RADIAL WRIST

The scaphoid sits with its proximal pole as an extension of the lunate contour in the radiocarpal joint and its distal pole anteriorly transposed to complete the mid-carpal joint. It has been likened to a rocker arm balanced over the radiocapitate ligament, compelled to flex when compressed from either end as in radial deviation or wrist flexion. In so doing it carries the lunate into flexion by pulling on the dorsal leash that binds them. The capitate, pulled by the scaphocapitate ligament and pushed

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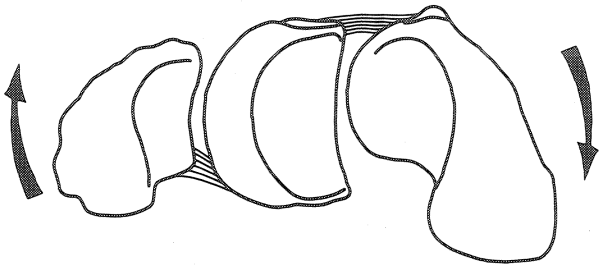

Figure 1
The scaphoid induces palmar torsion of the lunate, the triquetrum induces dorsal torsion of the lunate.

palmarward by the concavity of the lunate (as if emptying its contents), describes a modest volar translation and pronation. During ulnar deviation and extension the scaphoid is lifted at its distal end and extends. Fibers in the scapholunate ligament running in an opposite direction have less influence on the lunate which instead responds to the torsion supplied by the extending triquetrum. This flexion of the proximal carpal row with radial deviation and extension with ulnar deviation may be thought of as a conjunct, or out-of-plane, rotation to the primary motion in the coronal plane. (Fig. 2A–C)

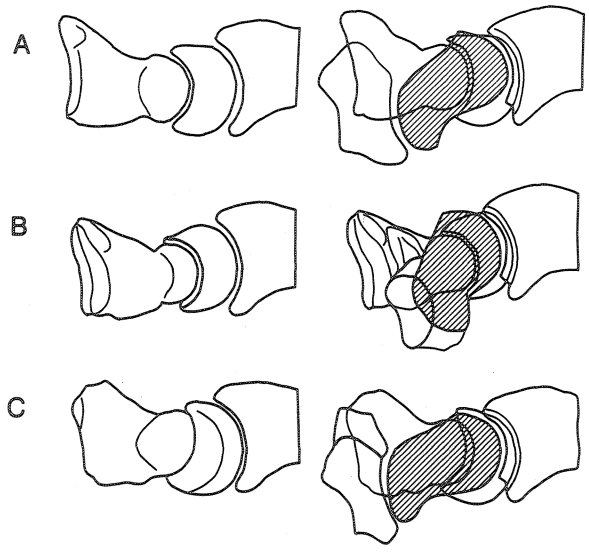

Figure 2A–C
Conjunct rotation of the proximal carpal row during radioulnar deviation.
(A) The radiolunatocapitate axes are approximately colinear in the neutral position of the wrist.
(B) During radial deviation the scaphoid is compressed between the radius and trapezium compelling it to flex. The dorsal radiolunate ligament pulls the lunate with it into flexion.
(C) During ulnar deviation the extension torsion supplied by the triquetrum extends the lunate through the lunatotriquetral ligament as the influence of the scaphoid is withdrawn by the distraction occurring in the radial aspect of the wrist.

When the scapholunate linkage is impaired a profound change in this kinematic behavior may develop. There are three conditions commonly seen on the radial aspect of the wrist that exhibit deformities associated with the loss of scapholunate orchestration. These are: scapholunate dissociation (SLD), scaphoid fractures, and scaphotrapeziotrapezoidal degenerative joint disease (STT DJD). (Fig. 3A–C) These share a collapse deformity associated with an extension of the lunate that often becomes slowly progressive and fixed with time. This angulation of the lunate relative to the longitudinal axis of the radius and capitate has been defined as a dorsiflexed intercalated segment instability or DISI. The proximal row may be considered an intercalated segment, as it has no active muscular controls and its stability depends on its articular contours and the ligamentous inclusions of the capsule that bind it proximally and distally.

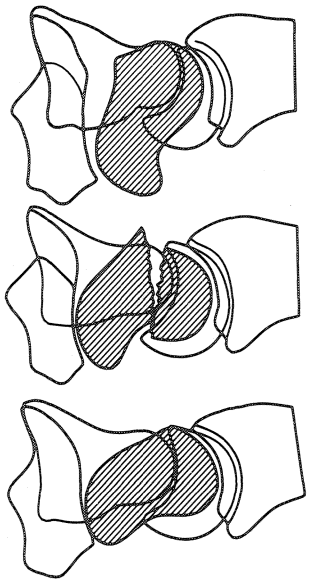

Figure 3A–C
Radial wrist instability.
(A) Scapholunate instability.
(B) Scaphoid nonunion.
(C) STT DJD. All three conditions result in a DISI deformity.

In SLD the scaphoid, freed of its ligamentous constraints from the lunate, is acted upon by a force couple at either pole. This tends to rotate the scaphoid into flexion over the radiocapitate ligament which lies under the scaphoid waist while the lunate dorsiflexes. The angle between the longitudinal axis of the two bones in the sagittal plane increases from a normal 45 degrees to greater than 70 degrees. The lunate, freed from the scaphoid, extends and slides on the inclined plane of the radius as the capitate intrudes between them. The normal conjunct motions of the proximal carpal row are either prevented or are converted from the smooth accommodation to the changing radioulnar deviation to an abrupt reversal of inclination at some place during this arc of motion.

Nonunion of scaphoid fractures, particularly in the waist, presents a similar finding except that the proximal pole of the scaphoid follows the lunate and angulation occurs through the fracture. This mechanical distortion of the scaphoid fragments is a major factor in the development of nonunion, as a dorsal and radial gap occurs which prevents sufficient coaption of the fracture fragments to allow healing. In some instances, the distal fragment is carried dorsally by the capitate which is displaced with the extended lunate. This malalignment also accounts for some of the poor late results which are now commonly recognized as malunions. The malunited scaphoid is best recognized with polyaxial tomograms or computer-enhanced imagery. Three-dimensional modeling of such problems may be considered obligatory before reconstruction.

STT DJD at the distal scaphoid results in a loss of functional length. The joint compressive force distally is decreased and the dynamic stability from the radial column of bone is less effective in preventing lunate extension. The distal pole slides dorsally on the trapezio-trapezoidal articular surface. One result of this translation is a narrowing of the entrance to the carpal canal as the insertion of the flexor retinaculum is carried posteriorly. This provides a mechanical etiology for carpal tunnel syndrome.

These three conditions have in common a loss of support of the radial aspect of the wrist.

THE CENTRAL WRIST

The central column of the wrist is inherently unstable and entirely dependent on the radial and ulnar columns to prevent its collapse under compressive stress as an intercalated segment. The stability imposed upon the central column from the side is dynamic. The radial influence of the scaphoid favors flexion and the ulnar influence of the triquetrum favors extension.

THE ULNAR WRIST

The ulnar aspect of the wrist has somewhat analogous problems to the radial side. Disruption of the linkage between the lunate and triquetrum also results in kinematic and static aberrations.[28,35] The easiest recognizable abnormality is lunatotriquetral dissociation (LTD) in which attenuation of the intrinsic lunatotriquetral ligament results in VISI. This may be recognizable clinically by a "shovel-shaped" deformity of the wrist and radiologically by static flexion of the lunate between the radius and capitate. Although scaphoid angulation is more easy to recognize, the triquetrum also angulates relative to the lunate. (Fig. 4A–B) This angular change into extension may be up to 30 degrees. The triquetrum also may proximally migrate, breaking the smooth arc provided by the proximal row on the PA radiograph. More precise three-dimensional techniques in the laboratory suggest the triquetrum supinates relative to the lunate. The kinematic behavior may also exhibit an abrupt change in lunate angulation as the wrist approaches full ulnar deviation. (Fig. 5A–B)

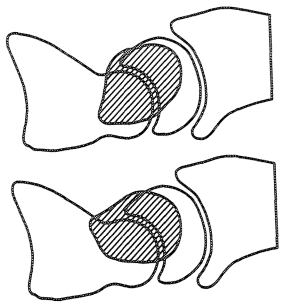

Figure 4A–B
Ulnar wrist instability.
(A) VISI deformity in which the lunatotriquetral angle is normal.
(B) Lunotriquetral dissociation with reversed angle of the lunate and triquetrum.

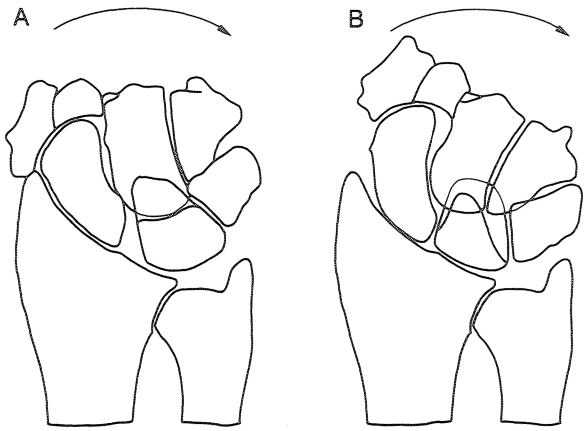

Figure 5A–B
(A) The "catch up clunk" occurs when the radially deviated wrist position is reversed and work must be done to force the lunate up the inclined plane. The space between the scaphoid and lunate is opened as the scaphoid is distracted.
(B) When the force is sufficient to overcome the resistance to the lunate it snaps into extension as well as radially often producing an uncomfortable sensation.

This same deformity and response may be seen without disruption of the lunatotriquetral ligament in some individuals susceptible to sudden or repetitious strains as a result of lax ligamentous habitus. This group of instabilities has been called mid-carpal instability, ulnar column instability or capitolunate instability.[4,5,9,19] To distinguish this problem from those deformities due to dissociation of the interosseous membranes on either aspect of the lunate, the term carpal instability nondissociative (CIND) has been suggested.[4] This is usually determined by failure to demonstrate carpal instability dissociative (CID) by arthrography, arthroscopy or surgical exploration. Its

presence, however, may often be suspected due to its occurrence in younger women and individuals with lax joints. Because the predominant presentation is a VISI pattern, there is often also a prominent ulnar head, particularly apparent with the wrist pronated. This frequently indicated a relative supination of the carpus to the radioulnar joint and occasionally a concomitant dorsal radioulnar subluxation.

The exact role of the palmar extrinsic ligaments in this condition is not understood. Certainly the problem is more common in those patients with lax ligamentous habitus or after minor wrist injury. Both the proximal and distal arcades of ligamentous fibers intersect on the triquetrum before continuing to the ulnocarpal origins. Attenuation of the triquetrocapitate and triquetrohamate portions of the distal arcade may allow the sag of intercarpal joint into the VISI stance.[14] Indeed, a modest VISI stance is normal and represents the rest position of least potential energy in the majority of people. This stance, however, becomes abnormal and symptomatic when its blocks the usual kinematic movements of functional use. Occasionally a fracture of the volar lip of the lunate associated with a subluxation of the capitate suggests the importance of the volar ligamentous integrity more clearly.[1] This finding is difficult to appreciate on conventional radiographs.

Recently, some aspects of this problem have been considered in association with the morphology of the radius and ulna. Under the image intensifier, the sudden change in angulation of the lunate during radioulnar deviation may be preceded by a hesitation of the translation of the lunate up the slope of the lunate fossa during radial deviation. A sudden release occurs with radial translation and simultaneous flexion of the lunate. This has been described as a "catch up clunk"[4], and along with other observations, suggests attention to radioulnar geometry is important in understanding wrist pathology.

RADIOULNAR MORPHOLOGY

The influence of the contours and lengths of the forearm bones relative to one another on wrist pathomechanics was first suggested by Hultén,[8] who noted a correlation of the incidence of Kienböck's disease[11] and a condition that has come to be known as ulna minus variant. This represents, by modern definition, an ulna that is shorter than the radius when measured by perpendiculars to the longitudinal axis of the forearm to the pole of the ulna and the cortical concavity of the lunate fossa on a PA radiograph.[26] The joint compressive force at the ulna neutral position distributes this force as 80 percent to the radius and 20 percent to the ulna.[25] With an ulna minus variant, the load on the ulnar head rapidly diminishes to zero, and conversely it accepts an increasing percentage of load with an ulna positive variant. As might be suspected, the triangular fibrocartilage (TFC) thickness varies inversely to ulnar length.[26]

The implications of these variables has surprisingly attracted little notice until recently. The association of Kienböck's disease with ulna minus variance suggests that the abrupt change in articular compliance between the lunate fossa and the TFC may not only represent uneven stress concentration in the static mode, but may also predispose the bone fracture or arterial damage during a dynamic wrist loading or deflection.[24] SLD is statistically associated with an ulna minus variant.[2] Scaphoid fracture, perilunate dislocation (PLD), some patterns of distal radius fractures, and wrist sprains may also be influenced by ulnar variance.

An ulna plus variance is now implicated in the ulnocarpal impingement syndrome.[28] This problem, originally noted in older individuals, is associated with a central defect in the TFC, an erosion on the ulnodorsal aspect of the lunate and a "kissing defect" on the pole of the ulna.[22] Sclerotic cortical changes and subcortical trabecular cystic changes are often noted on radiographs.[12] These degenerative changes with aging are predictable. Symptomatic ulnar compression syndromes in adolescents and young adults, particularly females, have been recognized in the last decade. This may be due to increased emphasis on more strenuous recreational activities. Czitrom, et al[2] frequently found a tear of the lunatotriquetral interosseous membrane with ulna plus or neutral variance in young patients with evidence of an ulnar impaction syndrome. Lunatotriquetral tears in this group seldom progress to the LTD pattern of VISI deformity and disruption of the proximal arc.

The slope of the radial articular surface may also play a significant role in the adaptation of the joint both to repetitive strenuous use and injury. The radial slope is the angle created by a line drawn from the tip of the styloid to the ulnar rim of the lunate fossa, and a line drawn perpendicular to the longitudinal axis of the radius. (Fig. 6A) This angle may, however, be less accurate in estimating the translatory forces acting on the carpus than the tangent to the lunate fossa. The former averages about 25 degrees and the latter 14 degrees. (Fig. 6B) The sine of 14 degrees is 0.28, suggesting that normally slightly over 25 percent of the intrinsic forces acting across the wrist induce an ulnar translatory component. If the slope increases to 30 degrees, as is occasionally seen, 50 percent of the acting force is translatory (Fig. 6C), which under normal circumstances is resisted by the radiocarpal ligaments. When the lunate fossa presents a nearly horizontal slope, the translatory force component is markedly reduced, and the joint is inherently more stable. An ulna minus variant and

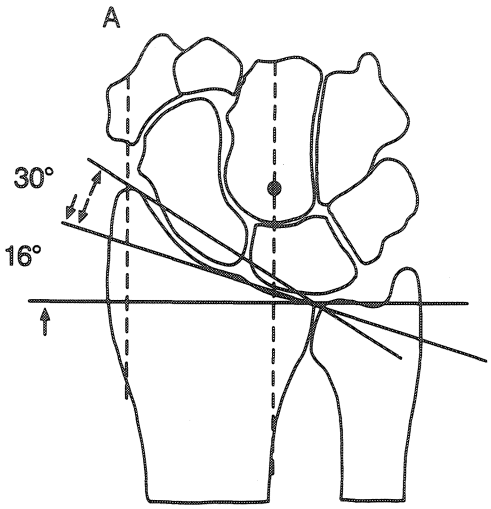

Figure 6A
Radioulnar morphology and its effect on radiocarpal stability. (A) The tangent to the lunate fossa is 16 degrees. The translatory component is 0.28. The ulnar variance is neutral.

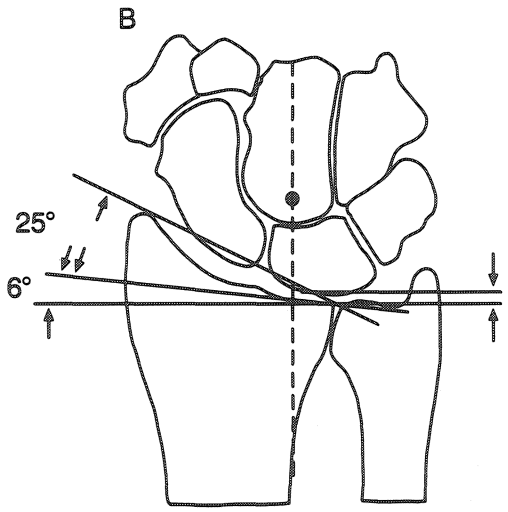

Figure 6B
The tangent to the lunate fossa is 6 degrees, and there is an ulnar plus variance. There is a minimal ulnar translatory component to the joint compressive force.

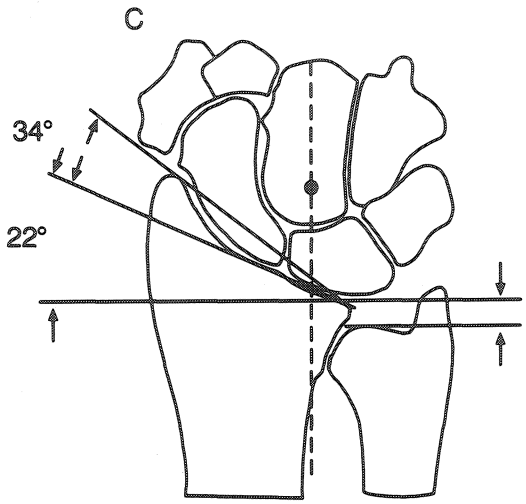

Figure 6C
The tangent to the lunate fossa is 22 degrees. The translatory component is half of the joint compressive force. The ulnar minus variance provides no significant support. The radiocarpal ligament must resist displacement.

an increased radial slope place marked reliance on the ligamentous structures for stability when compared with an ulna neutral variant and minimal radial slope.

The clinical implications may be seen in a number of examples, rheumatoid arthritis perhaps being the most graphic.[15] Progressive ulnar translation of the proximal row and progressive radial angulation appears to be accentuated in rheumatoid arthritis. This ulnar displacement acts on the volar aspect of the ulnar head, forcing it dorsally, further reducing support to the sliding carpus. Eventually, the lunate may slide completely off the lunate fossa, eroding the volar rim and increasing the stress concentration on the proximal scaphoid. By contrast, the more stable morphology, while it may not alleviate the rheumatoid destructive processes, is less likely to be associated with dorsal subluxation of the ulnar head and ulnar carpal displacement.

The "catch up clunk" mentioned earlier is more apt to occur in a group of patients who demonstrate an increased radial slope and ulna minus variance. The muscles of the wrist must do extra work to push the lunate up the increased slope. If the radiocarpal ligaments have stretched, even slightly, this ulnar displacement may then induce the unstable kinematic behavior.

A somewhat more obvious example of "slope instability" is provided by the malalignment of the radial articular surface into dorsal angulation as a residual of Colles' fracture.[5,34] The lunate tends to displace dorsally, and extend producing a DISI deformity. Fixed in dorsal displacement by the joint reactive force, the lunate cannot volarly translate to accomplish its normal conjunct trajectory into flexion as the wrist radially deviates.

CONCLUSION

The complex interrelationships of the wrist, when altered by disease or injury, provide a variety of intriguing problems for the orthopedist. Certain patterns are now commonly recognized, but ever more subtle problems seem to appear each time a solution is at hand. The proximal carpal row, inherently unstable under compression, is dependent on a dynamic torsion exerted in opposite directions from the scaphoid and lunate to maintain a balanced

stance. Disruption of a support strut by fracture or ligamentous attenuation readily alters this stance and often leads to kinematic abnormalities. Morphologic abnormalities or changes in the radioulnar lengths or contours may have similar predictable effects. Recognition of these variations has significantly altered our approaches to prevention and treatment. Advances in biomechanical understanding, improved imaging techniques, and clinical recognition promise to markedly enhance our perspective in the 1990's.

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SCREENING PROGRAMS IN ORTHOPAEDICS

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Orthopaedic surgeons have become acquainted with the special area of screening through programs to detect scoliosis and congenital dislocation of the hip (CDH). These programs, initiated by well-intentioned physicians in an effort to prevent late end-stage disease, have had varied acceptance in the United States.

Scoliosis school screening is now wide-spread, well-organized, legislated in over twenty states, and attracts a large number of volunteers every year. On the other hand, screening in the neonatal nursery for CDH is rarely conducted through an organized program by experts but rather is left to the individual physicians responsible for the child's care. In other countries, such as Great Britain, organized screening for CDH is far more common and scoliosis screening has not been instituted as a matter of public health policy.

Orthopaedic surgeons and other physicians need to be concerned about screening programs because of several factors which are more prevalent today than in past decades. First, the rising cost of health care makes screening attractive. On the one hand it implies that disease will be found earlier and costs will be saved in treatment; on the other hand, screening programs can be very expensive and will not be of value unless their benefit is shown.

Second, legislators and administrators are now making more and more decisions on health policy, often without the direct input of physicians. Part of this is due to the increased economic emphasis on the delivery of health care.

Third, increased public interest in health has spurred the acceptance of screening programs. These are often misinterpreted as health care, rather than screening programs, and are perceived as good by the public, legislators, and administrators.

Fourth, physicians should recognize that the pinnacle of their art is "prevention". Screening represents a form of secondary prevention; the prevention of disease before it reaches a symptomatic and easily diagnosed state.

Screening has been defined by the Commission on Chronic Illness as: "The presumptive identification of unrecognized disease or defects by the application of tests, examinations, or other procedures which can be applied rapidly. Screening tests sort out apparently well persons who probably do not have a disease from those who probably do have the disease. A screening test is not intended to be diagnostic. Persons with suspicious findings must be referred to their physicians for diagnosis and necessary treatment."[7]

There are important points to note in the definition of screening. First, screening does not stand by itself but implies diagnosis and treatment. Second, the test or tests assumes a central role in the program.

Three types of screening exist. The first is used in research as a pilot project for surveillance. A current example is the CDC's desire to draw blood on certain populations to determine the actual incidence of HIV infection. The second involves protection of public health, especially when dealing with communicable diseases. An example of this is screening for tuberculosis to prevent its spread. The third, called "prescriptive screening", contributes to the health of the individuals who are brought to the screening program. Scoliosis school screening and screening in the nursery for CDH fall into this latter category.

Certain problems have been recognized in screening programs for the last several decades, crossing all specialty lines and all screening programs.[10] First is failure to coordinate the final diagnosis and treatment. Screening by itself will not be of value unless diagnosis and treatment are both available and given. Many screening programs fail to provide these two essential ingredients or ensure that those screened as positive receive diagnosis and treatment. Second, initial training of screening personnel is often inadequate. Monitoring the performance of those in the field who are screening and of the tests being used adds additional burdens in terms of cost and personnel, but is essential to ensure quality in on-going screening programs. Third is use of unreliable tests. Those screened as false positives often undergo unnecessary diagnoses and treatment. Those screened as false negatives will have the disease but will be told that they do not. The validity of a test must be established prior to its use in a screening program. Finally, use of professional personnel increases costs of such programs. In addition, the professionals often derive secondary gain as patients are directed for diagnosis and treatment.

A successful screening program must meet certain criteria. A look of each of these criteria with respect to scoliosis school screening and CDH screening is an appropriate way to evaluate the current status of these programs.

THE DISEASE SHOULD BE AN IMPORTANT HEALTH PROBLEM

The condition being screened for should have importance to the community in terms of morbidity and mortality costs as well as personal suffering.

Whether or not scoliosis is an important disease in the community depends on its definition. The Scoliosis Research Society defines scoliosis as a curvature of 10 degrees or greater. However, most scoliosis does not result in morbidity or mortality until the curvature exceeds 40 degrees. Therefore, it would appear that scoliosis greater than 40 degrees should be defined as an important health problem but lesser degrees of scoliosis and non-progressive scoliosis are not important.

A large portion of adult osteoarthritis results from congenital hip disease. Screening for CDH in the nursery does not screen for a large portion of that disease that leads to osteoarthritis, i.e., acetabular dysplasia, and minor abnormalities of hip development.

THE FACILITIES FOR DIAGNOSIS AND TREATMENT SHOULD BE AVAILABLE

Facilities are readily available in this country, although access may be a problem.

THERE SHOULD BE AN EFFECTIVE TREATMENT FOR THE CONDITION BEING SCREENED

The American Cancer Society recently abandoned screening for lung cancer because the survival rate was not generally affected by the earlier diagnosis afforded by screening. Until an effective treatment for lung cancer in its early stages is available, there is little point in screening for it.

Controversy exists concerning the efficacy of scoliosis bracing. All previous studies on bracing fail to account for the natural history of scoliosis. Many cases of scoliosis may not progress with or without bracing.[6,8,14] However recent evidence suggests that the brace will improve the natural history of progressive idiopathic scoliosis by about 50%.[11]

The Pavlik harness or some form of abduction bracing is felt to be very effective in dislocated hips. However, a recent study of 100 patients treated with a Pavlik harness showed that of sixty-two patients who had true dislocated hips, only two-thirds achieved stability of the hip without some other form of treatment, such as closed reduction and casting.[19] Nevertheless, the Pavlik harness is more effective than the natural history, in which about one-half of the patients will achieve stability spontaneously.

THE TEST SHOULD BE ACCEPTABLE TO THOSE BEING SCREENED

Both the Adams forward bend test for scoliosis and the Ortolani and Barlow test for CDH are acceptable to patients and parents. Radiographic screening is unacceptable.

THE NATURAL HISTORY OF THE CONDITION SHOULD BE UNDERSTOOD

This is the single most important consideration that should be given to a disease before it is screened. If the early natural history of the disease is unknown, it will be difficult to recommend treatment. For example, overtreatment with attendant costs and complications may be advised for patients not requiring treatment.

Scoliosis was once thought to be progressive as all children with curves greater than 20 degrees were braced.[4] However, over the past fifteen to twenty years, it has become apparent that many curves will not progress. Rogala et al, in 1978, demonstrated that 21% of immature curves between 20 and 30 degrees showed no progression over a two-year period.[15] Lonstein and Carlson have recently developed more information based on the state of skeletal maturity and curve magnitude.[13] These data give better guidelines for treatment. However, in the patient typically found in school screening with a curve between 5 and 19 degrees with a Risser sign of 0 to 1, there is only 22.2% chance of progression. Inability to identify progressive curves makes it impossible for the treating physician to accurately prescribe treatment.

The natural history of CDH was first described by Barlow.[2] He observed that 58% of unstable hips stabilized spontaneously by one week of age. Does the normal hip (by exam) develop normally? That question has not been answered by the natural history studies, so it remains a matter of debate whether or not all hips which are noted to be unstable at birth should be treated.

THERE SHOULD BE A RECOGNIZABLE LATENT STAGE THAT PROVIDES A LONG LEAD TIME

The longer the lead time, that is, the preclinical state of the disease, the more likely it is that the disease will be detected. A longer lead time allows for more infrequent testing. Diseases with long lead times often remain asymptomatic.

In idiopathic scoliosis, the lead time is long. Progression occurs at approximately one degree per month during

adolescence. Therefore, infrequent screening (e.g., annually) can be done.

In established CDH, the lead time is short as most dislocations will become established between three and six months. The Ortolani and Barlow tests become relatively unreliable after three months, after which limited abduction becomes more accurate. If these two tests fail in the first three months, the disorder will probably not be diagnosed in a "pre-clinical" or asymptomatic stage. Therefore, more frequent and extensive screening is required.

THE TESTS SHOULD DIFFERENTIATE DISEASED FROM BORDERLINE FROM NON-DISEASED

In all clinical measurements, there will be overlap between normal and abnormal values. Definition of the disease and its parameters must be established prior to screening. In screening for hypertension, for example, what are the parameters that will determine hypertension? Are they age-dependent?

There are no reports which validate the forward bending test in the detection of scoliosis. One experiment in which doctors and nurses were trained to examine for scoliosis showed the false positive rate to be 60% and the false negative rate to be 23%.[20] A prominent right rib cage may be a normal variant in some patients.[5] In addition, it has been well-demonstrated that there is no relationship between rib hump and lateral curve of the spine.[17] Therefore, the accuracy of this test to discriminate between those with or without scoliosis is limited.

No data exists on the reproducibility, sensitivity, or specificity of the Ortolani and Barlow tests. Detection of neonatal instability varies in some series from 2.6 per 1,000 to 30.9 per 1,000. These differences are not due to geographical variations or the age at time of exam.[9,21]

THE CONDITION SHOULD BE RELATIVELY PREVALENT

Prevalence affects the yield. If the condition is quite rare, few cases will be found in the population screened. Therefore, it will be more costly to screen out each individual case. Prevalence will, of course, depend on the definition of the disease.

Prevalence has an enormous effect on test validity. Most screening tests have a low yield, and even including innate error in the test, the number of normals incorrectly diagnosed may exceed the number actually diagnosed correctly.

The incidence of scoliosis as defined by the Scoliosis Research Society (greater than ten degrees) is 1.4% of the general population greater than fourteen years of age. However, in curves greater than 30 degrees, the incidence falls to 0.2%.[16]

The incidence of CDH is low. Values range from 0.1 per 1,000 to 2 per 1,000.[3,18] However, this does not include all neonatal hip pathology, only detectable instability or established dislocations.

SCREENING SHOULD NOT HARM THE INDIVIDUAL BEING SCREENED

Screening differs from conventional diagnosis and treatment, in which the patient seeks the doctor and the doctor agrees to help the patient to the best of his or her knowledge and the resources available. This is the physician/patient contract. However, when the physician brings the patient into the healthcare system, he or she takes on a new obligation. Two presumptions exist in a screening situation: first that the situation will be identified, and second that those who are affected and correctly identified will benefit.[22]

Scoliosis screening has certain problems which may harm patients. First of all, many children are diagnosed with scoliosis who will have no significant problems from this disorder. This is true in the majority of patients whose curve never progresses beyond 30 degrees. However, these patients will suffer discrimination in obtaining employment and medical insurance coverage. In addition, it is well recognized that physicians both over-diagnose and over-treat. Even in the best of hands a significant number of children with non-progressive curves receive treatment. This is due to a lack of knowledge of the natural history. On the other hand, a false negative report gives a patient an unjustified sense of confidence and may delay accurate diagnosis.

In treating CDH, there have been reports of complications such as avascular necrosis in the opposite hip due to splinting in the neonatal period. However, in general this is a much more benign treatment than bracing for scoliosis with fewer complications and far less cost.

THE COST OF SCREENING, DIAGNOSIS, AND TREATMENT SHOULD BE REASONABLE WHEN COMPARED TO THE COST OF TREATMENT AT THE USUAL TIME OF DIAGNOSIS

The cost of screening usually includes a training program for the nurses, recording of data, and the actual screening programs which are done on a volunteer basis.[12] However, most of these programs lack significant monitoring, training, and retraining. Also, follow-up of all patients who are screened is rarely done. These factors would add significant additional costs, if included in the program.

Of far more significance, however, are the costs of diagnosis and treatment which are seldom included in a calculation of screening costs. In the case of scoliosis, costs of

referral to the family doctor and orthopaedic surgeon, the necessary radiographs, at time that the parent takes off from work, and any treatment that is prescribed must be included.

Given that approximately 3.4% of all patients screened are referred[12] and that approximately 0.27% of those screened need treatment,[15] it is apparent that both the false positive referral rate and the costs incurred are very great.

The costs of screening for CDH are probably less, given that radiographs are not required and treatment, if prescribed, is less expensive. However, treating all hip clicks results in an unnecessary increase in costs.

Screening programs, once instituted, are difficult to eliminate. Some are even legislated. They are perceived as health care by the community. It is, therefore, important to validate the program prior to adopting it for widespread use. In the event this is not done, a constant reappraisal must be made to assess and improve the program.

Better tests improve screening programs. Both scoliosis school screening and the detection of neonatal CDH require much more accurate tests. In school screening, it would perhaps be best to only refer those with significant curves. Whether all volunteers would feel comfortable with this type of referral, however, is questionable. In CDH, there is no accurate, inexpensive, quick test which is acceptable. Radiography is unacceptable and ultrasound is neither cheap nor easy to perform.

Changing the definition of the disease could eliminate some problems. If scoliosis greater than 20 or 30 degrees is defined as "disease" many unnecessary referrals could be eliminated. If rib rotation bore a direct relationship to the curve, large degrees of rotation could be the criteria for referral. Screening children in grades 1–6, although commonly done, is screening a low prevalence population. Whether boys need to be screened at all is questionable, given the lower prevalence of scoliosis in males.

Screening for CDH is most effectively done in the nursery. However, not all dislocated hips can be diagnosed by even the most experienced examiner. Thus, addition of other tests may improve the screening program. Emphasis on detection of limited or asymmetrical abduction in the first three to six months of life would probably increase the value of screening.

Both of these programs have pros and cons. Why scoliosis school screening has become so widespread, so well-organized and so entrenched, while screening for neonatal CDH is rarely done in this country remains a question without a satisfactory answer.

Neither program as currently performed meet the criteria for successful screening programs. Scoliosis school screening is now legislated in at least 20 states[1] and is not likely to be abandoned soon. Those responsible for such programs must take steps to address their shortcomings. New scoliosis and neonatal hip screening programs should not be instituted until they have been validated.

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SEGMENTAL BONE TRANSPORT WITH A UNILATERAL FIXATOR— A REPORT OF TWO CASES

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Bone loss is an occasional complication of fractures or infected nonunions. In severe extremity injuries, contaminated devascularized segments of cortical bone provide bone stock and structural support; however, because the risk of infection is high, the surgeon may choose to discard these cortical fragments thus creating a segmental defect. Bone loss is also encountered in the reconstruction of infected nonunions. When a nonunion is complicated by osteomyelitis, radical debridement is necessary to effect a cure, and this often leads to segmental bony defects. These defects are satisfactorily stabilized by external fixation; however, obtaining bony union is difficult. Several methods for reconstruction have been suggested, including massive autogenous graft[3], posterolateral graft[5], fibular transfer[2], or free vascularized fibular graft[14].

The formation of new bone by callus distraction or distraction osteogenesis is now well recognized and is used successfully for leg lengthening.[1,4,11] The use of callus distraction to transport segmental sections of bone to close gaps has recently been reported using small wire ring fixators. The initial results appear promising and segmental transport may prove to be a better solution for these difficult problems than traditional methods. Unfortunately, the use of ring fixators requires a large amount of equipment as well as constant adjustments during transport. Furthermore, the learning curve is steep. The combination of these problems limits the applicability of bone transport with ring fixators.

The paper reports two cases of segmental bone defects, one secondary to acute trauma, and one secondary to an infected nonunion. In each case union was achieved utilizing the principles of callus distraction and segmental transport with a new unilateral bone transport system.

CASE 1

A forty-four year old male involved in a bicycle vs. motor vehicle accident sustained a severe Type IIIB open tibial fracture with a segmental loss of bone. Soft tissue injury included a twelve by ten cm. anterior defect with loss of a portion of the anterior compartment musculature. Initial radiographs (Fig. 1A) revealed a 7½ cm. segmental loss of bone. An arteriogram showed occlusion of the anterior tibial artery at the fracture site, distal reconstitution of the dorsalis pedis, and intact peroneal and posterior tibial vessels. Following initial debridement, he was placed in an external fixator and transferred to University of Iowa Hospitals and Clinics one day after injury.

Following a second debridement three days post injury, the unilateral bone transport system was applied and a proximal corticotomy was performed (Fig. 1B, 1C). Muscle coverage of the anterior open wound was obtained by local transposition flaps five days post injury, followed by a split thickness skin graft.

Fourteen days after application of the unilateral bone transport system, distraction osteogenesis was initiated by increasing the distance between the central and proximal screw clamps on the unilateral tract. Transport, proceeding by ¼ mm. increments four times per day, was facilitated by use of the standard Orthofix compression distraction apparatus. Eight weeks later transport was discontinued.

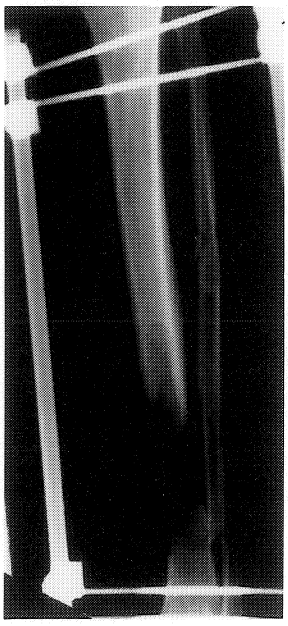

Figure 1A
A 7½ cm. segmental bone loss of the tibia in a forty-four year old man following a bicycle vs. motor vehicle accident.

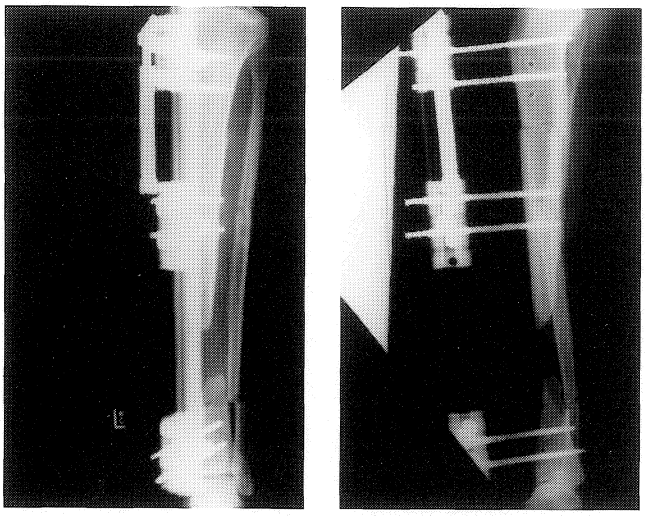

Figure 1B–C
AP (B) and lateral (C) views of tibia following placement of unilateral bone transport system and proximal tibial corticotomy.

Four weeks after discontinuing transport (a total of fourteen weeks from injury) a bridging callus was noted at the "docking site" (transport segment-distal fragment junction) as well as excellent osteogenesis at the distraction site (Fig. 1D–E). However, because of suboptimal apposition at the docking site as well as the oblique nature of the proximal and distal fragment, an anterolateral cancellous iliac crest bone graft was performed. The patient was advanced to full weight bearing, and ten weeks later the fixator was removed when there was clinical and radiographic healing at the docking site and at the site of distraction osteogenesis (Fig. 1F–G). He was protected for the next six weeks in a short leg brace. No adjustments to the frame were necessary during transport or subsequent consolidation.

The length of his segmental defect measured 7½ cm. and the total time from his injury to fixator removal and sound radiographic healing was twenty-four weeks. He required one course of antibiotics for pin site erythema and drainage, which resolved uneventfully.

CASE 2

A twenty-three year old female was admitted ten months after a Type IIIA open tibial fracture sustained in a pedestrian vs. automobile accident. She was ambulating in a short leg cast but had radiographic evidence of nonunion and sequestrum formation (Fig. 2A). Examination of the leg revealed gross motion at the nonunion site and drainage from an anterior sinus. A debridement and sequestrectomy was performed. Healthy bleeding bone was not obtained until a complete 2½ cm. defect had been created (Fig. 2B). Cultures were positive for coagulase negative staphylococcus and antibiotics and dressing changes were begun.

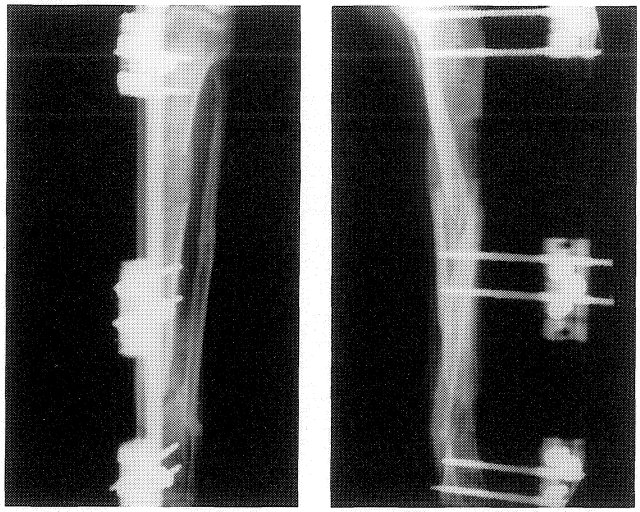

Figure 1D–E
AP (D) and lateral (E) views of tibia following distal segmental transport of the central section of the tibia. Note the osteogenesis at the distraction site and bridging callus at the docking site where a small anterolateral bone graft had been performed.

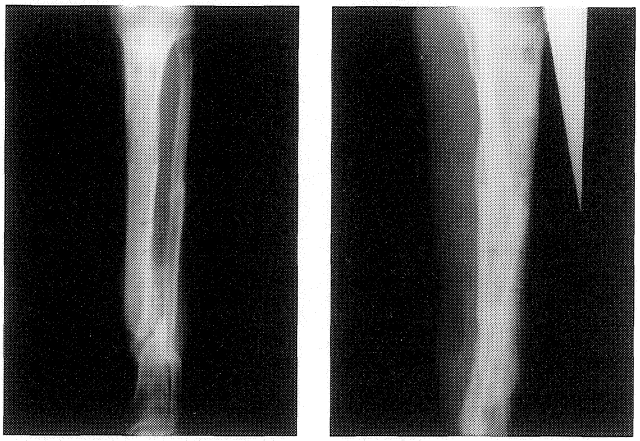

Figure 1F–G
AP (F) and lateral (G) views of the tibia following removal of the bone transport system. Sound radiographic healing is present at both the distraction osteogenesis and the docking sites.

Figure 2A
The radiographic appearance ten months following a Type IIIA open tibia fracture. Note the presence of the radiodense sequestrum.

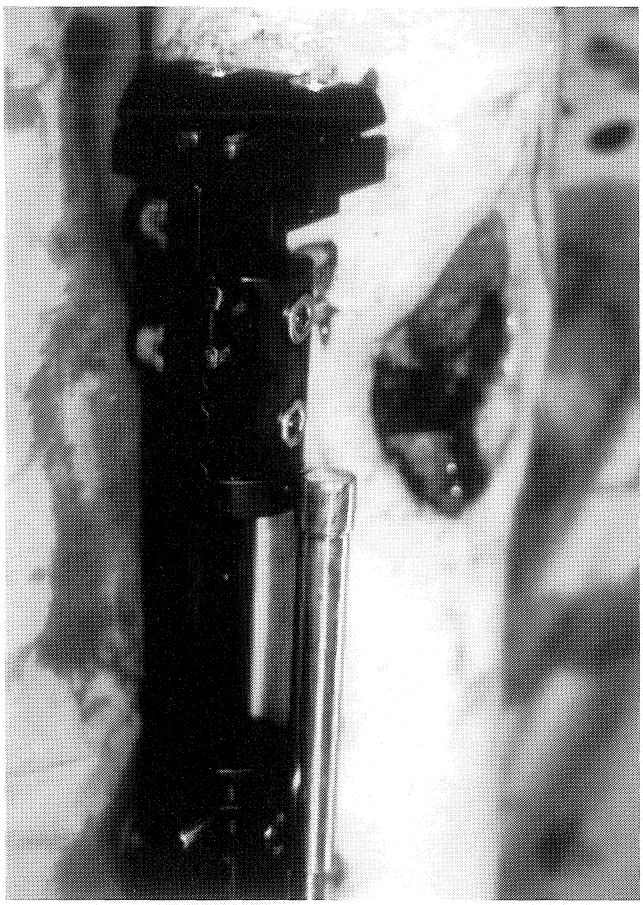

Figure 2B
The clinical appearance of the wound following debridement sequestrectomy and application of the unilateral bone transport system.

Two weeks after the initial debridement she returned to the operating room where the bone ends were squared off and the unilateral bone transport system was applied. A proximal subperiosteal corticotomy was performed (Fig. 2C) Two weeks after application, the middle clamp was distracted towards the bottom clamp at the rate of 1/4 mm four times per day. Docking was obtained within eighteen days. Distraction osteogenesis was evident radiographically (Fig. 2D). No manipulation of the the frame was required during transport. At thirteen weeks after application, both of the lower clamps were loosened to dynamize the transport system and she progressed to weight bearing as tolerated (Fig. 2E). The anteromedial wound gradually closed without any soft tissue procedures. Anteromedial callus was evident at the docking site (Fig. 2F).

Nineteen weeks after beginning treatment the 2 1/2 cm segmental defect was closed and radiographic and clinical healing was noted at both the docking site and the distraction osteogenesis site (Fig. 2G). The bone transport system was removed and she was placed in a short leg cast

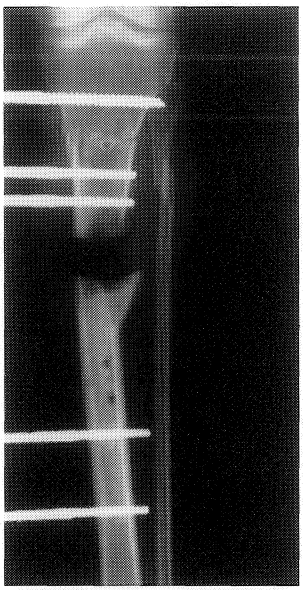

Figure 2C
Application of the three level screw fixator is demonstrated. Note the corticotomy between the proximal and middle screws. The bone ends at the anticipated docking sites were squared off after debridement to bleeding bone. A 2 1/2 cm gap remains.

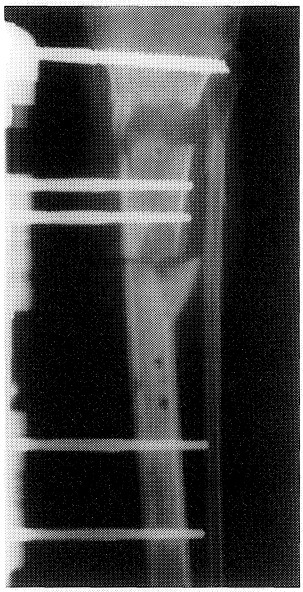

Figure 2D
Following distraction osteogenesis over eighteen days, the middle segment has docked.

Figure 2E
Patient weight bearing as tolerated in the fixator following segmental transport. After docking, the locking screws on the screw clamps are released to dynamize the fixator.

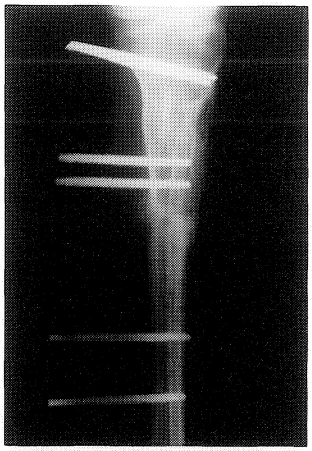

Figure 2F
Nineteen weeks following fixator application there is radiographic healing of both the docking and the distraction osteogenesis sites. The screws were removed.

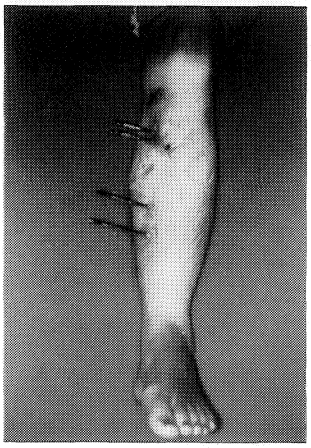

Figure 2G
The clinical appearance of the limb is demonstrated. Note complete involution of the wound.

for protection. Total treatment time was nineteen weeks. Follow-up at one month after fixator removal revealed 10° of valgus angulation through the docking site.

DISCUSSION

Segmental defects of bone pose difficult reconstructive problems in cases of acute and chronic trauma to the lower extremities. Many methods of bony defect reconstruction have been described. For each of these methods the treatment time is long and the complication rate is high.

Weiland et al. reported on thirteen cases of free vascularized bone transfer in the treatment of chronic osteomyelitis[14]. They had three failures, and of the ten that healed, four had persistent drainage. The time to healing was not described. Chacha et al. reported on ipsilateral fibular transfer for segmental defects of the tibia[2]. In their series of eleven cases, one patient required an amputation. Eight of ten cases united in four to six months, but required eighteen to twenty-four months for satisfactory hypertrophy of the fibular graft to allow unprotected ambulation. Two cases were complicated by late stress fracture.

Christian et al. reported on the reconstruction of large diaphyseal defects by free soft tissue transfer and massive cancellous grafting[3]. They obtained healing in each of their eight cases at an average of nine months. Their patients required an average of five operative procedures, and most required the harvest of at least two iliac crest bone grafts.

Review of our own experience in treating infected nonunions by segmental resection, external fixation, flap coverage, and posterolateral bone graft revealed that three of five cases with segmental defects greater than three cm. developed late stress fractures and angulation after healing.

Recently, the treatment of tibial defects using the method of Ilizarov has been described. Aronsen et al. obtained healing of an infected tibial nonunion with a four cm. leg length discrepancy in nine months. (1). Leg length was restored and the drainage ceased. Paley et al. reported on twenty-five cases with bony defects between one and twenty-three cm.[11] Healing was obtained in an average of 13.6 months. Complex four ring constructs were often used. Gold et al. reported on fifteen tibial nonunions treated by the method of Ilizarov[4]. Thirteen of fifteen patients healed. They had an average distraction osteogenesis of 5.7 cm., and the patients required 4.5 months in the Ilizarov fixator. Patient pain, discomfort, and compliance were all recognized problems in their series.

Review of these reports indicates that segmental transport of bone is an alternative to free fibular transfer or massive bone grafting procedures for tibial defects secondary to acute trauma or those created during reconstruction of infected nonunions. However, the complexity of the circular frame small wire transport apparatus creates difficulty in learning the technical details of application and post-operative management. Complex inventories of equipment and frequent manipulations during treatment are necessary. Patient compliance with the bulky apparatus, the need for frequent follow-up, and difficult treatment regimens may be a problem. In addition, the complication rate is not yet well defined.

Our preliminary experience with a unilateral bone transport system indicates that the simpler one-half frame apparatus may be utilized to obtain segmental distraction osteogenesis. Excellent consolidation of the distraction gap occurred in both of our cases with transport performed along a unilateral tract utilizing large half screws. No alteration in the course of the distracted segment was necessary during the course of treatment. Neither fibular osteotomy nor stripping of the interosseous membrane was performed in either case. Circular forces on the central segment were not required for satisfactory transport.

In both cases the screws and the central segment transported without difficulty; release of the "leading edge" skin was not performed and healing of the skin behind the

distracting segment occurred uneventfully. A minor proximal pin tract infection occurred in Case 1 and responded to antibiotics. Early partial weight bearing was possible in both cases.

While adjustments during transport were not necessary in either of these cases, they are also not possible with this system. Therefore, while the complexity of frame application and the hardware necessary are both less than with small wire ring systems, the application technique is still demanding. Accurate transport demands perpendicular insertion of all screws and parallel alignment between the shaft of the bone and the unilateral tract along which transport occurs. The slight medial transport evident in the radiographs of Case 1 is secondary to failure of parallel alignment between the proximal and distal segment and the transport body.

Radiographic healing in Case 1 and Case 2 was obtained in twenty-four and nineteen weeks, respectively. This healing period is shorter than we have been able to obtain in similar cases of segmental defects treated by external fixation, flap coverage, and posterolateral bone grafting. In addition, the need for a free tissue transfer was avoided. The radiographic appearance at this stage indicates that late stress fracture will not be a problem when segmental defects are treated with bone transport. However, the development of angulation at the docking site in Case 2 illustrates the problems that are encountered with healing at the completion of distraction. Possible methods to avoid this include routine grafting, "freshening" the bone ends before contact and sequential compression/distraction. Based on our favorable experience in Case 1, we now recommend routine grafting at the docking site. There remains a great deal to be learned about the biology of the docking site, the rate, rhythm, and timing of distraction and the ideal mechanics of the apparatus used to perform transport. Further experience will elucidate difficulties and complications with both unilateral and ring systems as well as their place along with traditional methods in reconstruction of the lower extremity.

The relative indications for ring fixators vs. this unilateral transport system will be clarified with further experience. The ability to gradually correct deformity, realign joints and overcome soft tissue contracture are particular advantages of the ring system. In aligned cases of segmental defects, the unilateral system seems easier for both the physician and patient.

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SLIPPED CAPITAL FEMORAL EPIPHYSIS IN A TWO-YEAR-OLD CHILD: A CASE REPORT

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The most common age range in which slipped capital femoral epiphysis (SCFE) tends to occur is between ten and sixteen years. We present and discuss an unusual case in a two-year-old girl.

CASE REPORT

Cloacal exstrophy was recognized at birth. At age one year, reduction of the pubis was performed with bilateral iliac osteotomies. At two years six months, the patient was given central venous hyperalimentation because of anorexia and vomiting. Two months later, limping was observed accompanied by right knee and hip pain. No apparent trauma had occurred.

The range of motion of the right hip joint was as follows: flexion 60°; abduction 20°; internal rotation was impossible. Drehmann's sign was positive.

Radiographs showed the right femoral head displaced in a posteroinferior direction (Fig. 1). Serum calcium, phosphorous, growth hormone, and estrogen were within the normal ranges.

Closed reduction attempted under general anesthesia was not successful. Following six weeks of skeletal traction, a subcapital wedge osteotomy through a Smith-Petersen approach was performed, taking great care not to injure the retinacular vessels on the posterolateral side. The femoral head was found to be displaced five mm. posteriorly (Fig. 2A and 2B). Three years post operatively, no complications, including avascular necrosis or chondrolysis were seen (Fig. 3). Hip range of motion was excellent.

DISCUSSION

SCFE usually occurs in adolescence, between ten and sixteen years of age. In this case involving a two-year-old girl, no disorder such as rickets or trauma was recognized. Hyperalimentation had been started two months

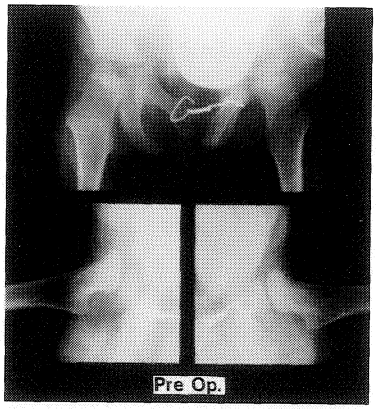

Figure 1
Pre-operative radiograph.

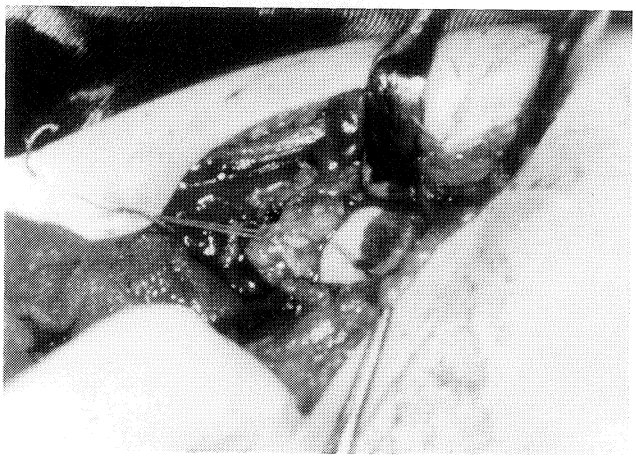

Figure 2a
Epiphysis of the femoral head is noted slipping posteriorly.

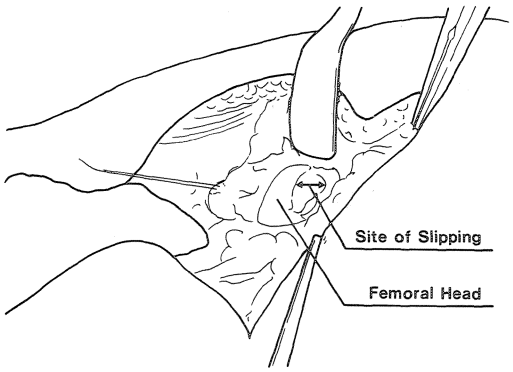

Figure 2b
Schema of the operative field.

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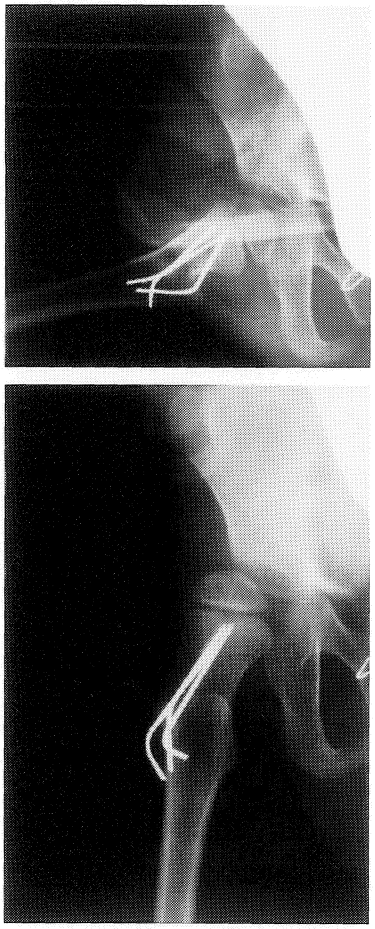

Figure 3
Radiographs taken three years post-operatively.

before onset of hip pain, and during the next two months her body weight increased from nine kg to twelve kg—a 33% increase in body weight over a relatively short period of time. Such an abnormal increase in weight may have contributed to SCFE. In addition, the patient was walking with the hip externally rotated following treatment of cloacal exstrophy, and this possibly increased the shear force on the epiphyseal plate.[1]

According to Welch[1], the musculoskeletal anomalies associated with cloacal exstrophy are talipes equinovarus, long bone abnormalities, dislocation of the hip and ankle disarticulation. There may be physeal abnormalities. Increased hip joint forces, due to rapid weight gain, and increased shear stress applied to the physis secondary to the patient's abnormal gait, perhaps contributed to SCFE in this young patient.

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MENISCUS: FUNCTION AND REPAIR

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The knee joint menisci have been studied for several centuries. In 1897 Sutton suggested that they were functionless remains of leg muscle origins which arose intra-articularly.[30] It was not until the late 1930's that the menisci were felt to be significant structures. In 1936, King advocated that menisci served four functions: protection of the articular cartilage, increasing joint stability, relieving joint incongruity and increasing mobility between the surfaces of the femur and the tibia, and lubrication.[18]

Numerous authors have suggested that the menisci function as weight bearing structures. While reviewing pre and post-operative radiographs of knees that had undergone meniscectomy, Fairbanks[9], in 1948, noted narrowing of the articular cartilage, generalized flattening of the femoral articular surface and ridge formation of the condyle (Fairbank's changes). He concluded that these changes resulted from the loss of the weight bearing function of the meniscus.

Years later additional studies were done. Kettlekamp[17], in 1972, looked at tibiofemoral contact areas in cadaveric knees. Each knee was placed between two pieces of plexiglass and barium sulfate was injected into the joint, after which the knee was compressed. Radiographs were then obtained and the contact area was determined from the contrast of the barium. The area within the borders of the menisci (intrameniscal area) was measured before testing and then compared to the contact area in the weight bearing position. In a majority of these specimens, the weight bearing contact area was greater than the intrameniscal area, suggesting that the meniscus acted as a weight bearing structure.

Walker[33] and Fukubayashi[10] also reported on tibio-femoral contact areas. Both employed a casting technique using PMMA and silicone, respectively. The casting material was placed between the tibio-femoral surfaces of the knees and the joint was compressed at varying loads and flexion angles. After the material cured, it was removed and the contact area was determined. The results indicated that the contact area in the unloaded case was primarily on the menisci. As the load increased to 100 to 150 kg., medially there was steady progression of the contact area shared by both the articular surface and the meniscus. In the lateral compartment, the area of contact was primarily on the meniscus with only a small portion on the uncovered articular cartilage. With increasing flexion the contact area moved posteriorly in both compartments.

Both authors also measured contact pressures in the knee and obtained similar results. Walker used a pressure transducer while Fukubayashi used pressure sensitive film. Uncovered cartilage in the medial compartment had the highest contact pressure while the meniscus in the lateral compartment had the highest contact pressure. Fukubayshi obtained absolute readings and noted that at constant loads, the surface pressure in intact knees was 50% less than in knees without menisci.

Krause, using an Instron testing device, was able to calculate the energy absorbed and the average stress in joints with and without the menisci.[20] Both canine and human knees were tested. Each human specimen was tested in extension and 45° of flexion with intact menisci, after medial meniscectomy, and after bilateral meniscectomy. At each flexion angle, each specimen was tested at three different tibial rotations and two different strain rates. The contact area was determined before and after meniscectomy by staining the articular surface with methylene blue and eosin red. The ratio of the applied load to the contact area gave the average stress. After meniscectomy the stress increased threefold as a result of a greater load acting across a decreased contact area. If the deflection of the articular surface was held constant, a greater load was transmitted across an intact joint than across a joint in which the menisci were excised. Conversely, for a given load, the amount of compression deformation in knees with meniscectomy was approximately twice that of intact joints. The author concluded that menisci transmit between 30 to 55% of the load.

Besides having an intra-articular weight bearing role, the menisci may also distribute loads to the surrounding cortical bone. Bourne, using strain gauge rosettes on the tibial cortical surface and testing limbs in axial compression, looked at the resultant strains before and after medial meniscectomy.[4] After meniscectomy, there was a

reduction of stress on the entire lateral cortex. On the medial cortex compression strains were increased at all levels beyond seventy mm. distal to the joint line; however, within fifty mm. of the joint line there was a significant reduction of medial cortical compression strain. It was hypothesized that compression strain alterations occurred because of a smaller and more centrally located tibiofemoral contact area. It appeared that the proximal medial tibial cortical surface and the entire lateral cortex were stress shielded while the load was transferred to the underlying cancellous bone and then to the distal medial cortex.

The meniscus may also have a role in joint stability. Oretorp, using a canine model, looked at the interaction of the menisci and their respective collateral ligaments.[26] For both the medial and lateral compartments, a statistically significant increase in varus and valgus rotation was observed after the meniscus had been removed. In addition, the maximum load to failure of the medial collateral ligament was greater in the intact case compared to the post-meniscectomy case.

Hsieh and Walker[14], and later Levy[21], studied the effects of meniscectomy on anterior translation in the human knee. Both noted that anterior translation did not increase with meniscectomy. Levy demonstrated that with sectioning the ACL followed by excision of the medial meniscus, anterior tibial translation significantly increased, especially at higher flexion angles. His study concluded that the ACL was the primary restraint to anterior translation and that after ACL sectioning the menisci were important secondary restraints.

Experimental work indicates that the menisci have many functions. Additional work using animal models has demonstrated an association between degenerative changes and meniscectomy. King, using a canine model looked at the results following partial and total medial meniscectomy.[18,19] He found that the degree of degeneration correlated with the amount of meniscus excised. Cox[8] later repeated this study and obtained similar results.

Clinical follow-up studies have been performed in an effort to determine if degenerative changes are seen in humans after meniscectomy. These early studies did a poor job of excluding, documenting, and recognizing knees with ligament and/or articular injuries, making it difficult to draw conclusions.

Fairbanks was one of the first to note an association between radiographic signs of degeneration and meniscectomy.[9] In a follow-up of 107 patients (with a previous meniscectomy) in which pre and post-operative radiographs were available, he noted three consistent findings: 1) formation of an anteroposterior ridge projecting downward from the marginal half of the femoral articular surface, 2) generalized flattening of the marginal half of the femoral articular surface, 3) narrowing of the joint space on the side of the operation. These findings occurred as early as five months after meniscectomy. At follow-up between 50–66% had one or more of these findings. However, he found no correlation between clinical and radiographic findings.

Later, long term studies by Jackson[15], Tapper[31], Johnson[16], and Appel[2] also found an association between meniscectomy and degenerative changes. These authors found that between 74–85% of the knees with a history of previous meniscectomy had radiographic degenerative changes, while only 4–6% of the controls had any changes. Tapper and Johnson, unlike Jackson, noted a correlation between symptoms and degenerative changes. In addition, Tapper noted that 25% of his patients were not able to return to full activity and 27% had crepitus. Only 68% of patients had a good to excellent result, while only 38% had a normal, symptom-free knee. Johnson, using a more detailed rating system and a more stringent grading scale, found 42% satisfactory and 58% unsatisfactory results. Although other studies have reported better results after meniscectomies, the above studies are long-term follow-ups (a minimum of ten years in Tapper's study, and a mean of 17.5 years in Johnson's study). In addition, both authors attempted to exclude those patients with preexisting degenerative joint disease, loose bodies, osteochondritis dissecans, and ligamentous instability.

Realizing that patients with meniscectomies have an increased incidence of degenerative changes and disappointing long-term results, it was hypothesized that repairing a torn meniscus may improve the results. The first reported meniscal repair was performed by Annandale in 1883.[1] At that time he repaired the anterior attachment of the medial meniscus and ten weeks later the patient was back to work. In the 1900's it became the standard to remove any meniscus that was torn or deformed. With the advent of arthroscopy, partial meniscectomy became accepted. However, even removing a portion of the meniscus increased the risk of developing symptoms and degenerative changes.[9,23] For these reasons, orthopaedists began performing meniscal repairs.

King's initial canine studies on meniscus repair and regeneration[18,19] found that if a complete meniscectomy was performed to the capsular and synovial attachment, partial regeneration of the cartilage would occur. However, no regeneration would occur with partial meniscectomy. He also determined that tears within the substance of the meniscus did not heal, while tears at the peripheral attachment did.

In the late 1970's Heatly[12] and Veth[32] using rabbits, Cabaud[6] using dogs and monkeys, and Arnoczky[3] using dogs, studied the healing properties of the meniscus. All four studies noted that tears of the periphery would con-

sistently heal, while tears within the substance of the meniscus would only occasionally heal. The rate of healing increased if the peripheral rim was removed so that the tear bordered the periphery, or if a vascular access channel was made. Heatley noted that sutures facilitated the healing process by possibly supplying bridges for synovial cells to migrate into the meniscus; however, Veth saw no difference in the healing rate with sutures. Grossly, the lesions healed circumferentially with the cells initially proliferating from the periphery. Vessels from the perimeniscal capillary plexus as well as vascular pannus from the proliferation of the adjacent synovium provided the necessary blood supply. As the lesion matured the synovial overgrowth subsided. Histologically, the scar tissue in the defect was cellular, composed of unorganized collagen without common ground substance. In summary, it appears that meniscal tears did heal, however they did not regenerate normal fibrocartilage.

Initially, repairs were performed in cases in which open ligament reconstruction was done.[11,27,34] As arthroscopic equipment and techniques improved, more meniscal repairs were done with arthroscopic assistance. Clinical success rates of repairs varied from 60–90%.[7,11,13,24,27,28,29,35] However, very few studies documented meniscal healing with post-operative arthroscopy or arthrography.[24,28,29]

One of the largest follow-up studies of meniscal repairs with postoperative documentation was performed by Scott.[29] In this prospective study several factors were evaluated to determine if they influenced meniscal healing including: dissection of the perimeniscal membrane, rim width, type of tear, tear length and position, preoperative history and length of symptoms, age, compartment, and associated ligament instability. Of the 240 patients with 260 meniscal repairs, 167 patients (70%) with 178 repairs (68%) were evaluated. All associated ligamentous injuries were repaired concurrently with the many different types of meniscal tears (single longitudinal, double longitudinal, radial, and flap). To document healing, all medial meniscal repairs were evaluated by arthrography, and all lateral meniscal repairs were evaluated by arthroscopy six months post-operatively. The results indicated that 62% of all tears were completely healed, 17% were incompletely healed, and 21% showed no healing at all. Dissection of the perimeniscal tissue was felt to be the most controllable factor in increasing the rate of healing. Those factors that could not be controlled by the surgeon, but were significant, included the width of the peripheral rim (the farther peripheral the tear, the better the healing rate), the type of tear (single horizontal tears showed better healing rates), and reconstruction of a ligament (meniscus repair with ligament reconstruction had a higher healing rate). In knees that had an isolated meniscus tear the rate of healing was only 40%.

Smaller studies with post-operative documentation revealed slightly better results. Rosenberg[28] followed up twenty-seven longitudinal meniscal tears in twenty-five patients in which each patient had a repeat arthroscopy at three months. Overall, 83% of the tears healed. In those knees that were stable the success rate was 96%, while only 40% of tears in unstable knees healed. Miller[24], in 1988, reported on seventy patients with meniscus repairs. All patients with an ACL rupture underwent ligament reconstruction at the time of meniscus repair. 67% of the patients with a meniscus repair had a repeat arthroscopy or an arthrogram. Fourteen patients (20%) had incomplete or no healing of their menisci. Again noted was a higher rate of healing in those patients with a concomitant ligament reconstruction. Although these studies indicated a high rate of meniscal healing, they are not long-term follow-ups. To determine if arthroscopic repair of meniscal tears decreases the incidence of degenerative changes, controlled studies with long-term follow-up will be needed.

TECHNIQUE OF MENISCAL REPAIR

During arthroscopy the meniscus should be carefully inspected and probed to determine the type of tear, other associated tears, the complexity of the tear, and the width of the peripheral rim. Occasionally a 70° arthroscope placed through the notch is needed to the see the posterior horn adequately. If repair is indicated, the meniscal bed is prepared. For peripheral, and red/white tears (tears located at the junction of the vascular and avascular zone), the borders of the meniscus and the perimeniscal synovium are roughened with an intra-articular rasp. Tears that are in the white/white zone are also rasped and, in addition, a fibrin clot may be placed in the tear prior to repair.

Although many different methods of repair have been described (open, arthroscopic inside/out, arthroscopic outside/in), our repairs are performed using an arthroscopically-assisted inside/out technique similar to that which Henning described.[13,22,25,29,43] For both medial and lateral tears, the respective capsules are exposed and retractors are placed to protect the neurovascular structures and to insure that the sutures are tied against the capsule rather than muscle. Tying sutures over tendons and muscle increases postoperative pain and may lead to premature suture failure.[22]

The knee is flexed and exposure of the medial and posteromedial capsule is begun with a five to six cm. incision, one cm. posterior and parallel to the medial collateral ligament. The incision is centered at the joint line. Blunt scissor dissection is used to expose layer one (superficial fascia). At the posterior and distal aspect of the wound the saphenous vein and nerve are located and protected. While dissecting through the subcutaneous tissue

branches of the saphenous nerve are protected. Layer one is incised and the pes anserine tendons are retracted posteriorly. The direct head of the semimembranosus is identified and the tendon sheath is entered superiorly. A plane is developed anterior to the medial head of the gastrocnemius. Frequently, the medial head of the gastrocnemius is mobile enough that release is not necessary. A popliteal retractor is then placed in this space bordered by the capsule anteriorly, the semimembranosus inferiorly, and the gastrocnemius posteriorly (Fig. 1).

To expose the lateral and the postero-lateral capsule a six to seven cm. incision is made one cm. posterior to the lateral collateral ligament (LCL). Because the slope of the lateral plateau directs the needles inferiorly, 1/3 of the incision is made above and 2/3 of the incision is made below the joint line. The interval between the biceps and the intermuscular septum is developed proximally, while distally, the interval between the LCL and the biceps tendon is developed. At the distal aspect of the incision a plane is developed anterior to the lateral head of the gastrocnemius. Laterally, the gastrocnemius is intimately attached

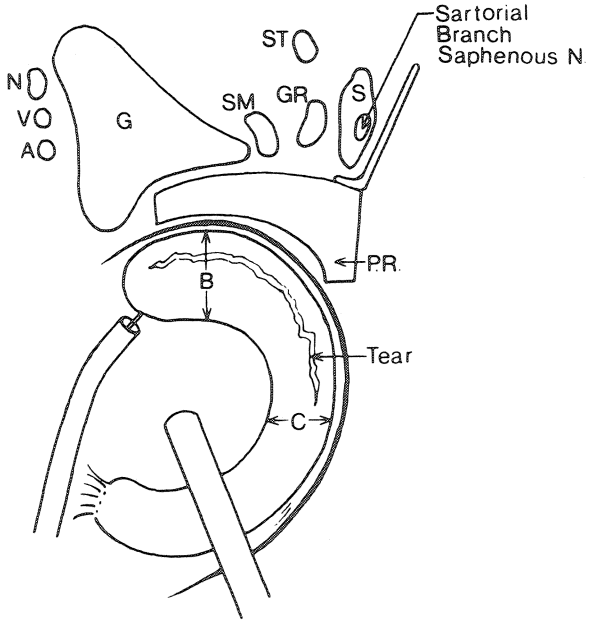

Figure 1
Medial compartment of a knee. The arthroscope is introduced in the medial portal while the cannula is placed in the lateral portal. The popliteal retractor (P.R.) is placed posterior and medial to the joint protecting the neurovascular bundle (N = nerve, V = vein, A = artery) and preventing the sutures from penetrating muscle (G = gastrocnemius, SM = semimembranosus, GR = gracilis, ST = semitendinosus, S = sartorius). Reprinted (modified) with permission from The Journal of Bone and Joint Surgery, 68A:853, Figure 7-B, July 1986.

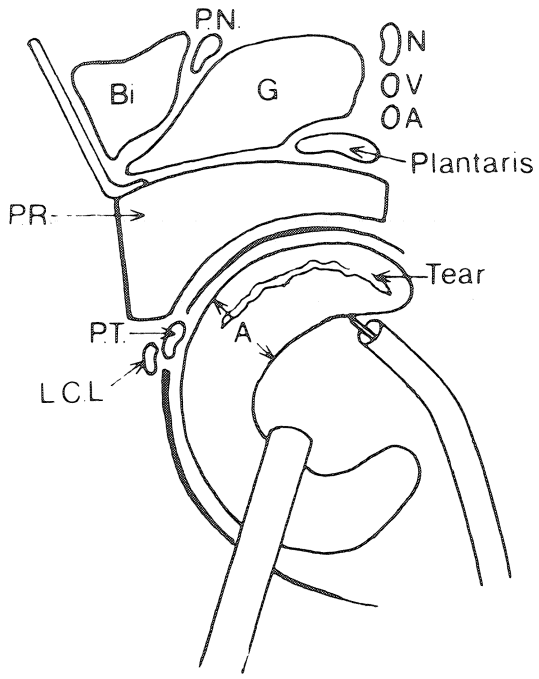

Figure 2
Lateral compartment of a knee. The arthroscope is introduced in the lateral portal while the cannula is placed in the medial portal. The popliteal retractor (P.R.) is placed posterior and lateral to the joint protecting the neurovascular bundle (N = nerve, V = vein, A = artery, P.N. = peroneal nerve) and preventing the sutures from penetrating muscle (G = gastrocnemius, Bi = biceps, P.T. = popliteal tendon). Reprinted (modified) with permission from The Journal of Bone and Joint Surgery, 68A:853, Figure 7-A, July 1986.

to the posterior capsule. Frequently, the plane needs to be developed with scissors and occasionally the gastrocnemius needs to be partially released proximally. A popliteal retractor is then placed in the triangle bordered by the biceps inferiorly, the capsule anteriorly, and the gastrocnemius posteriorly (Fig. 2).

The technique of suture placement is the same for each compartment. First, the leg is brought into extension, tightening the posterior capsule. As the sutures are placed they will exit through the distal aspect of the capsule. If the meniscal sutures are placed with the knee flexed, they will exit the capsule proximally. In this position, as the leg is extended the capsule will pull the meniscus proximally creating tension on the repair, therefore increasing the incidence of failure and possibly causing a flexion contracture.

To repair a medial meniscus tear, the arthroscope is introduced in the medial portal while the suture cannula is placed in the lateral portal (Fig. 1). The needles are directed in a oblique (medial) direction away from the neurovascular bundle. A single curved cannula is preferred over the double cannula because it is smaller and less

likely to injure the articular surface. Displaced tears of the meniscus are reduced and secured with vertical mattress sutures. Vertical sutures run perpendicular to the majority of collagen fibers[5] and are less likely to pull out compared to horizontal mattress sutures. Straight ten-inch needles with swedged-on 2-0 PDS or Maxon are used. Sutures may be placed from the superior or inferior surface of the meniscus. Superior sutures allow the surgeon to more easily obtain an accurate reduction and maintain this reduction during suture placement because the coronary ligament holds the peripheral rim in close apposition to the tibial articular surface. Pushing down on the displaced meniscus with a cannula places it on the tibial articular surface and stabilized next to the peripheral rim. Inferior placement of sutures will displace the meniscus proximal to the peripheral rim. If inferior sutures are needed, it is often helpful to first stabilize the meniscus in a reduced position using sutures placed superiorly.

To place superior sutures, the first needle is inserted into the superior aspect of the meniscus toward the inner rim. The needle is aimed distally so that as it exits the meniscus, it reapproximates the inferior aspect of the meniscus to the periphery. The second needle is placed along the superior aspect of the meniscus and advanced through the capsule parallel to the joint, reapproximating the superior aspect of the meniscus (Fig. 3). Sutures are placed in this manner every three to five mm. To insure an acceptable repair, the reduction should be maintained during suture placement. When completed, the tear is probed and additional sutures are placed if any unstable portions of the repair are detected.

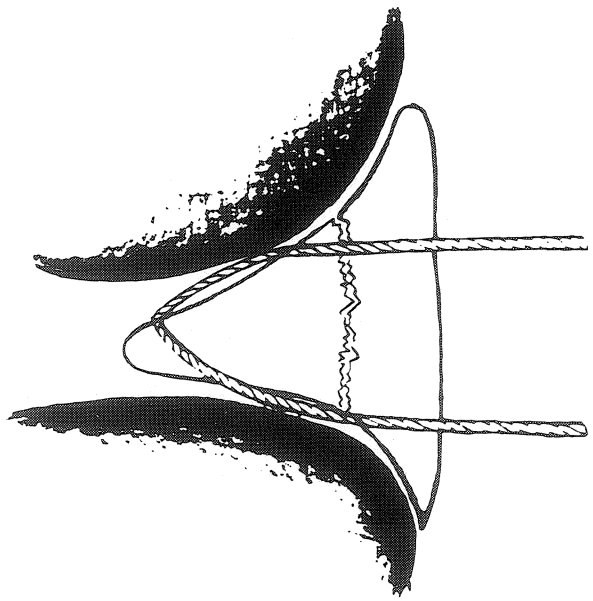

Figure 3
Cross Section of a meniscus.

Post-operatively, the patients are treated non-weight bearing for six weeks, with emphasis placed on quadriceps and hamstring exercises as well as range of motion. If the tear is posterior, full and forced flexion is not encouraged because flexion increases the amount of stress on the repair. After six weeks full weight bearing is allowed. At three months jogging is permitted; however, cutting, jumping, and twisting are not allowed until six months. Full squats are discouraged until one year after surgery.

The meniscus has many functions. Studies suggest that meniscectomy is associated with increased clinical and radiographic evidence of gonarthrosis. Presently, it is possible to repair many different types of tears. Hopefully, as patients with repairs are followed for longer periods of time, there will be a reduction in the incidence of degenerative joint disease.

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THE MEASUREMENT OF OXYGEN UPTAKE UNDER WHOLE BODY VIBRATION

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INTRODUCTION

Several epidemiologic studies have shown that exposure to driving is a risk factor in low back pain.[1,2] Gearhart implicated the vehicular environment found in helicopters.[3] Pope et al.[4] reported that many vehicular environments excite the driver's natural frequency and presumably increase the risk of injury. Excitation of these frequencies leads to large displacements of the vertebral column[5] and to the individual vertebrae.[5,6] It is also known that the electromyographic activity of the paravertebral muscles are related to mechanical resonance.[7] It is possible that those who are subjected to vibration may suffer large increases in oxygen consumption. This in turn could cause fatigue and thus put the soft tissues at risk for injury.

There are several studies that have shown that oxygen consumption is affected by vibration exposure. Bennett et al.[8] showed increases of oxygen uptake from 0.31 L/min to 0.42 L/min between vibration and no vibration. Cole and Withey[9] evaluated the oxygen uptake in subjects vibrated at six Hz at different acceleration levels. The oxygen uptake, varying from 0.35 L/min to 0.43 L/min., increased with acceleration level but did not change between sinus and random wave forms.

Webb et al.[10] measured oxygen uptake during vibration and found that there was increased uptake compared to no vibration. There were larger increases when the amplitude was greatest. Again, there were no differences in oxygen uptake related to vibration wave form. However, these workers concluded that the changes in oxygen consumption were small and related to maintenance of posture.

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In a study using the Oxylog to measure the energy expenditure of helicopter pilots[11] it was found that the mean oxygen uptake is 50% higher during level flying compared to sitting at rest. Hovering, in which many pilot control inputs are required, has an even higher[11] energy expenditure.

The energy expenditure of humans to vibration could, in part, be due to physiological factors or the response to job-related tasks. Bennett et al.[8] concluded that cognitive factors and personality are involved in maintenance of motor performance during vibration. The level of performance is probably associated with the physiologic costs. Thus, the combination of vibration and control tasks may lead to a high metabolic cost.

Oxygen uptake has been used in the measurement of the energy cost of certain tasks in industry. This has become more convenient following the development of the Oxylog, a portable measuring device. Harrison et al.[12] conducted over 400 measurements to conclude that the Oxylog is sufficiently accurate to determine oxygen uptake under field conditions. In addition, Astrand et al.[13] found that maximal oxygen uptake decreases with age above the age of sixty. For these reasons, we restricted our measurements to those less than forty-five years of age and exposed to submaximal task demands.

OBJECTIVES

The objectives of the present work are to establish the changes in oxygen uptake due to:

a) frequency, within a range of 0 to 8 Hz,
b) relaxed versus erect posture,
c) intermittent sinusoidal versus continuous sinusoidal vibration.

It was hypothesized that vibration would lead to an increase of muscular activity which would be reflected by increased oxygen consumption.

MATERIALS AND METHODS

The subjects were five males and five females. The ages of the subjects ranged from twenty-five to forty-four years (mean age 36.8 years) Their height ranged from 163

to 185 cm. (mean height 172.2 cm.) and their weight ranged from fifty-seven to eighty-one kg (mean weight 64.9 kg). All were free of low back pain or other health problems.

The subjects were seated in a machine (Fig. 1) capable of providing vertical sinusoidal vibrations at discrete frequencies.[6] Since the vibration comes from the oscillation of a simply supported beam there is little distortion of the pure sinusoid[6] and little cross coupling. No backrest or padding was provided. The subjects were fitted with an Oxylog to measure oxygen consumption. The Oxylog was modified to incorporate a gas mask so as to obviate the fitting problems attendant with the standard oronasal mask. The oxygen cells were adjusted to the actual barometric pressure prior to each session. The Oxylog had recently been recalibrated so we were confident of the accuracy of the apparatus. Because of some concern that the Oxylog may be inaccurate at low oxygen uptake levels we had the Oxylog independently calibrated. The comparison was made with testing recumbent subjects in a ventilation hood system for indirect calorimetry.[14] The Oxylog was within 2% of the calorimeter even at these very low levels. Before commencing the test, the machine was switched on for thirty minutes and, in addition, the subjects were given one minute of acclimatization in breathing through the mask to warm up the cells. The preliminary exposure also acclimated the subjects to the Oxylog.

The subjects were then exposed to thirty minutes of vibration at an amplitude of 0.1 g or of a controlled environment (no vibration) under the following conditions:

1. Sitting relaxed at 0 Hz (10 subjects).
2. Sitting erect at 0 Hz (4 subjects).
3. Sitting relaxed at 5 Hz intermittent (4 subjects).
4. Sitting erect at 5 Hz intermittent (4 subjects).
5. Sitting relaxed at 2.5 Hz (7 subjects).
6. Sitting relaxed at 5 Hz (10 subjects).
7. Sitting erect at 5 Hz (4 subjects).
8. Sitting relaxed at 8 Hz (6 subjects).

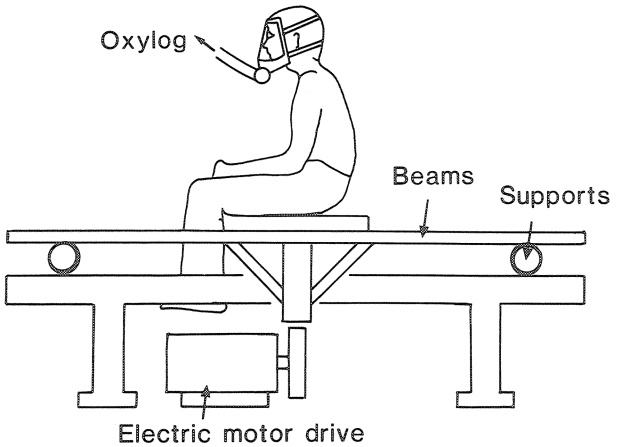

Figure 1

As can be observed from the above list, not all subjects completed all tests. However, no subjects received more than one exposure in one day, and the order was randomized so that there was no systematic bias in the order in which the tests were completed. The subjects were instructed to adapt a posture that they could maintain with the minimal amount of movement over thirty minutes. The erect posture was defined as one in which the pelvis, thoracic spine and occiput defined a plane at right angles to the seat. Since it was anticipated that subjects may have difficulty in the maintenance of this posture, the posture was periodically checked and adjusted if necessary. The relaxed posture was free from but was constrained to be symmetrical (free of rotation or lateral bend). The oxygen uptake was recorded at one minute intervals. The total oxygen uptake for the thirty minute test period was also computed.

In the case of the intermittent vibration, the subjects received ten sec of vibration each minute. The time at which the vibration began was selected from a random number table.

In addition, all subjects completed a visual analogue scale (VAS) to rate their discomfort. The VAS scale was a ten cm line with two end points (no discomfort to extremely uncomfortable) completed immediately following the exposure. Statistical analysis consisted of a Student's test.

RESULTS

We noticed some differences between the calculated resting oxygen uptake and that measured by the Oxylog. The calculated resting oxygen uptake ranged from a 10.7% overestimate to a 32.6% underestimate, with an average 11.9% underestimate. The females were, on average, underestimated by 1.8% while the males were overestimated by 21.9%. Since some conditioning had occurred there was no detectable learning effect.

A summary of the results is given in Table 1. The vibrated subjects always expended more energy than those sitting at rest (p is less than 0.0001). For example,

Table 1

Oxygen Uptake at Different Frequencies (LO_2/min).

Frequency (Hz)		0		2.5	5		8	intermittent 0/5	
Posture		R	E	R	R	E	R	R	E
n = 4	mean	.21	.24	.25	.25	.27	.26	.22	.24
	SD	.04	.05	.03	.04	.01	.07	.02	.05
n = 6	mean	.24	—	.27	.28	—	.27	—	—
	SD	.06	—	.04	.06	—	.06	—	—
n = 7	mean	.24	—	.26	.27	—	—	—	—
	SD	.06	—	.04	.05	—	—	—	—
n = 10	mean	.26	—	—	.29	—	—	—	—
	SD	.06	—	—	.05	—	—	—	—

Posture R = relaxed
E = erect

the average oxygen consumption of the vibrated subjects at 5 Hz was 0.27 $L0_2$/min compared to 0.24 $L0_2$/min for the same subjects at 0 Hz. These subjects were sitting erect. There was no trend in increasing oxygen uptake as a function of increasing frequency.

The relaxed subjects demonstrated less oxygen uptake than the same subjects sitting erect at 0 Hz (p is less than 0.05) (0.21 $L0_2$/min compared to 0.24 $L0_2$/min) at 5 Hz (p is less than 0.05) (0.24 $L0_2$/min compared to 0.27 $L0_2$/min). Under intermittent vibration at 5 Hz the oxygen uptake was 0.24 $L0_2$/min and in this case there was no difference between the erect and relaxed postures. The intermittent vibration resulted in increased uptake compared to no vibration in the relaxed position (0.21 $L0_2$/min compared to 0.24 $L0_2$/min), but no such tendency existed in the erect posture. There was decreased oxygen uptake with intermittent vibration as compared to 5 Hz vibration in the erect posture (0.27 $L0_2$/min compared to 0.24 $L0_2$/min) (p is less than 0.05). We compared the oxygen uptake in the first, second and third ten minutes of exposure but did not detect any differences in any of our test sequences.

The subjective ratings of the individuals using the VAS were also compared. There appeared to be no trend of discomfort rating with oxygen uptake. The subjects found the non-vibration seated posture as uncomfortable as the vibrated posture. There was a trend of increasing discomfort with increased frequency, but this was not statistically significant (Table 2).

Table 2

Visual Analogue Scale Readings at Different Frequencies (% of Intolerable Discomfort)**

Frequency (Hz)		0		2.5	5		8	intermittent 0/5	
Posture		R	E	R	R	E	R	R	E
n = 4	mean	61	55	47	53	62	71	59	74
	SD	31	38	10	19	13	2	5	5
n = 6	mean	61	—	49	51	—	63	—	—
	SD	26	—	24	17	—	2	—	—
n = 7	mean	62	—	44	50	—	—	—	—
	SD	24	—	28	18	—	—	—	—
n = 10	mean	62	—	—	50	—	—	—	—
	SD	22	—	—	19	—	—	—	—

Posture R = relaxed
E = erect

**0 = no discomfort
100 = Extremely uncomfortable

DISCUSSION

It is clear that vibration does cause an increase in the metabolic cost to the seated subject. For the levels of vibration used this represented an increased cost over the different conditions of 12.5%. The oxygen uptake in vibration was similar to those found in light machining work. We could not demonstrate an increase of metabolic cost with increased frequency. The extra metabolic demands are presumably due to the extra work to maintain the posture.

More energy is expended by sitting in an erect posture. This finding has relevance to those industrial or driving tasks involving maintenance of a single posture or involving great concentration. Helicopter pilots, who generally have to adopt an unchanging posture, especially during hovering tasks, have increased oxygen uptake.[11] These individuals also suffer a high prevalence of low back pain as compared to controls.[3] It is noteworthy that there was considerable oxygen uptake during the intermittent vibration. This vibration was for only ten seconds each minute but energy was apparently spent in attempting to respond to the vibration onset. However, the total cost was less than that of continuous vibration at the same frequency. Previous work[9,10] has shown that the higher the amplitude of vibration the more the energy uptake is increased. This may be because more energy is required to maintain the posture. This finding would tend to confirm our observations.

The discomfort reported by the subjects did not relate to the energy demands. It appeared that the prolonged sitting was itself so uncomfortable that other effects were masked. It may be inadvisable to rely on such scores to assess risk of injury.

Several workers have demonstrated a relationship between vibration exposure and low back pain and sciatica. The etiology of such complaints are unknown but it is possible that muscle contraction to maintain the posture eventually leads to muscle fatigue. Muscle fatigue would eventually shift loads on to the ligaments and discs. Those exposures that would lead to higher oxygen consumption may therefore indicate a greater propensity to muscle fatigue and thus to occupational low back pain. These hypotheses would have to be evaluated in further work. These present studies have demonstrated an increase of oxygen consumption to only modest levels. In any event, these data establish the need to compare measured oxygen uptake during a task with the actual oxygen uptake at rest for that same individual. Oxygen uptake appears to be a useful method for measuring the effect of vibration on the seated subject. The method is relevant to the assessment of the energy demands in industry. Field studies should be carried out to establish the utility of this method for assessing vibrational work demands in the industrial environment.

Our oxygen consumption levels are somewhat lower than those reported elsewhere[8,9] but the Oxylog was independently calibrated against an indirect calorimetry system. It should be noted that the levels of oxygen consumption under vibration are similar to those reported for light machining work.

CONCLUSIONS

1. Vibration leads to a higher energy expenditure.
2. The erect posture is more energy-consuming than the relaxed posture.
3. The subjective (VAS) rating is an unreliable means of assessing physiologic cost.
4. Intermittent vibration even for short periods of time does lead to an increase of energy expenditure.

ACKNOWLEDGEMENT

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ADOLESCENT IDIOPATHIC SCOLIOSIS: IN VIEW OF THE LONG TERM RESULTS IN UNTREATED PATIENTS, CAN SURGERY BE JUSTIFIED?

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Treatment of adolescent idiopathic scoliosis (AIS) is an attempt to alter the natural history. To be recommended, treatment must alter natural history in a positive way. To answer the question, "can surgery be justified?", we need to look at surgical indications in the adolescent and the adult and then compare the outcome of surgical management to natural history. Over the last twenty years we have learned a great deal about natural history of AIS[27-30]. The natural history data, however, has been accumulated on relatively small groups of patients and therefore conclusions represent generalities. Treatment decisions must thus be individualized.

In the adolescent the accepted indications for surgery are curve progression despite bracing or large curve magnitude. A curve too large for bracing, generally over 40°–45°, or one that has a high probability of progression, is an indication for surgical treatment. Surgical indications in the adolescents are generally for "prophylactic" reasons. Surgery is predicated on the fact that if the curve progresses the patient will have future problems related to pulmonary function, pain or psychosocial effects.

In the adult with AIS, surgery is most commonly indicated for pain unresponsive to nonoperative treatment and/or for pulmonary symptoms. In these cases, the surgical indication is intended to be "therapeutic". In the adult, surgery is also indicated for curve progression because of the possibility that this will lead to pain, increasing cosmetic deformity and psychosocial impairment. Under these circumstances surgery in the adult is intended to be "prophylactic".

The two most often quoted natural history studies about the poor outcomes of patients with adolescent idiopathic scoliosis used to justify surgery are those of Nachemson[19] and Nilsonne and Lundgren[20]. These studies reported extremely unfavorable long-term outcomes of patients with AIS. In the Nachemson study, however, only 45% of the patients had AIS, the remainder included patients with congenital scoliosis, paralytic scoliosis, and scoliosis secondary to tuberculosis or neurofibromatosis. Only twelve patients were actually seen in follow-up. Nachemson postulated that the backache reported by these patients (37%) was secondary to degenerative joint disease, yet no x-rays were available in these patients. The Nilsonne and Lundgren study also suffers from the fact that no x-rays were available and hence one cannot be certain as to the etiology of the patients' scoliosis.

Let us now examine the specific problems associated with AIS and compare the natural history of each parameter, including pulmonary symptomatology and mortality, pain, curve progression and cosmesis with the effect of surgery on these problems.

PULMONARY SYMPTOMATOLOGY AND MORTALITY

Only in high angled thoracic curves is there a direct correlation between increasing curve severity and decreasing vital capacity. The pattern is uniformly that of restrictive lung disease and smokers are more severely affected than nonsmokers. Only in these high angled curves of more than 100° is the morbidity (secondary to cor pulmonale) significant[27-30]. Thoracic lordosis (hypokyphosis) further compromises pulmonary function. The specific relationships between the loss of thoracic kyphosis and pulmonary compromise have yet to be quantitated. In the adolescent, surgery will stabilize pulmonary function and in some cases provide a 10–20% increase in lung volumes[14,25,31]. In the adult, however, minimal gains can be expected. Pulmonary function in general will be stabilized and symptoms may improve[23,25]. Hence, in the skeletally immature adolescent with a thoracic curve that progresses despite bracing, because of its high probability of continued progression leading to diminished pulmonary function, surgery is indicated. In the skeletally mature patient with a thoracic curve, surgery is indicated in documented pulmonary compromise. Surgery is also indicated if one is certain that the curve is progressing, and that if left untreated it will lead to pulmonary compromise and symptoms. In these circumstances, surgical indications can be based on objective parameters.

PAIN

The incidence of back pain in AIS is in general comparable to the incidence of back pain in the general population. Backache in AIS is also unrelated to the radiographic degenerative changes or to the curve severity, except in thoracolumbar, and lumbar curves with translatory shifts at the lower end of the curve.[27-30]

In the adolescent, pain is rarely an indication for surgery; if pain is present in the adolescent, the source of pain must be investigated (e.g., spondylolisthesis or tumor). In the adult, however, it cannot be assumed that the cause of pain is curve related. Sources of pain may be discogenic, mechanical, facet joint or nerve root related. Most reports of adults with AIS treated surgically for pain show improvement of pain following surgery[12,16,18,21,25]. These studies can be criticized on their methods of pain evaluation. Back pain dimensions are questionnaire dependent. Howe and Frymoyer, evaluating 207 patients followed a minimum of ten years after a single lumbar disc operation, and using fourteen different questionnaires measuring surgical outcomes, demonstrated that outcome depends on the questionnaire design[10]. In their review satisfactory outcomes for this procedure ranged from 97 to 60% depending on the questionnaire (this was statistically significant). The authors concluded that the reported outcomes for lumbar spinal surgery are significantly manipulated by the criteria selected for the assessment of end results.

Pain must be evaluated by the severity and frequency of peak or constant pain and the constant pain and functional limitations[23]. These can be evaluated by methods such as the visual analog scale which have high validity and interrater reliability. Pain location can be accurately represented by pain diagrams. Sponseller et al in a surgical treatment study using these pain evaluation parameters demonstrated at an average seven year follow-up of surgically treated adults the percentage of patients pain-free and the frequency of peak pain did not change. The level of peak pain and constant pain increased 15% and 20% respectively. Neck and buttock pain also increased postoperatively. The source of the patients' pain was not identified preoperatively and therefore, we are uncertain whether the source of pain is curve related or unrelated.

Another factor that must be considered is that the follow-up studies of surgically treated patients are relatively short term. Whether these patients will develop future problems is unknown.

As previously noted, other sites of pain may arise after fusion. In the report of Moscowitz et al prior to the use of Harrington rodding, there was no increase in the incidence of low back pain, but there was a 57% incidence of neck pain[18]. Ginsburg et al., reporting on 147 patients followed longitudinally between 1946 and 1972, showed that the average back ache increased from 26% at thirteen year follow-up to 44% at sixteen year follow-up[7,8]. This study also showed that the incidence of backache in patients fused to L3 increased from 6% to 47% between thirteen and sixteen year follow-up. In addition, the incidence of disabling lumbosacral pain increased markedly in those patients fused to L4 or L5 (Table 1). Cochran and Nachemson reported similar findings in patients fused to the low lumbar spine[2].

Despite contouring of the rods, another post surgical problem is loss of lumbar lordosis creating painful back deformities[5,9,13,17]. Distraction of the lumbar spine reverses lumbar lordosis and may create a kyphosis below the rod.

Table 1

	Back Pain Overall (%)	Significant (%)	Fused to L4, L5 (%)
Ginsburg et. al. ('78)	26	6	45
Ginsburg et. al. ('86)	44	8	53
Michel, LaCain ('85)	48	21	27
Cochran et. al. ('83)	41	24	71
Moscowitz et. al. ('80)	—	15	—
Kitahara et. al. ('88)	—	—	94 (L5) 50 (S1)

CURVE PROGRESSION

In the adult, surgery is recommended for documented progression because of the potential consequences of progression: pulmonary function compromise, pain or psychosocial problems. We have already addressed pulmonary function, thus the key question is "does progression in the lumbar, thoracolumbar, or double major curves *always* cause pain?".

In view of the high surgical complication rates ranging up to 60%[3,4,12,15,16,21,22,23,24,25,26] in adults, we must be certain to identify the source of pain; whether it is curve related or unrelated. Sponseller et al wrote that "no adult can be promised a normal back as a result of surgical correction of scoliosis but a significant improvement in symptoms can be expected"[23]. They further commented that due to the high rate of complications, the limited gains to be derived from spinal fusion should be assessed and clearly explained to patients before the surgery.

The most problematic cases are the lumbar and thoracolumbar curves with a translatory shift, which demonstrate a slightly greater incidence of back pain than other curve patterns. In these patients, we can usually localize the pain to the area of the translatory shift. Localization of the pain source may be difficult. Techniques such as discography or MRI may be helpful in pain localization. Hopefully segment-sparing methods of treatment such as anterior fusion preserving lumbar lordosis, and short segment fusions, will allow these patients to have satisfactory

long-term outcomes. But at present, however, we cannot be certain. We cannot always assume that the patient's pain is curve related.

COSMESIS, PSYCHOSOCIAL PROBLEMS

Cosmetic deformity and patient's perceptions of body image do not always correlate with curve magnitude[27-30]. Spinal decompensation improves with time in untreated patients. Compensatory curves increase in many patients to better balance the spine over time. In our long term study, no patient was decompensated by more than 3.5 cm.[27]

Cosmesis is an extremely important concern to most patients. In the Iowa long term study, 63% of the untreated patients felt that their deformity was apparent to others, while 21% expressed severe psychosocial limitations (although none was severe enough to require psychiatric treatment)[27].

Sponseller et al reported that in twenty-one of the forty-five adults with fused AIS, cosmesis was the patients' main concern although it was not the surgeons' indication for surgery[23]. They further reported that the patients' ability to maintain a positive self image due to their back significantly improved following surgery.

Surgery, however, does not remove all cosmetic or psychosocial problems[1,11,26]. Van Grouw reported that in fifty-one patients with an average 10 year follow-up, 33% remained self-conscious about their residual scar and 43% were still concerned about their residual deformity[26]. In a recent study, Kitahara et al reported that of 209 patients treated surgically, 39% still had cosmesis concerns and 36% still had concerns about their surgical scar[11].

Returning to our original question, "In view of the long term results in untreated patients, can surgery be justified?", it would be inappropriate to say that surgery is never justified. Caution must be exercised in surgical decision making. Treatment decisions must be individualized and "cookbook" decision making avoided. Decisions should be based on as much objective data as possible, including documented curve progression, identification of the source of pain, etc., to ensure that surgical outcome will be better than natural history. "Primum non nocere" (first do no harm) must always underlie all treatment decisions. We must always ask the two questions; "do the benefits of surgery out weigh the risks?"; "do the long term results of the proposed procedure improve the natural history of the patient?"

As orthopaedic surgeons treating adolescents and adults with AIS, we must continue to learn more about natural history. We must continue to follow and evaluate our surgical patients hopefully by objective, valid and reliable criteria. Only by these measures will we be able to further define surgical indications and identify those patients whose natural history can be improved by surgery.

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ABDUCTOR CONTRACTURE OF THE HIP

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INTRODUCTION

Congenital dislocation of the hip (CDH) has a variable incidence. In the United Kingdom, true hip instability is seen in 1 per 200 neonates/infants, of whom greater than half will become stable within one to two weeks. Late presentation of CDH has a much smaller incidence, in the order of 0.6 per 1000 live births. General practitioners are encouraged to refer all cases where hip instability is suspected.

Among these referrals is a small group who appear to have no hip abnormalities but in whom the problem is asymmetry in the arcs of motion between the two sides. We will discuss the diagnosis, examination, and assessment of these children along with various associations commonly encountered. These children may be difficult to identify and some, once identified, may in fact turn out to be true cases of instability and require conventional treatment. Several papers have been published which discuss the treatment of these children; we suggest that in many no treatment apart from regular assessment is required.

MATERIALS AND METHODS

A study was carried out, in Edinburgh, by the senior author on referrals between July 1980 and June 1983.[1] A total of forty-five children were seen. During the same period there were 13,424 live births. Twenty-nine had been referred shortly after birth because of some concern of hip instability at the initial neonatal examination. Sixteen were referred around the age of four months because of buttock fold asymmetry. There were forty females and five males. Pathology involved the right hip in forty-one, the left hip in four.

Of those referred shortly after birth for instability, six required treatment in a Pavlik harness. The remaining twenty-three were simply assessed regularly by clinical and radiological examination. At eighteen months all had hips which were both clinically and radiographically normal, without evidence of abductor contracture or apparent contralateral hip dysplasia. However, by four months they developed abductor contractures and, in some, other associated conditions (Fig. 1).

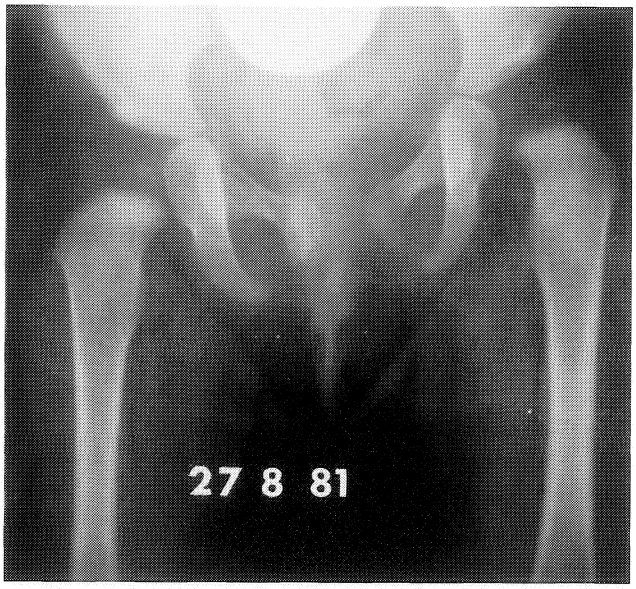

Figure 1
This child had normal radiographs with subsequent development of a right-sided abductor contracture followed by normal hip development.

The remaining sixteen patients were referred initially around age four months because of buttock fold asymmetry and all were found to have abductor contractures.

ASSOCIATED ASYMMETRY

Many of these children had more widespread asymmetry, giving rise to the expression "skeletal skew".[2] The skew was not present at assessment shortly after birth but developed by about four months. In the Edinburgh study the following were noted:

Plagiocephaly	68%	(Fig. 2)
Anterior thoracic molding	31%	(Fig. 2)
Scoliosis	22%	
Foot deformity	4%	
Torticollis	2%	

These babies may also have unilateral "bat-ear." (Fig. 3)

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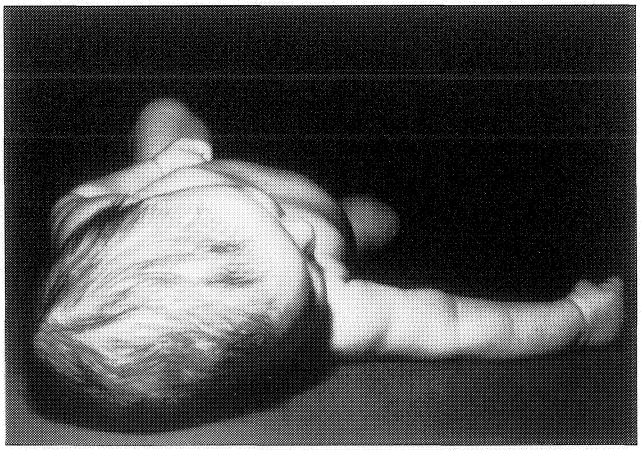

Figure 2
Photograph of an infant showing plagiocephaly and anterior thoracic molding.

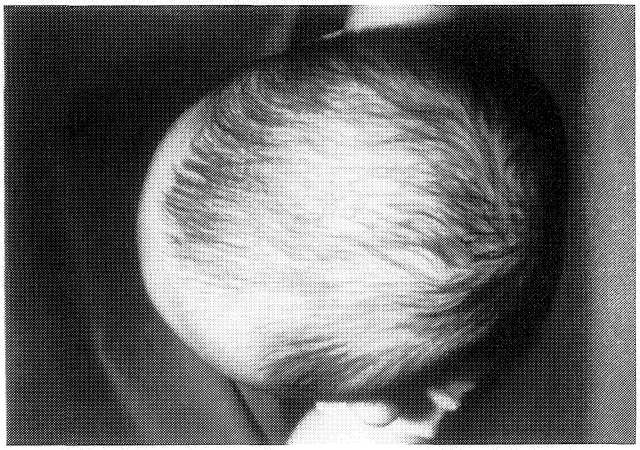

Figure 3
This photograph demonstrates unilateral "bat ear".

These anomalies are probably related to the posture the baby adopts in bed. Habitual side-lying will result in some or all of these findings.[2,3,4] This posture may be adopted simply because this is the position that the baby is placed in by the mother but will also occur when the bed is against a wall with the interesting objects on the outer side, therefore causing the baby to look predominately in one direction. If the child prefers to lie on the right side this may lead to a left plagiocephaly, left thoracic molding, a right sided bat-ear, an abductor contracture of the right hip and apparent dysplasia of the left side. A similar situation occurs when the baby is prone but tends to face predominately in one direction. (Fig. 4)

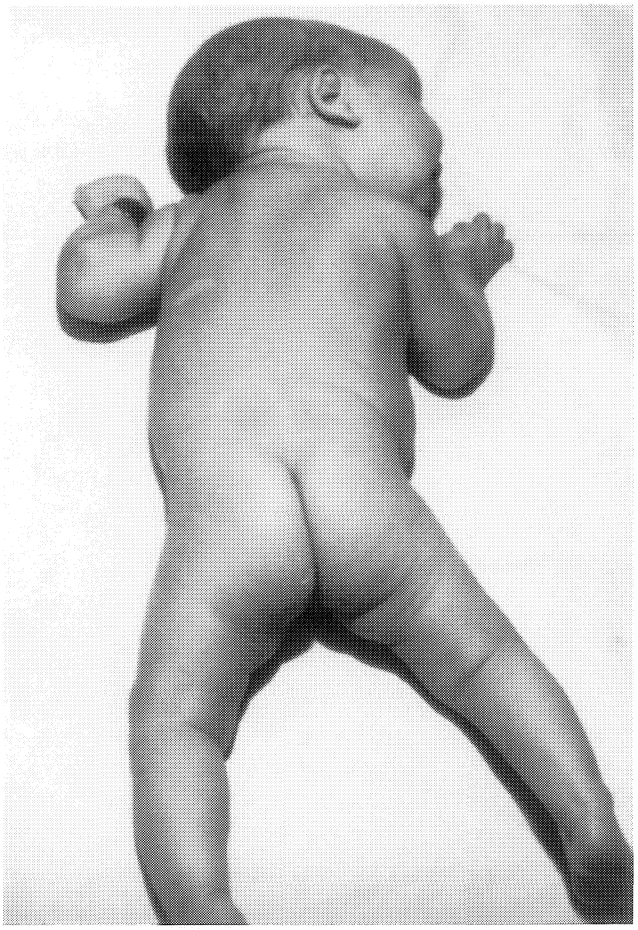

Figure 4

EXAMINATION

Careful assessment and examination of these babies is required in order to avoid unnecessary treatment. The mother must be asked about the sleeping habits of the baby, the position of the cot within a room, and how the baby is placed or lies within it. General examination should look for anomalies associated with skeletal skew, e.g., plagiocephaly and unilateral bat-ear.

All authors emphasize the use of the prone position to assess the degree of abductor contracture (Fig. 5). Hip assessment should be carried out with the baby in both the supine and the prone position. In the supine position emphasis should be placed on any limitation of abduction with the hips flexed to 90 degrees. With the baby in the prone position it is much easier to assess the degree of abductor contracture with the pelvis fixed (Fig. 6). The so-called dysplastic hip may appear adducted, but the total range of motion is equal on both sides with different arcs in relation to the midline.

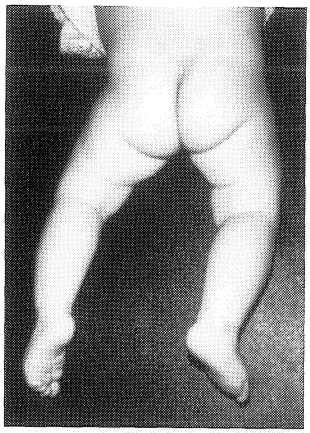

Figure 5

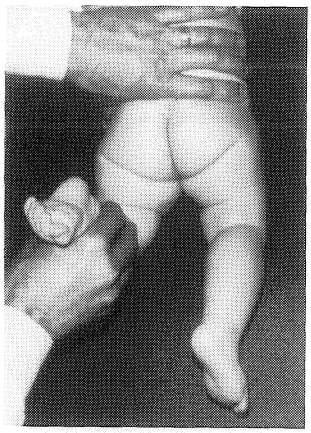

Figure 6

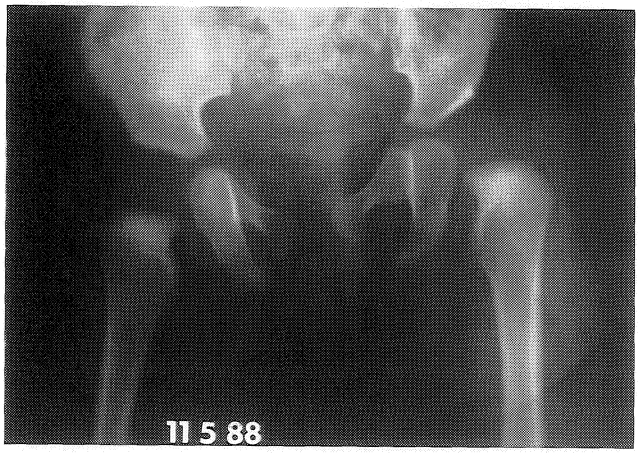

Figure 7
A rotated pelvic X-ray in which the left hip appears to be dysplastic.

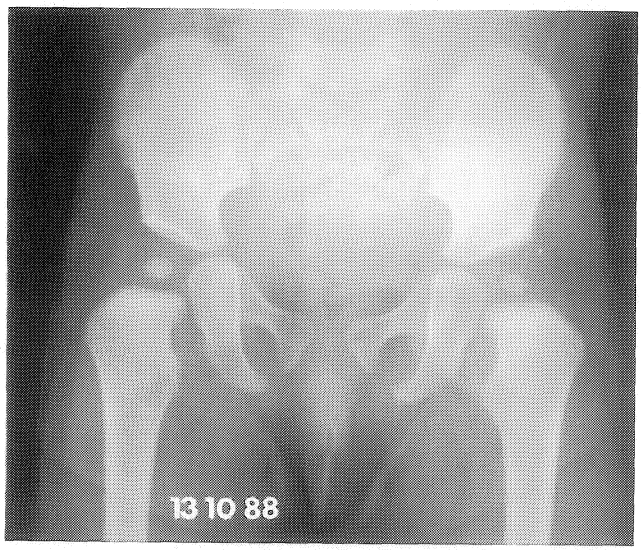

Figure 8
The same child showing normal hip development (note that there is no rotation and no pelvic obliquity).

Quality radiographs play an important role in the initial assessment of these babies. Rotation can be assessed by comparing the width of the iliac wings and the shape of the obturator foramina. In some cases of abductor contracture simply squaring the pelvis will demonstrate that the so-called dysplastic hip is in fact normal (Figs. 7 and 8).

If there are any concerns regarding head congruity within the acetabulum, arthrography may be used (Fig. 9). Ultrasound scanning may likewise be useful.

After initial assessment the child is seen at three month intervals, as a small proportion may require treatment in a Pavlik harness. Rarely, an adductor tenotomy is necessary for established contralateral dysplasia. The majority require no treatment and the child normally becomes symmetrical between walking age and eighteen months.

Figure 9
Radiograph (top) demonstrating apparent left hip dysplasia with a normal arthrogram one month later. The final radiograph (bottom) shows normal congruous development of the left hip.

DISCUSSION

Abductor contracture of the hip associated with contralateral hip dysplasia was first described by Weissman[5] in 1957. He studied fifty-one infants referred because of thigh skin crease asymmetry and apparent leg-length inequality. Examination revealed that leg-length was in fact equal and the inequality was due to an abductor contracture of one hip with downward tilt of the pelvis causing the abducted leg to appear longer. In Weissman's study the majority of children were greater than three months old at presentation but fourteen children were younger and presented with marked contracture. Of the fifty-one children, thirteen were not treated and spontaneous resolution occurred. Thirty-six were treated with abduction splinting, twenty-six responding rapidly and ten more slowly. Two had marked contractures and presented early. One developed a true dislocation at five months and the other had subluxation on radiographs but a normal hip at one year.

Weissman felt that the abductor contracture on one side led to the development of contralateral dysplasia. He felt that each then evolved separately, the contracture going on to spontaneous regression and the untreated dysplasia progressing to frank dislocation. The slow resolution of the contracture was attributed to the treatment of the dysplasia. He felt that some of the late presenters of true dislocation may have had a contralateral abductor contracture which had resolved spontaneously.

Griffin and Green[6] produced a similar study in 1982. Eighteen children, age three weeks to eight months, were referred because of gluteal fold asymmetry and apparent leg-length inequality. Examination revealed an abductor contracture of one hip with apparent dysplasia of the other. All were treated, fifteen with a Pavlik harness, two with stretching of the abducted side and one by with casts to correct the contracture. At subsequent assessment all hips were normal. They concluded that abduction splinting of the dysplastic hip with stretching of the contralateral hip leads to normal hip development. They had confirmed an association between acetabular dysplasia and abduction contracture of the contralateral hip.

In 1985, Heikkila et al[3] published a paper which dealt with a similar group of children. They studied forty-one infants with reduced abduction and dysplasia in the same hip. All had been treated with abduction-adduction exercises carried out at home by the parent. Hip development was normal in all cases. They concluded that acetabular dysplasia in the absence of instability was not significant. The authors noted some aspects of "skeletal skew" and the likely association with habitual half-side lying. Abductor contracture of the contralateral hip was not noted, but was probably present if examination for contracture was performed.

All four studies discussed above were looking at similar groups of children. Neither Weissman nor Green noted associated "skeletal skew", but we feel that associated anomalies were not looked for specifically.

The penalties for missing cases of true dislocation or potential instability may be catastrophic with a child doomed to multiple operations and possibly a total hip arthroplasty at an early age. The children with frank dislocation at birth should be picked up by an enthusiastic screening program. There is a spectrum of hip problems with true congenital dislocation at one end and true established dysplasia at the other. Within this spectrum are several groups with an uncertain degree of overlap between them:

A. Children with true congenital hip dislocation.
B. Children with a suggestion of instability at birth and a degree of abductor contracture in whom some may develop true subluxation.
C. Children who appear normal at birth with subsequent development of an abductor contracture and other aspects of "skeletal skew" but in whom later hip development is normal.
D. Children in whom the abductor contracture becomes fixed resulting in established contralateral dysplasia with some progressing to hip subluxation.[7]

Children who are late presenters with hip dislocation do not appear to fall within any of the above groups and probably represent another discrete group.

In Weissman's and Green's studies, the authors did not identify any manifestation of "skeletal skew". Identifying "skeletal skew" may have selected a group in whom treatment was not required thereby avoiding the potential risks of abduction bracing. The Finnish group was aware of the association but did not place any emphasis upon it.

Weissman treated the majority and Green treated all children with the combination of abductor contracture and apparent contralateral dysplasia. Neither author states whether or not any of the hips were clinically unstable. It is likely that only those which showed some instability required treatment, the remainder simply needed close observation. In Finland no hips were considered unstable but all the studied patients were treated by simple stretching exercises; even this was probably unnecessary.

In conclusion, there is a group of children referred with apparent hip dysplasia, who are stable on examination, have contralateral abductor contracture, and possibly some other manifestation of "skeletal skew." The majority of these hips are in fact normal and, apart from routine assessment, require no treatment.

Careful assessment is required in order to detect these children and avoid treatment with its small but definite risks. We would suggest that many of Weissman and Green's patients did not require "treatment." Similarly,

even the minimal treatment carried out in the group studied by Heikkila was probably unnecessary.

The child presenting around four months of age with abductor contracture and apparent contralateral hip dysplasia represents part of a spectrum of hip disorders. Many will have manifestation of "skeletal skew." Overlap between the various groups within this spectrum occurs and those requiring treatment must not be missed. The child referred early may have a greater tendency to true dysplasia than those who are seen later with the manifestations of skeletal skew.

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INTRAARTICULAR SPOROTRICHOSIS OF THE WRIST

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INTRODUCTION

Sporotrichosis is a chronic, indolent fungal disease with a multitude of clinical manifestations. The vast majority of infections are of the lymphocutaneous type, characterized by nodular and ulcerated violaceous lesions that follow the distribution of lymphatic vessels. Extracutaneous involvement is uncommon but can occur in the musculoskeletal, pulmonary, genitourinary, gastrointestinal and central nervous systems. The skeletal system is the most commonly affected extracutaneous site.[2]

The etiologic agent, *Sporothrix schenckii,* is a ubiquitous, saprophytic fungus first described by Schenck in 1889.[8] The organism has been isolated from decaying vegetation, timber and soil in both temperate and tropical climates.[6] In the United States, most cases of sporotrichosis have been reported in the North Central region and the organism is considered endemic to the Mississippi Valley.[4] Cutaneous infection is usually acquired through traumatic implantation of spores; however, the respiratory and gastrointestinal systems have also been implicated as portals of entry.[6] Bone and joint involvement usually results from hematogenous spread. Alternative routes are contiguous spread from adjacent subcutaneous lesions or direct inoculation.[10]

First described by Sicard in 1908, intraarticular sporotrichosis is an uncommon clinical entity.[9] Rowe et al. recently reported eleven cases seen over a twenty-eight year period.[7] Only three of these cases involved the wrist. This report describes a case of intraarticular sporotrichosis of the wrist joint and reviews the problems associated with this unusual and challenging infection.

CASE REPORT

A seventy-six year old retired mechanic first complained of pain and swelling in his left hand in March 1985. Examination revealed a large fluctuant nodule on the dorsum of his wrist which was incised and drained with subsequent relief of his symptoms. The patient remained asymptomatic until November 1986 when he experienced similar arthralgias followed by the development of nonpainful, violaceous nodules and ulcerating skin lesions on his left wrist and forearm. He did not seek treatment until April 1987 when skin biopsy and cultures were obtained. The cultures were positive for *Sporothrix schenckii* and lymphocutaneous sporotrichosis was diagnosed. The patient was treated with potassium iodide oral solution (SSKI) and his joint and skin lesions improved immediately. However, his course was complicated by the development of myasthenia gravis. Following complete resolution of the skin lesions and joint symptoms, and a negative repeat skin biopsy, the oral potassium iodide was stopped. Prednisone and Imuran were started for the treatment of myasthenia gravis. However, the Imuran was discontinued ten weeks later after the patient became anemic.

The patient remained asymptomatic until July 1988 when he complained of insidious swelling and pain about his left wrist. Examination revealed two 4 × 1 cm. nonpainful, freely moveable, fluctuant, erythematous masses on the radial styloid and dorsal ulnar surfaces. Range of motion of the wrist was limited to 10 degrees of radial/ulnar deviation and 10 degrees dorsiflexion. The patient was incapable of palmar flexion because of pain. Labora-

tory data were normal except for an erythrocyte sedimentation rate (ESR) of 45mm/hr. Radiographs of the hand demonstrated soft tissue swelling, extensive demineralization with subchondral erosions and radiocarpal joint space narrowing. (Fig. 1). An open biopsy and synovectomy was performed. The pathologic specimens demonstrated irregular dense fibrous tissue with an extensive mononuclear and plasma cell infiltrate consistent with chronic synovitis. Fungal cultures were positive for *Sporothrix schenckii.* The patient was started on parenteral amphotericin B and received a total of 2.5 grams over nineteen weeks.

Figure 1
Anteroposterior radiograph of the left wrist at presentation demonstrating soft tissue swelling, osteopenia, radiocarpal joint space narrowing, capitate-lunate fusion and erosions.

At one year follow-up, the patient was completely asymptomatic. There was no evidence of active cutaneous disease despite continued Prednisone therapy for myasthenia gravis. Range of motion of the wrist (right/left) was: dorsiflexion 50/43 degrees, palmar flexion 35/30 degrees, radial deviation 20/8 degrees, ulnar deviation 40/28 degrees. Maximum grip strength as measured on the Jamar dynamometer (right/left) was 28 kg./12 kg. Radiographs (Fig. 2) demonstrated mild collapse of the carpus

Figure 2
Anteroposterior radiograph of the left wrist at one year follow-up demonstrating multiple cysts and erosions and progression of joint space narrowing.

with progressive destructive changes consisting of joint space narrowing and multiple cysts and erosions.

DISCUSSION

Intraarticular infection is a rare manifestation of sporotrichosis. Two distinct clinical forms have been described: a unifocal form where joint involvement is the sole manifestation, usually involving one or a few joints; and a multifocal form of multiple joint involvement, along with skin and other organ system involvement.[12] Sporotrichal arthritis usually affects men fifty years of age or older.[12] Certain occupational groups appear to be at increased risk: farmers, florists, gardeners, and immunosuppressed patients. The majority of patients present with signs and symptoms suggestive of an inflammatory process, i.e., pain, warmth, swelling and limitation of motion. Morning stiffness and fever are typically absent.[3] Symptoms are usually prolonged and progressive. The most commonly involved joints (in descending order of frequency) are the knee, ankle, wrist and elbow.[1] The hips, shoulders, mandible, vertebra and ribs are usually spared.[4]

The most common laboratory finding in articular sporotrichosis is an elevated erythrocyte sedimentation rate. The white blood cell count is usually normal to slightly elevated.[12] Eosinophilia is occasionally seen, but usually does not exceed ten percent of the total leukocyte count.[11]

The synovial fluid is viscous and serosanguineous. Analysis of the fluid reveals an elevated leukocyte count[11], poor mucin clot formation[5], and a relative decrease in glucose concentration.[3]

As in our case, the radiographic appearance of sporotrichal arthritis is characterized by variable osteopenia, joint space narrowing, irregularity or erosions of articular surfaces, and soft tissue swelling. The differential diagnosis includes syphilis, pyogenic arthritis, metastatic disease, gout, rheumatoid arthritis, and pigmented villonodular synovitis.[4]

Histopathologic examination of synovial tissue typically reveals nodules with central necrosis surrounded by polymorphonuclear leukocytes, macrophages, epithelioid and multinuclear giant cells. These nonspecific subacute and chronic granulomatous inflammatory changes can also be found in other fungal infections, tuberculosis, rheumatoid arthritis and syphilis.[4] However, the presence of asteroid and cigar bodies suggests a diagnosis of sporotrichosis.[12]

The diagnosis is established by culturing *Sporothrix schenckii* from synovial tissue or fluid. Crout et al. showed that synovial tissue culture was more likely to be positive than synovial fluid.[3] However, when used together, they are more likely to produce positive results than either culture alone. The average time from onset of joint symptoms to correct diagnosis is twenty-five months (twenty-eight months in our patient).[3] The diagnosis is often delayed because sporotrichosis is an uncommon cause of arthritis, articular involvement often occurs in the absence of characteristic skin lesions, and the signs and symptoms are nonspecific.[12]

The cutaneous and lymphocutaneous forms of sporotrichosis are treated with oral potassium iodide solution (SSKI). Extracutaneous infection requires alternative therapy because many authors have described failure with iodide therapy alone. Parenteral amphotericin B, used alone or in combination with surgical debridement, is the treatment of choice in articular sporotrichosis.[4] The usual therapeutic dose is 1–2.5 grams administered over several months. Common complications from amphotericin B therapy include fever, chills, nausea, vomiting, hypokalemia, hypomagnesemia, anemia, and renal toxicity.[12]

The outcome of patients with articular sporotrichosis is not well documented in the literature. Several reports have described progressive joint destruction and functional impairment despite treatment, often requiring multiple surgical debridements and eventual arthrodesis. It is unclear if such changes are the result of treatment failure, persistent disease, or a consequence of delayed diagnosis and initiation of therapy.

SUMMARY

Sporotrichosis is an uncommon cause of joint infection, but articular involvement should always be included in the differential diagnosis of a patient with chronic monoarticular or oligoarticular arthritis. Radiologic, histologic and laboratory findings are relatively nonspecific. Diagnosis is established by culturing the responsible organism, *Sporothrix schenckii,* from synovial tissue or fluid. Delay in diagnosis is common, often resulting in increased morbidity and functional impairment. Treatment with amphotericin B and surgical debridement is effective in most cases.

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CHRONIC RECURRENT MULTIFOCAL OSTEOMYELITIS: EVIDENCE OF AN IMMUNOLOGICAL ETIOLOGY

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INTRODUCTION

Since its original recognition by Giedion in 1972[3] over sixty cases of chronic recurrent multifocal osteomyelitis (CRMO) have been reported.[4] There is general agreement that this is a discrete and definable syndrome but the precise etiology, or even a broad categorization of the cause, remains uncertain. The most commonly expressed opinion is that the condition represents an immunological process although there has been little collaborative evidence available to support this view. Indeed some authorities discount an immunological etiology altogether.

We report a case in whom typical features of CRMO were associated with marginal keratitis, a disorder generally recognized as being of an immunological nature.

CASE REPORT

A nine-year-old girl presented with a four week history of bilateral painful, red eyes. She also complained of pain in the interscapular region and in the anterior chest wall. Three years previously she had experienced episodes of pain and swelling in the ankles and more recently in the left knee. Ophthalmological examination established a diagnosis of marginal keratitis. Radiographs showed collapse of the fifth thoracic vertebral body, expansion of the anterior end of the right first rib and a flat lucent region with surrounding sclerosis abutting the left proximal tibial growth plate (Fig. 1A–1C). Similar metaphyseal lesions had been demonstrated radiographically in the distal tibiae three years previously (Fig. 1D).

Laboratory investigation showed a erythrocyte sedimentation rate (ESR) of 75 mm per hr. Hemoglobin, white

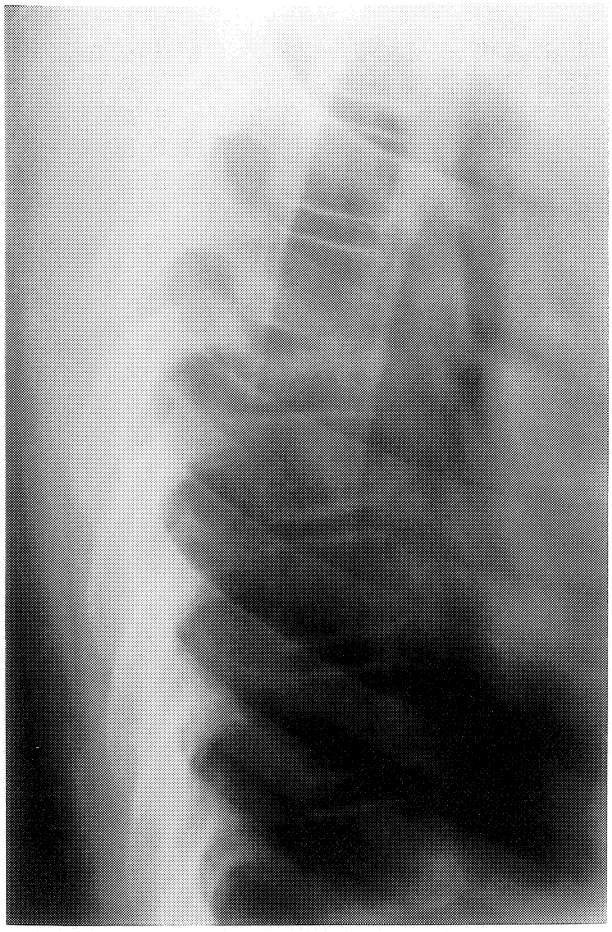

Figure 1A
The fifth thoracic vertebral body has collapsed.

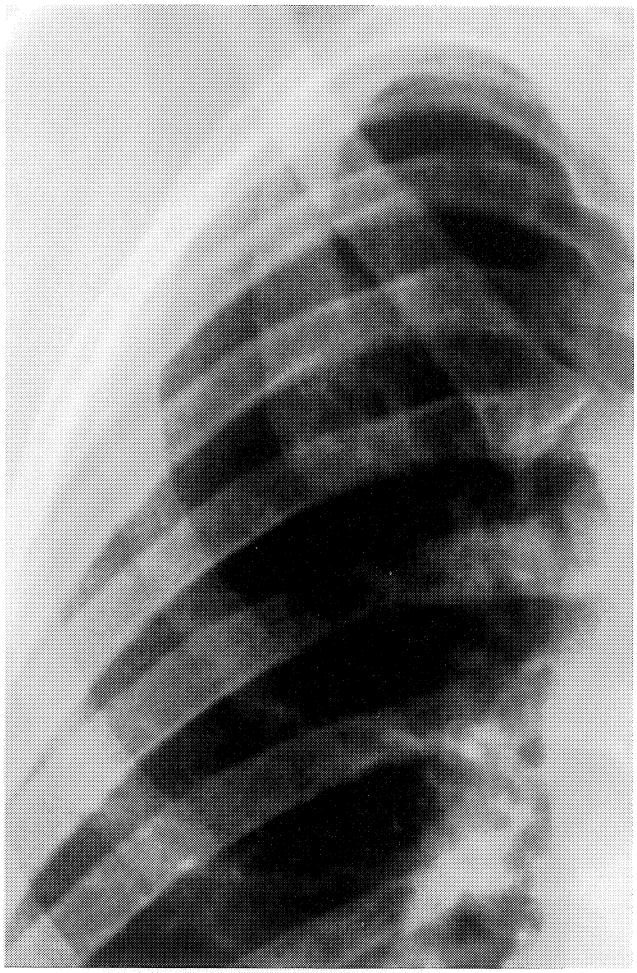

Figure 1B
There is expansion and destruction of the anterior end of the first rib.

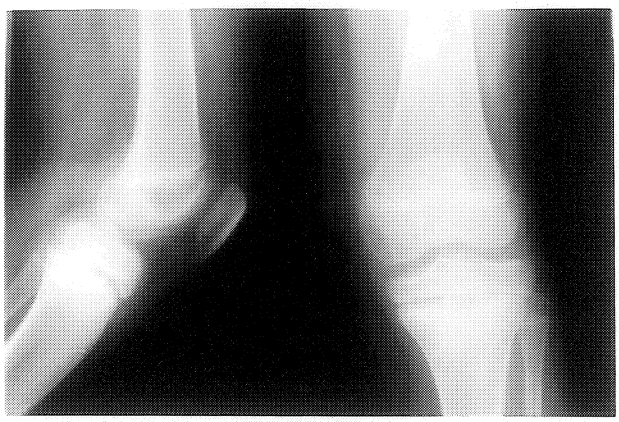

Figure 1C
Typical appearance of CRMO in proximal tibial metaphysis.

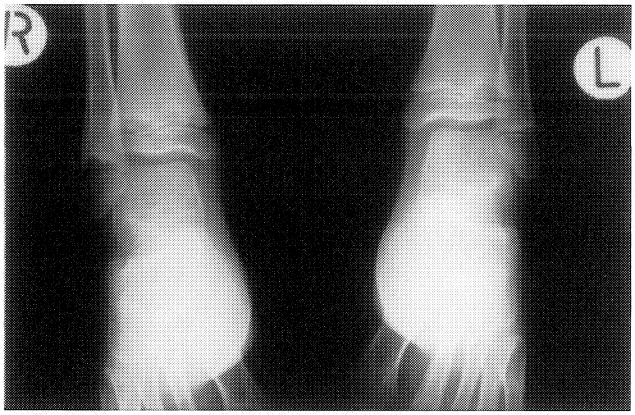

Figure 1D
Bilateral distal tibial metaphyseal lesions were noted three years previously.

cell count, liver function tests, serum electrolytes, antinuclear factor, rheumatoid factor, angiotensin converting enzyme, antistreptolysin 0 titer and urinary catecholamine estimations were all normal. The Mantoux test was negative.

A biopsy of the first rib lesion revealed histological features of active chronic osteomyelitis. No organisms could be cultured from specimens obtained at biopsy. Flucloxacillin 250 mgs tid was administered for three months and, although symptoms subsided, the radiological appearances remained unchanged.

DISCUSSION

CRMO is a condition characterized by the insidious onset of bone pain sometimes with localized tenderness and swelling. Radiographs suggest a subacute inflammatory process and biopsy reveals an inflammatory infiltrate which may be either acute or chronic depending upon the stage of the disease. Characteristically no pathogen can be identified and antibiotics do not influence the course of the condition; improvement has been reported with steroid administration.[5] Symptoms settle spontaneously after weeks or months only to recur later at another site. The condition may persist for up to fifteen years but can be expected to resolve without sequelae.

The cause of CRMO is not known. While the presence of a pathogen too fastidious to be cultured using current techniques has been suggested[6], debate has centered upon the evidence for or against this being an autoimmune process. Giedion et. al.[3] originally suggested an autoimmune etiology, in view of the distribution and pattern of the lesions and because autoimmune models were

accepted for such diseases as sympathetic ophthalmopathy. Further supportive evidence is the usual finding of a elevated ESR; the often favorable response to steroids and the observation that in 25% of reported cases there has been a elevated antistreptolysin titer.[2] Conversely, Bjorksten et. al., concluded that CRMO does not have an immunological basis when exhaustive investigation of nine affected patients revealed no consistent immunological abnormality.[1]

The case reported here has typical features of CRMO in combination with an unequivocal diagnosis of marginal keratitis, an inflammatory process in the eye which is a recognized component of such autoimmune processes as juvenile chronic arthritis (JCA). While the association might be coincidental, a common autoimmune etiology to both conditions is probable. Our interpretation of the available evidence is that CRMO represents an autoimmune process analogous to JCA but where an antigenic response is evoked not by synovial elements but by components of bone. This conclusion is not invalidated by normal laboratory tests for immune deficiency and autoimmune disease as they also are commonly normal in JCA. Perhaps a more appropriate and less cumbersome label for this condition would be Juvenile Chronic Osteomyelitis (JCO).

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THE HISTORY OF INFORMED CONSENT

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HISTORY OF INFORMED CONSENT

Informed consent for surgical procedures is a relatively new trend in the practice of surgery. For thousands of years physicians felt that deception was an integral part of the practice of medicine. Over the last 150 years, the concept of physicians establishing a "standard of care" has gradually been replaced by the idea that the well-informed patient can be the master of his/her own body. Thus, the practice of informed consent has emerged as surgery has become more patient-oriented.

EARLY HISTORY

In ancient Greece patient participation in decision making for medical treatment was considered undesirable. It was generally accepted that the physician's primary task was to inspire the confidence of the patient in the treatment. Any disclosure of possible difficulties might erode patient trust. Later, during medieval times, medical writing encouraged doctors to use their conversations with patients as an opportunity to offer comfort and hope while emphasizing the need for the doctor to be manipulative and deceitful. To effect a treatment cure, it was widely felt that authority must be coupled with obedience.[9]

During the Era of Enlightenment, new views emerged stating that patients had the capacity to listen to the doctor, but it was still felt that deception was necessary to facilitate patient care. During the 1800's the medical profession was split over whether to disclose a dire prognosis to a patient. However, most physicians of the time argued against informing patients of their condition.[9]

The doctrine of assault and battery has its roots in early English Common Law. This Doctrine forms the basis for the possible "injury" or "liability" incurred from surgery without proper consent.[3] Common Law is the combination of customs, traditions, and case law; it is distinct from legislative law which is law enacted by a governing body.[7] Many of these English Common Law doctrines have influenced our tort system of justice. Assault is a threat by one person to do bodily harm to another while battery is the actual touching of a person by another. Therefore, the theory of tort battery became the unauthorized touching of a person by another.[3]

As the concept of informed consent gained popularity during the twentieth century, the courts extended the English Common Law Tort doctrine of negligence to the field of surgery by equating negligence with breach of duty and breach of duty with an incomplete patient consent. Currently, the failure of a physician to provide adequate information to the patient about his/her own treatment is interpreted by the courts as a breach of duty by the physician.[3,9]

With this early background, let us turn in chronological order to some of the more significant legal cases of the twentieth century and then examine how these cases have shaped the current doctrine of informed consent.

Luka v. Lowrie, 136 N.W. 1106, Michigan 1912

In this case, a surgeon believed that an emergency amputation was necessary to save a child who had sustained a crush injury to his foot. Before proceeding with procedure the surgeon consulted four other physicians, all of whom agreed that an emergency amputation of the child's foot was necessary. The child's parents were unavailable to discuss the matter. Subsequently, the court ruled that if they had been available, the parents would have agreed with the need for an emergency amputation when informed that multiple physicians had been consulted, all of whom agreed with the need of an emergency procedure.

Schoendorff v. Society of New York Hospital, 211 N.Y. 215,105 N.E. 92,1914

This case has had probably the most impact on the doctrine of informed consent, and first established that the patient was an active participant in the treatment decision process. In this case, Justice Benjamin Cardozo summarized

> "every human being of adult years in sound mind has a right to determine what shall be done with his own body; and a surgeon who performs an operation without his patients consent commits a battery for which he is liable in damages".

Dicenzo v. Berg, 16 A2d 15, Pennsylvania, 1940

In this case, the court supported the defendant's (the physician) attempt to supply the patient with a description of the procedure to be performed even though the plaintiff (the patient) was not pleased with the outcome. The

patient had originally consented to a surgical procedure on his neck but was quite concerned about scarring the exposed portion of his neck. After the surgery, the patient felt that the surgeon's incision and subsequent scar were inappropriate, and subsequently brought suit. The court eventually ruled that the surgeon must be given sufficient latitude within the boundaries of the patient's consent to operate. The court determined that the surgeon had obtained adequate consent from the patient and had placed the incision appropriately and therefore should not be liable.

Prince v. Massachusetts, 321 US 158, 1944

Early in this century, the courts established a concept that has remained: parents cannot refuse treatment to their children on the basis of religious beliefs. In this case the Supreme Court stated "Parents may be free to become martyrs themselves, but it does not follow that they are free, in identical circumstances, to make martyrs of their children before they have reached the age of full and legal discretion when they can make that choice for themselves." Two examples are members of the Jehovah's Witness Church denying medically-necessary blood transfusions to their children and Fundamentalist Christians in southern West Virginia requiring children to handle snakes during worship services and refusing them medical attention once bitten. In both of these situations the parents would be subject to child neglect laws.

Bang v. Charles T. Miller Hospital, 251 Minn, 427.88 N.W. 2d 186, Minnesota, 1955

This case established that the patient was entitled to know inevitable risks or results of surgery. In this case an elderly male patient consented to a transurethral prostatectomy. He was not specifically informed prior to the procedure that the accepted surgical technique would in all likelihood leave him sterile post-operatively. The surgeons in this case were found liable.

Corn v. French, 71 Nev. 280,289 P. 2d 173, Nevada, 1955

Corn v. French established that the surgeon must not misrepresent the surgery to be performed. In this case, after examining the patient, the physician advised that she undergo a test for a possible malignancy of the breast. The patient subsequently asked the doctor if he intended to remove her breast, to which the physician replied "no". The patient then signed a written form consenting to a "mastectomy" even though she received no explanation of the procedure. Inevitably, the physician was found liable for an unauthorized procedure.

Natanson v. Kline, 350 P2d 1093, Kansas, 1960

In this case the court found that the patient, not the surgeon, must be the final decision maker. The final summary read: "A man is the master of his own body and he may expressively prohibit the performance of life-saving surgery or other treatment." A doctor may believe that an operation or other form of treatment is desirable or necessary, but the law does not permit him to substitute his own judgement for that of the patient by any form of misrepresentation or deception.

Darrah v. Kite, 32 A2d 108, New York, 1969

The verdict in this case established that each invasive diagnostic test requires a separate consent. This lawsuit resulted when the parents consented to having their child admitted to the hospital for "routine" brain tests in order rule out a developmental disorder. The physician then proceeded with a complete workup including invasive tests. Ultimately, the court ruled against the physician finding that "routine" brain tests did not include significant invasive studies and established that patients should not be admitted to a hospital under a general consent of admission and then receive a wide variety of invasive diagnostic tests without separate specific consents.

Green Case, 296 A.2d 681, Pennsylvania, 1971

In this case the court authorized blood transfusions for a Jehovah's Witness child with paralytic scoliosis. This patient had a 94° curve with pulmonary and cardiac impairment. The mother consented to a spinal fusion, but refused to consent to any blood transfusions. The court ruled that without the scoliosis surgery (and the incumbent blood transfusions) the patient would be considered under state law a neglected child because he did not receive the surgery required for his well-being. Subsequently, a court- appointed guardian authorized the scoliosis surgery and subsequent blood transfusions.

In re Osborne, 294 A2d 372, Washington, D.C., 1972

The courts have traditionally held that if a patient with dependents refuses a blood transfusion necessary to save his or her own life, the transfusion can be given. In this situation an individual's religious freedom can be superseded by the right of society to reduce the number of people on welfare and attempt to preserve the family unit. Over time, however, the courts have developed limitations to these restrictions based mainly on the doctrine of informed consent. An example of this is the Osborne case where a thirty-four-year-old married man with two children was severely injured when struck by a tree. The patient refused to accept blood transfusions on the basis

of religious beliefs. The patient was deemed fully competent and expressed the desire to obtain "everlasting life" rather than receive a blood transfusion. Subsequently the courts found that his wife was competent to run the family business and provide for the children. Additionally, if the wife was unsuccessful in managing the family business, then the wife's parents and brother affirmed that they would care for the children if necessary. The court then could find no obvious interest to society in restricting this patient's religious freedom, and so a blood transfusion was not ordered.

Cobbs v. Grant, 502 P2d 1 California, 1972

Prior to this ruling, courts in most states had upheld the prevailing "standard of practice" rule with respect to risk disclosure. The decision in this case posed the more liberal patient-oriented concept of the disclosure of risks:

> "Had the patient, judged as a reasonable and prudent person, been provided adequate information about the procedure and its risks prior to consenting to the procedure, or if some material risk had been presented, would the patient have refused to proceed with surgery?"

In this case the plaintiff (patient) underwent surgery for a duodenal ulcer and an artery at the base of the spleen was lacerated resulting in splenectomy. The patient had not been informed that injuries to the spleen occur in approximately 5% of duodenal ulcer repairs. Subsequently the patient sued for malpractice at time of surgery and for negligence on the part of the physician for failure to obtain a complete informed consent. The jury returned a verdict in favor of the plaintiff and assessed damages against the hospital and the surgeon.

Canterbury v. Spence, 464 F2d 772, Washington, D.C., 1972

The courts have generally affirmed that rare risks of surgery do not need to be specifically discussed as part of the consent unless these rare risks pose critical consequences. In this case Mr. Canterbury sought medical treatment for back pain from an neurosurgeon, Dr. Spence. Dr. Spence performed a myelogram which demonstrated a filling defect at the T4 level consistent with a herniated thoracic disc. Dr. Spence then proceeded to recommend the laminectomy which was performed. Preoperatively Dr. Spence did not provide a thorough description of the procedure and did not indicate that paralysis was a known complication to the procedure. Additionally, he did not indicate any alternative methods of treatment to Mr. Canterbury. Mr. Canterbury underwent an uneventful laminectomy and did well post-operatively until he fell from bed incurring a T4 complete paraplegia. In the lawsuit that followed the court held that Dr. Spence had been negligent in obtaining a complete consent. The court also stated that in consenting a patient the following must be included in order to assure that the patient has adequate knowledge of the procedure, the diagnosis and differential diagnosis, required diagnostic procedures, detailed description of the surgical procedure with any postoperative treatment necessary, the risks of the surgical procedure, any alternative methods of treatment, and expected results.

Richardson, 284 So.2d 195 Louisiana, 1973

The courts had established that when parents grant consent for children the procedure to be performed must have some specific benefit for the patient. In the Richardson case a child developed renal failure requiring renal transplantation. A second child in the Richardson family who was mentally retarded was deemed a renal transplantation candidate to the first child. The court later ruled that the parents could not authorize the mentally retarded child to become a renal transplantation donor because there was no specific derived benefit to the mentally retarded child.

Reif v. Weinberger, 372 F.Supp. 1196, District Court Washington, D.C., 1974

This case established that any consent given under physical or mental duress is invalid. In this case tubal ligation was recommended to a patient on welfare. The patient was also advised that if she did not have the tubal ligation, her welfare benefits would be significantly reduced. The District Court of Washington, D.C. determined that this was consent given under duress and not a voluntary consent. The consent was therefore deemed invalid and the surgeon was found liable for assault and battery.

In re Melideo, 390 N.Y.S. 2d 523, New York, 1976

In the Melideo case, Mrs. Melideo received a dilatation and curettage of the uterus for diagnostic purposes. After surgery, she developed significant bleeding. Mrs. Melideo refused blood transfusions on the basis of her religious belief against blood transfusions. Subsequently a court order was sought by the hospital in an attempt to authorize a transfusion against the expressed desires of the patient. The court determined that a patient may decline treatment and that to order such a treatment that is expressively refused by the patient on religious grounds would be a violation of that patients constitutional protection of religious freedom. Subsequently, the transfusion was not ordered.

Robert Quachenbush, 383 A2d 785, New Jersey, 1978

This case illustrates that medically necessary treatment other than blood transfusions can be refused for reasons other than religious reasons. Additionally, this case

points out that a patient's refusal of medically necessary treatment does not determine competence in treatment decisions.

Robert Quachenbush was an elderly male with a long history of peripheral vascular disease admitted to a hospital for treatment of bilateral lower leg gangrene. His temperature was elevated and cultures were positive for clostridium. The patient's lower extremities were black and drained purulent fluid; however, the use of IV antibiotics produced a temperature defervescence. The patient's physician recommended bilateral above the knee amputations on an emergent basis. Mr. Quachenbush, however, stated that he had objected to most medical care for over forty years and subsequently refused the recommended surgical debridements and amputations. The surgeon believed that Mr. Quachenbush was suffering from organic brain syndrome and presented the situation to hospital administrators. The hospital in turn petitioned the court to have a guardian appointed to make medical decisions for Mr. Quachenbush, who was felt to be incompetent to make treatment decisions because of his organic brain syndrome.

The court, however, found that refusal for above the knee amputations interfered with the accepted medical treatment for his condition. Mr. Quachenbush did have an understanding of the proposed procedure with his risk in expectations. The court felt that Mr. Quachenbush had a valid concern about the risks and subsequent rehabilitation after bilateral above the knee amputations. Therefore, the court found the patient to be competent to decide on surgical alternatives and ruled that the amputations could not be required based on the right to privacy under Federal Constitutional Law.

Bech v. Lovell, 362 So.2d 802 Louisiana, 1978

The State Court ruled that a spouse or family member cannot consent for surgery in place of the competent patient. The only exception to this situation would be the added presence of a medical emergency where the otherwise competent patient might be unable to participate in the consenting process. A family member's consent for an otherwise competent patient who had been sedated would therefore be inadequate. A second situation that could arise is the physician obtaining consent from a family member because the unavailability of the patient; such a consent would be considered inadequate based on this ruling.

Truman v. Thomas, 27 Cal.3d 285, California, 1980

Although the patient has a right to refuse tests or treatment, the courts have established that the physician has a duty to inform patients of the risks of refusal. In Truman v. Thomas, the patient rejected a family doctor's advice to have a pap smear. Subsequently, on repeated occasions the family doctor recommend a complete physical examination including a pap smear. The patient refused each of these pap smears and the physician assumed that the patient knew the purpose of the test and did not specially discuss with her the risks of failing to have the pap smear. Eventually, the patient developed advanced cervical cancer. In the lawsuit that followed, the California Supreme Court overturned a lower court ruling and stated that the physician had the duty to disclose all information to patients, including the possible outcome of refusing recommended screening tests for cancer.

Perna v Pirozz, 92 N.J. 446,457 A.2d 431, New Jersey, 1983

Surgery performed by a person other than the surgeon named by the patient at the time of consent constitutes battery. Additionally, the originally authorized surgeon who obtained the consent but failed to perform the surgical procedure is therefore liable for malpractice on the basis of breech of duty.

Precourt v. Frederich, 395 689,481 N.E.2d 1144 Massachusetts, 1985

The decision handed down in this case set limitations upon a physician's duty of risk of disclosure at the time of consent and could be interpreted as a "Tort Reform" case. In this case a patient underwent a surgical procedure on the eye for which prednisone was given postoperatively to control inflammation. Subsequently, the patient developed aseptic necrosis of both hips and a lawsuit resulted. Even though the Physician Desk Reference (PDR) lists aseptic necrosis of the hips as a complication from prednisone therapy, a witness for the defense testified that a library search of articles on the subject showed no reports of aseptic necrosis of the hips developing secondary to the postoperative use of prednisone after eye surgery. Therefore, a higher court overturned a lower court's jury verdict in favor of the plaintiff stating "in this case there was no evidence of the likelihood that a person would develop aseptic necrosis after taking prednisone or that Dr. Frederich knew or should of known that the likelihood was other than negligible.

Large v. Superior Court of Arizona, 714 P.2d 399, 1986

This case demonstrates that competence for consenting to surgical procedures may differ significantly from the competence necessary to execute other activities. In Large v. Superior Court of Arizona a women with organic brain syndrome and poor cognitive function was admitted to the hospital with a hip fracture subsequent to a fall. The risks and expected outcome of surgical repair for hip fracture was discussed with the patient by the operating

surgeon. At that time the patient was felt to understand the material presented and subsequently consented to the procedure. At the same time she executed a will in the presence of a lawyer. Postoperatively, the patient died and both the consent to surgery and her stated will were reviewed by the court. The court found that the will was invalid due to her lack of testamentary competence (the patient did not know the extent of her property or her family members). However, the surgical consent was considered valid by the court because the patient was able to understand the procedure, its risks, and potential benefits.

Younts v. St. Francis Hospital, 469 P2d 338 (1986)

In many states adolescents over fourteen years of age are considered adults with the right of privacy, confidentiality and competency to consent to surgical procedures. In Younts v. St. Francis Hospital a seventeen year old girl presented with a distal phalanx tuft fracture and skin avulsion after trapping the finger in a car door. The girl's mother was under general anesthesia at the time of her injury and her father (divorced from the mother) could not be located. After several attempts to locate the father the procedure to be performed was explained to the patient along with its risks, benefits, and alternatives. She subsequently consented to the procedure but a lawsuit followed. Ultimately, the court held that the patient, even though she was a minor, understood the nature of the surgery, possible risks, and potential benefits. Therefore, the consent was found to be valid.

With the above case decisions in mind, some conclusions about the doctrine of informed consent can be drawn. Whenever a physician obtains a consent from a patient, that physician should be mindful of the conditions necessary for informed consent, the information requirements necessary for an informed consent, patient competence in delivering his/her own consent and how consents in an emergency situations may be obtained.

CONSIDERATIONS FOR VALID CONSENT

As viewed by the courts, a consent is the authorization by a patient to have a certain medical treatment or surgery performed on that person. A consent may be expressed or implied. An expressed consent is one that is either written or spoken by the patient. An implied consent is one demonstrated by the acts of a patient. An example of an implied consent might be the presence of a patient in an examining room of a doctor's office. Although this patient has not formally said or written that he or she consents to a physical examination by a physician, he or she is present on his or her own free will and offers no resistance to examination. Therefore, a complete consent form is not a legal paper but merely a documentation of the patient's expressed desires for medical or surgical treatment.

For a consent to be valid it must be obtained from a knowledgeable patient who understands the procedure to be performed, as well as that procedures risks, complications, and possible alternatives. Additionally, the consent must be voluntarily given and not received under duress or threat. Most importantly, the consent must be given by a patient who is deemed competent to offer a medical consent.[3]

INFORMATION NECESSARY FOR A CONSENT

In Canterbury v. Spence 464 F2d 772 Washington, D.C. 1972, the court held that the consent must address six different information requirements for the patient to be truly informed. 1) The patient must be aware of the diagnosis. 2) The patient must be aware of any diagnostic procedures necessary to ascertain the diagnosis. 3) The surgical procedure must be described in a way that the patient understands. 4) The patient must be informed of any inevitable risks from surgery (frequent outcomes of surgery) and any collateral risks (any complication arising indirectly as a result of surgery). 5) The patient must be informed all alternative methods of treatment both surgical and conservative, and 6) the expected results and their probability should be discussed in sufficient detail with the patient prior to surgery.

CONSENTING COMPETENCE

For a patient to consent to a surgical procedure or a medical treatment he or she must be deemed competent from a medical point of view which, as pointed out earlier, may differ significantly from a legal point of view (Large v. Superior Court of Arizona, 714 P2d 399, 1986). The patient is considered medically competent and able to give consent when that person understands the procedure to be performed, appreciates the reason for the proposed procedure, and is aware of the risks of the procedure and the expected outcome. If the patient is considered incompetent to give a consent, the consent may be obtained from the next of kin (mother, father, wife, sibling, or child) or the statute of *parens patriae* may be evoked by the courts. A statute of *parens patriae* allows the court to appoint a guardian for a patient for the purposes of medical decision making.

Historically, children have not been considered incompetent to make medical decisions; however, in some states adolescents fourteen years or older are considered adults for medical consent purposes. Exceptions to the historical trend, however, include: 1) children or adolescents who are pregnant, 2) children or adolescents who are parents, 3) children or adolescents deemed self-reliant in that they

are living away from home and are independent, 4) children or adolescents who are members of the Armed Forces, and 5) adolescents who are considered mature minors being financially independent and self-reliant despite living at home with parents.[1]

EMERGENCY CONSENT

There are certain exceptions to the previously mentioned criteria for a valid informed consent. Such exceptions exist for emergency consenting. In this situation the physician may proceed with treatment without formal consent from the patient. This exception to the formal consent process was created based on the understanding that the patient, if able, would consent for the proposed procedure. However, frequently certain situations arise where severely injured patients cannot give consent and family members are unavailable. In these situations, treatment frequently cannot be delayed and it must be assumed by the physician that the patient or the family would provide authorization for the proposed treatment given the urgency of the situation. It is generally felt that for the physician to proceed in an emergency situation without consent the following must exist: 1) a true medical emergency, 2) the physician is truly unable to obtain consent from the patient or next of kin, 3) the proposed treatment is for the ultimate benefit of the patient.[2]

CONCLUSION

The doctrine of informed consent is a relatively new idea in the history of medical practice. The ancient practitioners of medicine adopted a paternalistic attitude towards patient care, and seldom involved the patient in the decision-making process. In the 18th and 19th centuries, the concept of assault and battery arose from English Common Law and established the idea that the surgeon must receive authorization from a patient before performing surgery or otherwise be liable for breach of duty. During the 20th century, various legal decisions have gradually swung the pendulum from a paternalistic, "standard of care" decision making approach to a more patient-centered concept:

"a man is the master of his own body...", (Natanson v. Kline, 350 P2d 1093, Kansas, 1960).

A valid consent, then, represents the evolutionary process from paternalistic medicine to patient-centered medicine. The consent must be given voluntarily by a competent, knowledgeable patient who understands the proposed treatments with their incumbent risks and alternatives.

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DECISION MAKING IN BUNION SURGERY

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INTRODUCTION

The decision making process in bunion surgery is critical if one hopes to achieve a satisfactory result on a consistent basis. This process starts with a careful history including the chief complaint, a work and athletic history, and identification of the type of shoe the patient commonly wears. Assessing the patient's expectation regarding the surgical procedure is critical. Many people feel that most foot surgery will achieve a perfect result and they can wear any shoe they wish after surgery. In our experience, one-third of patients still cannot wear the shoe they desire following foot surgery. Also, complications including joint pain, stiffness, a recurrence of the deformity, callus formation, avascular necrosis of the first metatarsal head or possible nerve entrapment should be explained to the patient.

The physical examination starts with the patient standing. The longitudinal arch is assessed and the degree of deformity of the great toe and lesser toes is observed. The patient is then seated and range of motion of the ankle, subtalar, transverse tarsal and metatarsophalangeal joints is noted. The mobility of the first metatarsocuneiform joint is checked by dorsiflexion and plantar flexion of the first metatarsal. The plantar aspect of the foot is carefully examined for callus formation beneath the metatarsal heads. The lesser toes are examined for evidence of subluxation or dislocation of the metatarsophalangeal joint as well as deformities of the interphalangeal joints.

The neurovascular status of the foot is carefully determined and doppler pressures are obtained if appropriate. The foot should be assessed for evidence of peripheral neuropathy.

RADIOGRAPHIC EVALUATION

Radiographs of the foot are always taken with the patient weight-bearing. The following radiographic determinations should be made:

1. The hallux valgus angle (normally less than fifteen degrees).
2. The intermetatarsal angle (normally less than nine degrees).
3. The presence of hallux valgus interphalangeus (lateral deviation of the distal phalanx, normally less than ten degrees).
4. The distal metatarsal articular angle (DMAA) (the relationship of the articular surface of the metatarsal head to the long axis of the first metatarsal, normally ten degrees or less of lateral deviation).
5. The degree of sesamoid displacement.
6. The size of the medial eminence (determined by a line drawn down the medial side of the first metatarsal shaft).
7. The presence of joint congruence (determined by drawing a line through the articular surface of the proximal phalanx and of the first metatarsal head. These lines are parallel to each other if the joint is congruent and nonparallel if the joint is incongruent).
8. The shape of the metatarsocuneiform joint (a laterally-sloped joint is less stable than a square shaped joint).
9. The presence of arthrosis of the metatarsophalangeal joint.

CLINICAL SIGNIFICANCE OF THE RADIOGRAPHIC FINDINGS

The radiographic findings must be carefully correlated with the physical findings, the patient's age, and the level of the patient's activities when planning hallux valgus surgery.

Hallux valgus interphalangeus is the intrinsic lateral deviation of the hallux itself. Whether or not this represents the entire deformity or if the deformity is at the metatarsophalangeal joint level must be determined. Obviously, a procedure at the metatarsophalangeal joint level will not correct hallux valgus interphalangeus. Only a phalangeal osteotomy will correct hallux valgus interphalangeus.

The hallux valgus angle defines the amount of lateral sloping of the proximal phalanx on the metatarsal head. This must be correlated with the congruency of the metatarsophalangeal joint. If the metatarsophalangeal joint is incongruent or subluxated laterally, then the proximal phalanx can be reduced to achieve correction of the hallux valgus deformity. If, however, the hallux valgus deformity

is associated with a congruent joint without lateral subluxation, a simple reduction would not be possible. Any attempt at correction would produce a recurrence of the deformity, or a stiff, painful joint.

The intermetatarsal angle, the angle formed by intersecting lines drawn along the first and second metatarsals, normally should be less than nine degrees. In order for a soft tissue procedure about the metatarsophalangeal joint to be successful the intermetatarsal angle needs to be corrected. If, however, the intermetatarsal angle cannot be corrected, a distal soft tissue procedure will probably fail to bring about a lasting result. Utilizing a distal soft tissue procedure alone, the average correction of the intermetatarsal angle is 5.2 degrees. If the intermetatarsal angle is fifteen degrees or more, the intermetatarsal angle cannot be adequately corrected with a soft tissue procedure alone. Therefore, metatarsal osteotomy probably needs to be added to achieve a satisfactory result.

The size of the medial eminence needs to be carefully evaluated in relation to a line drawn down the medial aspect of the first metatarsal shaft. At times, a rather severe deformity may be present with a small medial eminence; conversely, there may be a small hallux valgus deformity with a rather large medial eminence. Taking off a large piece of the metatarsal head will not correct the hallux valgus deformity and may result in a severe complication.

Arthrosis of the first metatarsophalangeal joint in my experience has not been a significant problem in most patients with a hallux valgus deformity. If a significant degree of arthrosis exists, usually any type of soft tissue procedure will fail.

EVALUATION OF BASIC SURGICAL PROCEDURES

In general, the types of bunion procedures include distal soft tissue procedures about the metatarsophalangeal joint, distal metatarsal osteotomies, proximal metatarsal osteotomies (combined with distal soft tissue procedures), phalangeal osteotomies, arthrodeses, and implants.

The distal soft tissue procedure has evolved over a period of time and consists basically of releasing the contracted structures on the lateral side of the metatarsophalangeal joint: the adductor hallucis, the transverse metatarsal ligament, and the lateral joint capsule. The soft tissues on the medial side of the joint, which have become somewhat attenuated, are plicated following removal of the medial eminence. This procedure yields satisfactory results in hallux valgus deformities (with an incongruent joint) measuring up to thirty degrees, and an intermetatarsal angle of less than fifteen degrees. If the intermetatarsal angle is fixed, even with a mild deformity, and a distal soft tissue procedure alone is carried out, a recurrence of the deformity may result.

Two common distal metatarsal osteotomies performed are the Chevron and Mitchell procedures. These procedures differ slightly from one another. The Chevron osteotomy translates the metatarsal head laterally 3–5 mm, which narrows the foot. If the distal metatarsal articular angle is sloped laterally more than fifteen degrees, one might consider adding a closing wedge osteotomy by removing 1–2 mm of bone from the proximal medial Chevron cut. This allows the articular surface to be rotated in relation to the metatarsal shaft, thereby aiding in correction of the hallux valgus deformity. The degree of correction afforded by the Chevron is limited. If the intermetatarsal angle is fifteen degrees or greater, the hallux valgus angle is 30 degrees or greater, or if significant pronation is present, full correction usually cannot be achieved.

The Mitchell procedure is a distal osteotomy capable of correcting a greater degree of deformity than the Chevron. The Mitchell procedure can be utilized for deformities up to forty degrees with an intermetatarsal angle of seventeen degrees. The distal fragment needs to be slightly plantar-flexed in order to compensate for shortening of the first metatarsal. The distal fragment can be slightly rotated to realign the distal articular surface, if indicated.

The proximal metatarsal osteotomy can achieve the greatest degree of correction of the intermetatarsal angle. When this osteotomy is carried out, it is always combined with a distal soft tissue procedure. There are three basic proximal metatarsal osteotomies: a crescentic-shaped cut, a closing wedge, and an opening wedge. The crescentic osteotomy, with the concavity facing proximally, is very stable and produces minimal shortening. The closing wedge osteotomy may produce some shortening and possibly even dorsiflexion of the metatarsal. An opening wedge osteotomy is somewhat unstable and can potentially lengthen the first metatarsal, further tightening tissue across the joint.

An osteotomy of the proximal phalanx (Akin procedure) corrects hallux valgus interphalangeus. It may also be used in a patient with a hallux valgus deformity associated with a congruent joint and a DMAA of less than fifteen degrees. Under these circumstances, the phalangeal osteotomy is combined with removal of the medial eminence. This procedure, however, is not capable of correcting any significant deformity of the metatarsophalangeal joint, and if one attempts to do so a recurrence or even a more severe deformity may result. The phalangeal osteotomy is also useful in the case of residual deformity after hallux valgus correction.

An arthrodesis of the metatarsophalangeal joint is an excellent procedure for the correction of severe deformities, failed bunion procedures, and/or advanced arthrosis of the MTP joint.

A metatarsocuneiform arthrodesis should be added to the hallux valgus correction when there is marked hypermobility of the first metatarsocuneiform joint. This, however, is encountered infrequently.

The use of a silastic implant in primary bunion surgery, in my opinion, is rarely, if ever, indicated. In patients with advanced arthrosis who do not desire an arthrodesis, a bipolar implant can be considered. The basic principle, however, in the utilization of any implant is that the implant itself cannot maintain the correction. Therefore it is imperative that the soft tissues be realigned and the intermetatarsal angle corrected so that the implant serves only as a spacer and not as a device attempting to hold the toe into proper alignment.

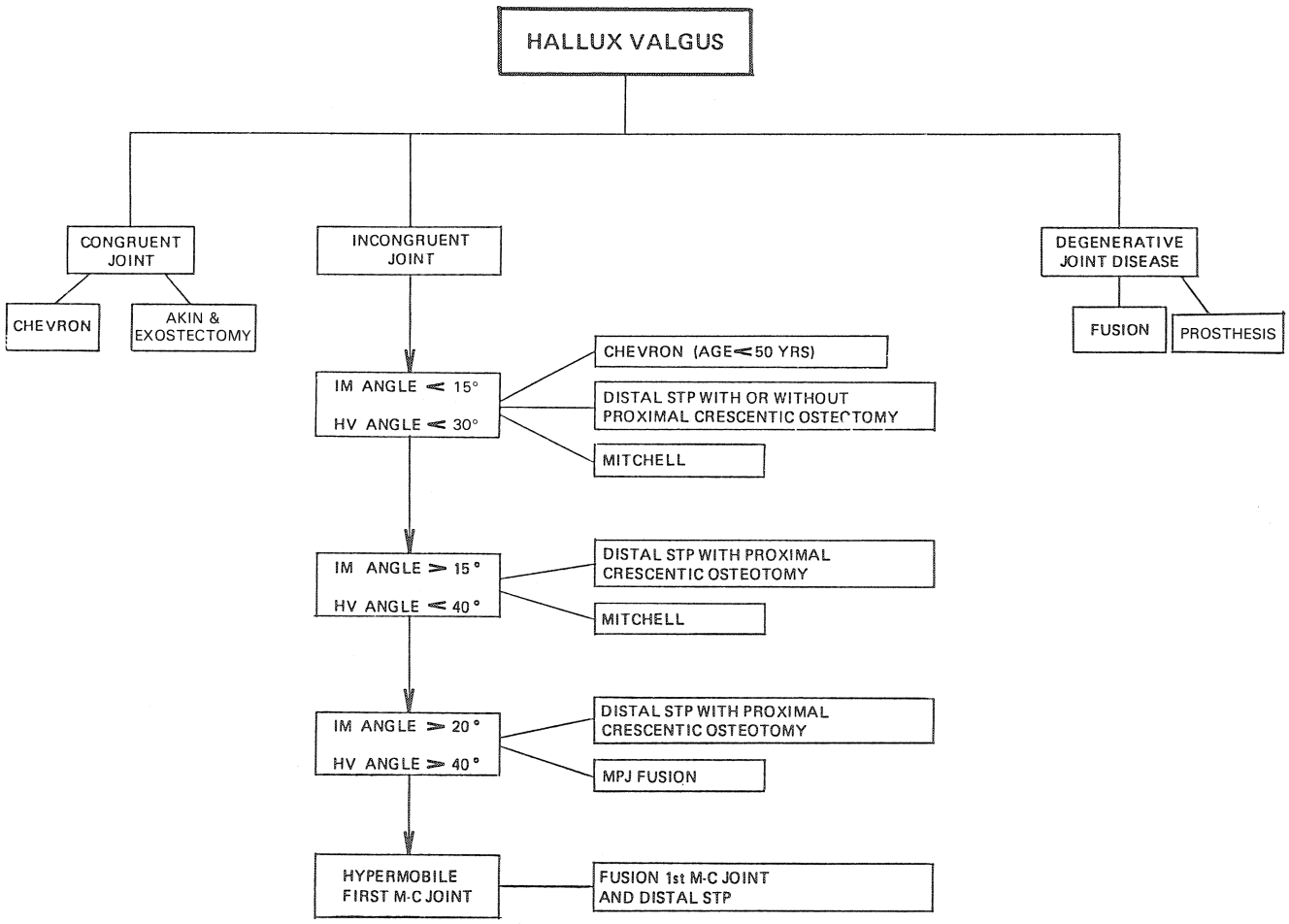
DECISION-MAKING PROCESS IN HALLUX VALGUS SURGERY

Many factors must be considered when selecting the operative procedures for hallux valgus deformity. I have developed an algorithm which I find useful in organizing my thoughts when contemplating hallux valgus surgery. It is based upon the pathologic anatomy as well as the various procedures that have been described in the literature. The main purpose of this rather arbitrary scheme is to permit the surgeon to logically approach the patient with a hallux valgus deformity. There are many other procedures besides those described in this algorithm which can be utilized to produce a satisfactory result. (Fig. 1).

The initial step is to assess the congruency and degree of arthrosis of the metatarsophalangeal joint. After consulting the algorithm, the following procedures can be considered.

If the joint is congruent a Chevron osteotomy or an Akin procedure with an exostostectomy can be performed. At times, the distal soft tissue procedure alone may also give a satisfactory result. If only hallux valgus interphalangeus is present, an Akin procedure will result in satisfactory correction. If the joint surfaces are congruent, any attempt to change the congruency will result in the development of an incongruent joint leading to stiffness, pain and recurrence of the deformity.

With an incongruent metatarsophalangeal joint the selection of procedures is based upon the severity of the deformity.



1. If the intermetatarsal angle is less than fifteen degrees and the hallux valgus angle less than thirty degrees, a Chevron osteotomy, a distal soft tissue procedure (with or without a proximal crescentic osteotomy) and a Mitchell procedure may all result in a satisfactory correction. As a general rule, the Chevron osteotomy produces a better result in patients less than fifty years of age with little or no pronation of the great toe. In patients with this degree of deformity, if the intermetatarsal angle does not correct adequately at the time of a soft tissue procedure, a proximal metatarsal osteotomy must be added to the procedure or a recurrence of the deformity may result.
2. If the intermetatarsal angle is greater than fifteen degrees and the hallux valgus angle less than forty degrees, the distal soft tissue procedure with a proximal crescentic osteotomy and Mitchell procedure are indicated. The Chevron osteotomy usually is not capable of correcting a deformity of this magnitude.
3. If the intermetatarsal angle is greater than twenty degrees and the hallux valgus angle greater than forty degrees one can correct the deformity by utilizing a distal soft tissue procedure with a proximal crescentic osteotomy or a metatarsophalangeal joint arthrodesis. The Mitchell procedure, as a general rule, does not produce consistent results in severe deformities. When evaluating a patient with a severe deformity, one must assess the soft tissues of the patient's foot. If the tissues are quite taut and the foot rather inflexible, an arthrodesis is better than a reconstructive procedure. The advantage of the arthrodesis is that the joint may be decompressed by resecting a sufficient bone to correct a deformity of any magnitude.
4. If there is hypermobility of the first metatarsocuneiform joint, a distal soft tissue procedure with an arthrodesis of the first metatarsocuneiform joint to correct the intermetatarsal angle and to plantar flex the first ray usually results in satisfactory correction. This procedure, however, is indicated in only two to three percent of patients with hallux valgus. I do not believe it should be used unless there is marked hypermobility of the first metatarsocuneiform joint with callus formation beneath the second metatarsal head indicating transfer of weight bearing from the first to the second ray.
5. The last classification is that of degenerative joint disease. If the degree of arthrosis precludes any reconstructive procedure then an arthrodesis or prosthesis may be utilized. I prefer the arthrodesis since it results in a more predictable outcome. A bipolar prosthesis has problems such as tissue reaction, breakage and osteolysis. The long-term result with a prosthesis certainly does not approach that seen following an arthrodesis. On rare occasions a Keller procedure may be utilized in the patient with degenerative joint disease; however, following this procedure, complications such as migration of the great toe with recurrence of the deformity and transfer lesions beneath the second metatarsal may occur.

Although a hallux valgus deformity is easily diagnosed, it must be carefully evaluated prior to selecting the operative procedure for each patient. In this way, satisfactory results can often be achieved.

INDIVIDUAL MEDICAL CARE ACCOUNTS

A PROPOSAL TO IMPROVE THE DELIVERY OF MEDICAL CARE

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Two roads diverged in a wood, and I—
I took the road less travelled by,
and that has made all the difference.
Robert Frost

The focus of debate over medical care is misdirected. It is commonly assumed that a market system exists, but this is a fallacy because a market system requires a consumer. The only party that can be a consumer in the traditional sense of restraining costs, stimulating maximum productive activity, and engendering responsible behavior, trust, and respect among all participants is the patient. Yet, the patient has been removed from this role, thereby creating an untenable relationship between third parties and providers, an arena which the government has been more than willing to enter with ever increasing vigor.

CURRENT SYSTEM

At present, few patients really care about costs because they do not pay the bills. The bills are paid by third parties and charges to patients are indirect, eliminating the patient as a consumer in the classical sense. Therefore, under the current system patients demand their rights, the opposite function of a traditional consumer who serves to restrain prices. Physicians in turn are not concerned about costs because patients do not continually complain to them about medical expenses, not only physician's bills, but charges from all providers. As a result, all parties involved, including hospitals, laboratories, suppliers, physicians, therapists, and others charge the absolute maximum which each feels lies near the boundary between ethical and unethical. It is exactly what a neutral observer viewing the scene would predict, given the system that exists.

In effect, the patient has become a means to an end, not a vital cog in the mechanism, but a tool manipulated by third parties and by providers. The current trend does not serve the best interests of anyone.

In actuality, the economic system that controls medicine today is a command (or controlled) economy. When this is recognized, the problems that exist in financing health care (epitomized by cost escalations erroneously perceived as uncontrollable short of government regulation) are no surprise. Not only predictable, they are inevitable, because the current system does not breed responsibility and accountability; it generates the opposite. In this sense, the system itself is unethical, undermining the most fundamental right honored by our forefathers and incorporated in our system of government: The right of individuals to control their own destinies with minimal coercion from the state. The net result has been to shortchange patients by usurping their rights and in so doing to condemn the population to less than optimum medical care.

All current systems, including prepaid, fee-for-service, or government sponsored plans eliminate the patient as a viable entity. While major differences exist between the current systems, they reside in a controlled economy, so the differences are minimal when compared to a market system. For instance, a study on the cost of medical care in a nonprofit compared to a for-profit hospital should not be expected to discover any significant difference. Both are part of a command economy. Neither functions as a market system and to state or imply that such a relationship exists is pretentious, most likely due to a misunderstanding of our medical care system as it currently exists.

There can be little question that the problems will continue to worsen until the patient gains control of the purse strings.

HISTORICAL PERSPECTIVE

The dominant feature of our medical care system over the past forty years has been an accelerating trend toward centralized control, a phenomenon paralleled only by the rapid escalation of costs. One of the early casualties during this period was the consumer (the patient) who has become a passive bystander, not an active participant because his rights have been usurped by politicians, government officials, insurance companies, and other third parties.

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After the government established Medicare in 1965, medical expenses for the majority of patients were paid by third parties. The money went directly from the insurance carrier to the provider, bypassing the patient. In general, patients paid either a minimum or a small percentage, so they demanded their rights regardless of cost because "I have paid for it." The true costs were indirect enough to be invisible to the average patient, so few really cared about them except as an intellectual exercise. Physicians in turn had little interest because patients did not continually complain to them about their medical bills.

To a physician viewing the scene between 1965 and 1983, the year Congress approved the DRG system, a make-believe world existed for there were no visible constraints on costs. Medical care providers, including physicians, hospitals, laboratories, and suppliers set prices at whatever level desired without regard to market forces because the consumer had been emasculated and no longer played a role in the economic system. In the absence of constraining market forces, decisions regarding prices had little basis in reality. Because medical bills were paid by faceless third parties, not by patients, escalations in costs were dramatic.

This system was untenable and it helped create a frame of mind that generated friction between doctors and patients. It also led to unrealistic expectations in patients who, freed from realistic monetary concerns, not only insisted that "the sky is the limit," but expected unrealistic results from treatment. Physicians, both individually and as a group, found it necessary to compete for their share of the health care dollar, thereby gaining the image of self-righteous egotists capable of focusing only on monetary gain.

In addition to hospitals, manufacturers, and physicians, other providers also maneuvered into positions where they could automatically tap into their share of the third-party cornucopia. For example, podiatrists, supported by a vigorous advertising campaign, justified fees that surpassed those of orthopaedic surgeons. Chiropractors discovered a windfall from third parties that paid for 50–150 treatments following an injury. And, in an increasing number of states, physical therapists gained the right of independent practice, in particular, approval to diagnose and treat medical problems without referral from a physician.

It was or, more accurately, it appeared to be the best of times after those providing medical care discovered the pleasures derived from spending someone else's money. But the system, based on faulty economic assumptions, was metastable, thereby precluding the possibility of achieving stability until the balance shifted toward either a market or a more completely controlled economy. With the passage of time the hope that compromise might salvage the time-honored strengths of our medical care system became an illusion.

Transiency produced an aura of unreality and uncertainty with expectations alternating between a sense of optimism to one of doom; optimism arising from confidence that the give and take of the American system would lead to a suitable solution, and doom propelled by rumblings of government actions.

In response to the continuing escalation in prices, the government introduced its own "solution," the DRG system, in 1983. This prospective reimbursement system under Medicare classifies patients into one of 468 diagnosis-related groups. Regardless of one's personal views on the merits of this system, it did reintroduce the concept of costs to medical care. Even so, it has also generated new problems, as expected from a program based on hypothesis, rather than experience, and enacted by fiat. Not only does the new system further estrange the patient, it creates an adversarial relationship between doctors and hospitals. These are regressive, rather than progressive, steps.

Because the underlying stimulus for governmental action has been rapid and medical costs continue to increase, success must be measured by the influence of past actions on costs. With such criteria, the judgment must inevitably be that the "solutions" introduced by the government have been dismal failures. Medical inflation has escalated to the point where it is now twice that of the consumer price index, making it the fastest growing category in the budgets of both government and business. Over 11% of our GNP is spent on health care, a figure which may exceed 15% by the year 2000.

A logical conclusion would be that the poor results obtained to date from attempts to control costs will stimulate a reevaluation of our medical care delivery system, leading to critical analyses based on reality, not on speculation. Unfortunately, current evidence indicates otherwise. The recent decisions of the federal government are increasingly rigid and punitive, giving life to the term "the hard hand of government." Even so, these actions are exactly what the historical record predicts: Government intervention invariably serves to increase the power of the government, rarely if ever to benefit the people. Therefore, new laws, regulations, and taxes invariably strengthen the hand of insurance companies and government agencies at the expense of the individual, whose options decrease another notch. Individuals, even those who are self-employed, have no right to withdraw from social security or Medicare in preference of another method of financing. The person who would like to establish an independent fund for medical expenses is soon discouraged by the tax laws which effectively eliminate this option. Yet prepaid health plans receive favorable treatment, even those where physicians receive monetary

bonuses proportional to their success in curtailing consultations, laboratory tests, and hospitalizations. Furthermore, the individual who questions the dictates of a third party feels powerless, which in fact is true because he does not pay the bills.

Likewise, government controls on hospitals and on physicians have steadily grown more onerous. In fact, the point has been reached where an independent physician who does not remain abreast of the latest rules is in danger of prosecution for unintentionally violating an administrative dictate, regardless of the physician's medical capabilities or the quality of care provided.

THE MARKET SYSTEM

A legitimate question could be posed: "If these views are correct, why hasn't the market system been adopted before, or even considered as a viable alternative?" Insight might be gained by reflecting on the overall status of the market system throughout the world. A more perplexing question would be: "Why has a system which has repeatedly demonstrated its merit economically over hundreds of years and one which recent events have shown to be the only system which can be justified on a moral and ethical basis been rejected by the majority of countries in the world?" The answers seem as obvious as they are frightening. Obvious because a market system requires a more sophisticated infrastructure than is found in many countries of the world. Perhaps the greatest stumbling block in most countries is the political structures that exist because the prerequisites for a market system include economic freedom, human rights, and private property rights, liberties which most autocratic rulers neither understand, nor will voluntarily relinquish. Frightening because even in the handful of nations where a market economy exists it is constantly placed on the defensive by those seeking special privileges from the government and by those who do not recognize its value, confirming Madison's warning that, "The price of liberty is eternal vigilance."

The fact that the market has survived in spite of constant opposition is evidence of its enormous power. It can easily outperform any other economic system, and despots vigorously oppose it, for when it gains a foothold they no longer have absolute control. Recent events in Eastern Europe clearly demonstrated this lesson.

A market system is desirable for reasons other than economic considerations per se. Most important is the fact that it recognizes the value of individuals, in contrast to governments or groups. It helps individuals to mature, to develop into independent, self-sufficient, adult citizens whose interests continue to expand, and to grow to their maximum potential by constantly reaching toward new challenges. It requires responsibilities, and it makes each person accountable for his/her own actions. While gaining confidence and self respect, the individual develops increasing respect for others which leads to cooperative, voluntary relationships, whether for business, personal, or societal purposes.

Consider the subject of budgets. In a government system accountability is nil. Budgets become wish lists to be judged according to the whims of those at higher levels. When control is centered at the top, individuals become relatively unimportant and will be neither rewarded nor penalized by the outcome. When productivity, efficiency, and financial responsibility are ignored, the basis for rational decisions has been lost, creating a haven for ineptitude and inefficiency. Could there be a better way to stifle incentive and individual initiative?

The defense industry provides insight on this subject. Few would question the critical importance of maintaining adequate military strength in today's world. Yet, problems arise because the unique nature of national defense dictates that some industries be kept viable to back-up the immediate deployment of military forces. The defense budget has grown large enough to dominate major areas of production in the private sector. Each year $125–135 billion flows from the military to private business. The distribution of this money is not market driven and this leads to legendary cost overruns. The budgetary excesses are not absorbed by the corporations at fault (as would occur in a market system) but by the government. Thus, this segment of the economy functions as a socialistic system, creating unhealthy ties between business and government.

The defense industry, being protected by the government, has had little incentive to remain competitive. As a result, it has developed a set of mores and a value system at odds with our economic heritage. This seriously handicaps a large segment of our manufacturing industry, which in turn influences the overall competitive position of the country. (It is not the intent of this discussion to reflect negatively on the defense industry. The question of how to fund an adequate military force while minimizing the negative effects on the country is a complex issue, for which there are no easy answers).

In contrast, the private sector that is outside the sphere of the defense industry is controlled by the market (except as distorted by government regulations and special favors). Therefore, this segment remains competitive by offering quality for cost.

Can proof of the above be found? Abundant examples exist, but postwar Germany provides one of the most dramatic. In 1938, the area which is now East Germany was highly industrialized and produced 10% more than the area which is now West Germany, as well as two-thirds of total German exports. Thirty-five years after the Second

World War ended, West German exports were approximately $188 billion and East German exports $21 billion, with West Germany holding the largest gold and foreign currency reserves in the world. In contrast, East Germany was billions of dollars in debt to the West. There seems to be no mystery about why these differences evolved.

The decade of the 1980's proved to be one of the most exciting decades in history. Not only did we witness the moral and economic bankruptcy of socialism, but the philosophical underpinnings of liberty were rediscovered and strengthened. We have watched people around the world discover the benefits and excitement of independence. More people now live under freedom than ever before in history.

Major strides have been made in this country as well, but we still have far to go. We have learned that "old fashioned" concepts are by no means dead. They may lie dormant for long periods of time, but once recalled to service, they are powerful as ever. Ten years ago the market system was moribund with serious concern for survival. Today, Adam Smith has been reincarnated and the market system has not only rebounded, but has eliminated the competition.

If a market system were implemented in medicine, the decrease in costs would be substantial, probably 25–50%, but some prices would drop to one-third of the current level. Furthermore, the decrease would be real, not theoretical. For instance, if a decrease in costs occurred under our current system any theoretical savings would be offset by the hidden costs of maintaining an adequate staff to monitor the system and to punish offenders.

It is said by some that a market system will not work in medicine because the patient is completely dependent on the physician, especially when under stress. The physician, therefore, is free to order unnecessary tests, to recommend unnecessary operations, and to charge exorbitant fees. In actuality, this argument would be stronger in support of a market system than against it because the system desired is one that will encourage mature, responsible behavior in all parties and cooperation between them. Only a market system has this capability.

PROPOSAL

1) *Change the tax law to permit individual tax-free accounts designated for medical care expenditures. These can be called Individual Medical Care Accounts.* All money paid for health insurance (currently over $2,500 for most employees, but frequently over $4,500), including that paid by the company as well as that paid by the employee, would be deposited in the account with the individual retaining complete control. The company would offer this plan to its employees in addition to the choice of a standard insurance plan or an HMO.

Most individuals would purchase an insurance policy to protect themselves against catastrophic costs. A major decrease in the cost of insurance occurs when policies have deductibles of $1,000 or more. Each family would determine the out-of-pocket expenses it could afford, whether $1,000, $5,000, $20,000, or more, and purchase a policy with that deductible. Therefore, it would be possible to secure adequate protection, yet most of the money would still be available to increase the capital reserve.

In effect, this plan would redirect some of the money that is currently controlled by insurance companies, as well as that needed to pay for monitoring adherence to ever-increasing regulations. This money would be deposited in savings accounts that would benefit the average citizen. An increase in savings would also benefit the country by providing the capital to finance job-creating investment. In the last forty years we have learned that "nothing works as well in a developed country as legalized tax-avoidance."[1] After World War II the Japanese discovered that a high savings rate would lower the cost of capital and the adoption of such a policy established a powerful competitive advantage. This suggests that tax-free accounts in this country could be intoxicating, an effect which not only has the power to decrease the cost of medical care without decreasing its quality, but would also have an unprecedented effect on the savings rate.

2) *Adapt the Individual Income Tax Return Forms to include a section for reporting the yearly activity of Individual Medical Care Accounts.*

Because the fund will be tax-deductible, there must be some mechanism to guarantee accountability. The simplest method probably would be a separate section on the Individual Income Tax Return Forms. This could then be completed by the individual, by a tax accountant, or by one of the investment or management services that the private sector inevitably will establish in order to assist individuals in establishing and overseeing these accounts.

IMPLEMENTATION

Implementation of any change in the status quo is dependent on a constituency, but cultivation of an interest group of this type is not a simple task. There are many forces against change. In addition to the natural resistance engendered by changes in the status quo, the major players, especially those with clout, have their own reasons for opposing any shift in direction, especially one that alters the philosophical base. The reasons in part stem from confusion concerning the type of system that currently exists, and in part from a lack of awareness of its implications. Resistance also is generated by a natural reluctance to relinquish control, in effect to voluntarily give up power. Therefore, those in a position to make the changes needed (politicians and government officials) are

unlikely to veer from their present course until such time as it serves their interests to do so. Insurance companies will be reluctant to consider changes they feel might be detrimental to their business.

Providers will probably resist the necessary changes, fearing that FDA restrictions will price them out of the market once competition reduces prices to their natural level.

There is little hope that planners will ever find the right answers. Their eyesight is too poor. A strange type of visual disorder invariably afflicts them. It is a curious phenomenon endemic to planners but also prevalent among certain other groups. Planners can see that quality, efficiency, and productivity are enhanced if resources are consolidated, duplication is eliminated, and control is centralized. However, they fail to see that this only happens on paper, not in the real world where the opposite occurs if the restrictions are mandatory, not voluntary, and are imposed by superiors. This seemingly paradoxical response is found because every action involving people, whether individuals or groups, has dynamic as well as static effects, with the static effects receiving the most attention. The dynamic effects are more subtle, but also more important. They occur because an action produces a response that would be predictable if it had no effect on the thinking and behavior of the individuals affected by it. In the real world, the action does alter response. This is probably most apparent in the economy, especially with changes in the tax code where the response to a tax increase or a tax decrease is not a simple arithmetic relationship that permits the resulting change in revenue to be calculated directly. The change in taxes alters spending habits and productivity making it far more difficult to predict the results. Thus it is essential to consider dynamic effects in any analysis, yet this is rarely done.

There probably is no group other than physicians that could devise and successfully promote a system that would preserve the positive attributes which have characterized medicine in this country. No other group is likely to have sufficient interest, nor is any other group likely to develop a working system that is based on reality, not on fantasy.

Yet, even physicians have been reluctant to support such changes. They will need to be educated and won over to this position. Physicians have prospered under the current system and like lemmings have adhered to their present course, arguing vigorously against changes they fear would adversely affect their income. Nevertheless, resistance from physicians is not based on the philosophical differences between a market economy vs a controlled economy or on the ultimate effect the economic structure has on patient care. Resistance is based on a feeling of insecurity due to an inability to influence events. Physicians are by necessity individualists, and the overwhelming majority are deeply concerned about their patients. Because of this, physicians can be expected to shift their support toward a workable solution as their knowledge increases. Even so, major support by physicians is more likely to emanate from the private sector than from the academic community where institutional security severely limits peripheral vision.

Last (as usual) is the patient, but such will not be true for long if realistic choices become available to the common man. Individual Medical Care Accounts are likely to be very popular. Not only do individuals in general prefer to control their own destinies, the opportunity to control what eventually may become a large amount of money will be very compelling. And when the patient gains control of the finances, a new era will begin.

How many individuals must establish these accounts to be effective as a dominant market force? Probably a majority of the non-indigent population will need to establish accounts. The precise number is less important than the type and capabilities of those who participate, and those most drawn to such accounts will be those most influential. In contrast, it should be recognized that a decrease in the overall cost of medical care will make it easier to provide care for the indigent population. Therefore, support for this type of plan permits delivery of the best medical care possible to the economically disadvantaged.

CONCLUSIONS

What is the likelihood that this type of plan might succeed, a plan generally accorded the least likely chance to even gain a hearing? Perhaps the odds are not as bleak as it currently appears, for this plan contains a secret weapon not yet widely recognized. It is built on an indestructible idea, an idea termed liberty which as recent events around the world have demonstrated, is more than a moribund remnant of the past.

The path of history from Euripides (Dionysus, 406 BC) to the collapse of the Berlin Wall on November 9, 1989 has repeatedly demonstrated the perils of government-sponsored coercion, not only on individual human liberties but on society itself. Furthermore, both history and theory demonstrate the existence of an obligatory symbiosis between a market economy and a political structure that respects both human liberties and private property. It is now known that one cannot survive without the other.

Finally, whether the issue is approached as an economic problem, as a philosophical issue focused on the long-term interest of the country, as a personal approach to the question: What can I do for my country?, or as a practical problem of health care delivery, a common point of interaction

can be found where the divergent views merge. From this point on the way is clear: Medical care is too important to be sacrificed by default to the vagaries of politics and the merciless hand of government. Further erosion of the economic base must be averted by establishing a stable source of funding, a foundation that is impenetrable. Now is the time to take the initiative and reestablish medicine as a national asset, rather than a political plum. We must resist the enticements of false prophets, look beyond the whims of politicians and focus on the welfare of the patient. Clear vision is needed to see the issues in perspective, together with a professional bearing lest we be sidetracked by personal bias.

If additional incentive is needed, reflect on the alternatives. The luxury of choice has disappeared, a time when blind adherence to the status quo could continue the present course. Only two alternatives remain: Either we relinquish complete control to the state or we reestablish the patient as the central figure in our medical care system.

Let us hope that we, as Robert Frost, can look back with satisfaction at having made the difficult choice.

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UNDERSTANDING THE CURRENT PRACTICE ENVIRONMENT

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Many physicians regard the current practice environment as a puzzling, uncomfortable, and often hostile milieu in which to practice medicine. Among other irritations, challenged medical decisions, excessive administrative regulations, and unwelcomed government intrusion into their professional affairs are cited frequently in support of this assessment.

Consequently, a wary and sometimes adversarial relationship seems to exist between the medical profession on one side and the Federal government and society on the other in regard to the conduct of medical practice and related care issues.

The current practice environment is unsettled because of interactions between differing health care objectives promulgated by government, society, and the medical profession. Practice environment turbulence associated with these interactions will not abate soon but an appreciation of the root causes underlying these differing health care objectives should, at least, contribute understanding as to why the current practice environment seems uncomfortable and hostile to some physicians. The practice environment has indeed changed dramatically over the past thirty five years and the reasons and events shaping that change must be appreciated if the current practice environment is to be evaluated in the proper context. The first step toward achieving a more serene and comfortable practice environment is to develop an appreciation and understanding among government, society, and the medical profession of each other's reasons for promulgating certain health care objectives. Understanding alone will not assure a more comfortable practice environment but it is an essential first step.

WHY DIFFERING HEALTH CARE OBJECTIVES EXIST

From the time this country was founded until 1965, the view prevailed in government and among the people and their representatives, collectively referred to as Society, that health care in general and medical care in particular was the exclusive business of physicians and they alone played the central role. Access to medical care was viewed as a family concern to be dealt with in the voluntary or private sector. Government saw its role limited to public health measures and assisting the very poor. That view, of course, does not prevail today. Societal and political changes occurring since 1965 effected marked differences and medicine no longer exerts much, if any, control over the economics of medical care. Physicians now practice medicine in an environment in which authority for many health care decisions is shared with society. An appreciation of some of the events contributing to this change is vital to an understanding of the current practice environment.

Among the plethora of events contributing to this change, three seem particularly germane. First was the Social Security Act passed in the 1930's. This legislation can be said to be the event that turned the Federal government's attention to having a national health policy. The second important event was the impressive role medicine played during and immediately after World War II. Government and society were impressed with what the profession accomplished in the care and rehabilitation of the wounded and this good feeling was translated into strong financial support for biomedical research and further enlargement of the NIH. This good feeling and increased support for biomedical research had, however, both positive and negative effects in regard to the practice environment. Attention focused on the ability of the medical profession to prevent and cure disease resulted in the development of some unrealistic expectations as to what the profession could do with regard to bettering the general health of society. When it became apparent that many of these expectations were not going to be fulfilled, at least in the foreseeable future, a type of rebound effect set in resulting in a lessening of the image of medicine previously held by government and society. The third significant event in the creation of the current practice environment climate was the passage of Medicare-Medicaid in the mid 1960's. This legislation marks the Federal government's first deliberate attempt to influence the delivery of health care. Because political compromise had to be reached with organized medicine, this legislation, as

finally passed, contained no checks or balances on the volume of provided physician services or physician fees. The economic consequences of Medicare-Medicaid can be appreciated better when it is noted that during the past twenty years these two programs pumped 1.13 trillion dollars into an essentially non-market medical economy lacking checks, balances, and regulatory feedback.[4] Ensuing attempts to constrain escalating costs of health care associated, in part, with the almost open-checkbook Medicare-Medicaid payment system for hospitals and doctors, have been major contributors to the unrest believed to exist in the current practice environment. Gaining control over the continuing escalation of health care costs has become the major focus of this country's national health policy since available financial resources do have finite limits. Between 1982 and 1987, expenditures for health care in the United States more than doubled to about $500 billion. The Federal government and society both believe the medical profession lacks the will and the ability to constrain health care costs without their intervention, direction, and, possibly, control. Constraining health costs, therefore, is the driving force for change in the delivery of health care from the viewpoint of the Federal government and the reason behind most of its health care objectives.

Neither the Federal government nor society is satisfied at this time with the performance of the medical profession, particularly as this performance relates to physician practice styles, utilization of health care resources, access to health care, and effectiveness of rendered care. Society, from their viewpoint, has become increasingly concerned that it is not getting the best quality of medical care for the dollars it spends. Despite the highest per capita expenditure for health and medical care in the world, this country has neither equity in access to health services nor the highest level of health compared with other developed countries. Furthermore, health services researchers have questioned the depth of the scientific base on which medical practice rests and have identified difficult to explain variations in physician practice styles relating to both uncertainties in medical decision making and geographic locations.[2,3,5] As a consequence society has, in effect, asked the medical profession to respond to the following unsettling questions:

1) How do physicians determine fees for their services and why is there such a variation in fees for the same services?
2) What standards of care or practice guidelines do physicians follow in their every day practice activities?
3) Can medicine prove its care is appropriate, effective, and high quality?
4) How are competent physicians validated and incompetent ones identified?
5) How much science is there in medical science?

The fallout associated with attempts to address these concerns of both government and society will influence, to a great degree, the climate of the current and future practice environment. The practice environment will be affected to a large extent by the profession's attempts to respond to the questions posed by society and, hopefully, by the profession reacting in a responsible fashion to governmental efforts to constrain rising health care costs. The practice environment will be serene or turbulent in proportion to how well the participants in this encounter address these challenges and how completely society and the medical profession understand and accept each other's primary responsibilities within the practice environment.

A CONCEPT OF THE PRACTICE ENVIRONMENT

A concept is suggested which, although hypothetical, can assist physicians to a better understanding of the environment in which they now practice. The current practice environment can be more readily understood if viewed as being composed of two distinct environmental compartments, structurally separate but functionally interrelated.

The first compartment, the professional environment, encompasses professional knowledge and values and relates to how physicians practice as professionals. This compartment is controlled by physicians but can be influenced, to some extent, by society. Issues that belong in this environmental compartment and, therefore, should be controlled by medicine include the knowledge base for medicine, quality of care issues, professional ethics, physician competence, practice guidelines, and peer review.

The second compartment, the socioeconomic environment, encompasses those factors relating to the environment in which physicians practice. This compartment is controlled by society but can be influenced, to some extent, by physicians. Society exerts control mostly by demands and desires expressed to legislators and those controlling the economics of medical care. Issues that belong in this compartment are those of the economics of health care and include topics such as physician and hospital reimbursement, catastrophic health insurance, funding for graduate medical education, and professional liability. It is the dynamics associated with each compartment and the interactions between them that determine and influence the climate of the practice environment.

Although separate and distinct by definition, the two environmental compartments can be considered as having permeable boundaries which allow some osmotic activity between them. Nevertheless, each compartment possesses its own particular characteristics and responsibilities and these qualities are dissimilar between compartments. For example, quality of medical care would seem

to be an issue standing astride both environmental compartments and an issue into which both physicians and society have major input. However, defining what constitutes quality medical care is a responsibility belonging to physicians and the professional compartment of the practice environment, while deciding how much to pay for quality medical care is a responsibility belonging to society and the socioeconomic compartment of the practice environment. It is when these responsibilities become confused and inappropriately interchanged (such as a PRO attempting to define standards of care) that increasing unrest and turbulence characterizes the practice environment. The key to understanding the current practice environment is to appreciate and accept the responsibilities belonging to each compartment and to recognize the proper interrelationships that should occur between these two environmental compartments. This concept of the practice environment suggests that interactions between physicians and society on health care matters could be more harmonious and productive if the principals in each compartment recognized and accepted each other's prerogatives and responsibilities.

Professional liability is a convenient topic to use to illustrate how the practice environment can be disturbed when the responsibilities of the two environmental compartments become confused and inappropriately interchanged. Medical organizations have spent enormous amounts of time and money at state and federal levels trying to decrease the professional liability problem by attempting to influence legislators to accept tort reform, screening panels, and caps on noneconomic damages, among other changes, with only limited success to show for this effort and expense. This concept of the practice environment would suggest that these attempts by the medical profession to ease the professional liability burden borne by physicians were doomed to enjoy only limited success because the profession aimed its efforts at the wrong environmental compartment. Medicine chose to concentrate its efforts in the socioeconomic compartment which is controlled by society and is, therefore, the wrong compartment for the profession to select if maximal results are desired. This practice environment concept suggests that the medical profession's efforts to influence professional liability in a positive fashion would be more effective if concentrated in the professional compartment of the practice environment and focused on those issues which the medical profession controls such as quality, effectiveness, and appropriateness of medical care and physician competence. The ideal way to defuse the professional liability problem, of course, would be to mount effective initiatives in both environmental compartments but, to date, medicine has done little in the professional compartment to counteract the burden physicians carry because of professional liability.

Practice guidelines and quality of medical care issues are convenient topics to use to illustrate how the practice environment would not be disturbed when the responsibilities of the two compartments are utilized appropriately. Practice guidelines and other quality of medical care issues clearly belong to the professional compartment of the environment and should be developed and implemented under the direction and control of physicians. It seems clear that defining and documenting quality of medical care in some objective manner is a professional responsibility. Only physicians, by virtue of their education and professional background, are capable of writing meaningful practice guidelines, defining quality medical care in objective terms, and indicating what is and what is not appropriate and effective medical care. Presently, government, insurance companies, and industry agree as far as these particular topics are concerned and are on record saying they will act only if the medical profession fails to do so. As long as each party acts responsibly and within its own prerogatives, the practice environment should not be affected. If, however, at some future time government, insurance companies, or industry reverse this decision unilaterally and decide to involve themselves in the establishment of practice guidelines or other quality of care issues belonging to medicine, the practice environment will become quite turbulent. This type of intrusion from one compartment to the other represents a usurping of prerogatives and an inappropriate interchange of primary responsibilities between the two environmental compartments.

Although society controls the socioeconomic compartment of the practice environment, this compartment can be influenced, to some extent, by physicians who have every right to try to do so. Government and society tend to approach most health care issues from the single focus of cost. One of the medicine's professional responsibilities toward government and society is to supply the understanding of professional views and values that will allow the discussion of health care issues to occur along a broader base than the single focus of cost. Medicine's views are sought and listened to when these views and values are presented in terms of being advocates for the best interests of patients. Medicine's influence is greatly weakened and its views less respected when the medical profession comes to the discussion speaking for professional self-interests. The medical profession does its best job of influencing the other environmental compartment when its speaks as an advocate for patients on issues in which it cannot be accused of intervening because of professional self-interest.

WHY UNDERSTANDING IS ESSENTIAL

Clinicians recognize that the actual practice environment is not as precisely structured as this hypothetical concept would suggest. Yet, thinking of the practice environment in terms of two compartments can lead to a fuller appreciation of practice environment dynamics and clearer understanding of the contributions of both society and the medical profession to the climate of this environment.

Each environmental compartment has a distinct primary responsibility and the principals in each compartment must appreciate and accept each other's primacy if subsequent interactions are to be harmonious and productive. Although the actual practice environment may seem more complex than can be explained by a single primary responsibility for each compartment, careful study will show that every issue identified in either compartment is a derivative issue of the primary responsibility. If it is not a derivative issue of the primary compartmental responsibility, it represents an inappropriate interchange between the two compartments.

In the context of the socioeconomic compartment, society's primary responsibility to the health care system is economic. Society must provide the funding to run the health care system in this country.

In the context of the professional compartment, medicine's primary responsibility to the health care system is to better the human condition and heal the sick and injured. In that regard the medical profession must provide:

1) access to health care for all patients needing care.
2) competent practitioners.
3) quality medical care provided with compassion and at reasonable costs.

In addition, the medical profession must work to improve the professional compartment of the practice environment and provide useful information and understanding to the environmental compartment controlled by society. Willingness to supply that information and understanding is essential if quality health care is not to be sacrificed to economic expediency.

It is hoped that physicians will come to regard the current practice environment as less threatening as they develop a better understanding of the forces interacting within this environment. It will become increasingly important for physicians to understand the effects of these interactions as this country's national health policy attempts to respond to concerns with costs, quality, and access to health care in the near future. The medical profession must respond to these attempts in a positive fashion but this will occur only if there is understanding of the reasons underlying these attempts. It seems possible, for example, that containing health care costs can be accomplished but at a price that might include national health insurance and/or health care rationing.[1] It cannot be denied that a growing debate about the American health care system has produced calls for radical reform of the system. Since escalating health care costs are a major problem for this country's economy and since society has an obligation to use available resources to provide the best possible health care to the greatest number of people, the kind of health care system this country should have and how to pay for it are questions that are going to be agonized over in both environmental compartments for some time to come.

Most physicians would prefer to find a way to improve the present health care system without dismantling it and destroying its fundamental strengths. This effort will succeed only if the medical profession is willing to work with others to eliminate weaknesses acknowledged to exist in the present system. It must be hoped that victory in this debate will not go to the side with the loudest voice but, rather, to the side that can convince society it can ensure the best health care at reasonable costs. It must be hoped that victory in this debate will go to the reasoned voice of a medical profession concerned not for its professional self-interests, but for its professional ideals, and a medical profession not willing to allow quality health care be sacrificed to economic expediency by government and society. Society will make the final decision in this debate and that decision will be influenced to a great extent by how well society believes they have been treated as patients by the medical profession.

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OSTEOID OSTEOMA OF THE PISIFORM

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Hiene[1], in 1927, reported the first case of osteoid osteoma. Since that time, examples of osteoid osteoma appeared in the literature under various descriptions until Jaffe[2] named the pathological entity in 1935. In 1953, Carroll described osteoid osteoma of the hand.[3] By 1976 involvement in all carpal bones had been described except for the pisiform.[4] In 1985 two cases of osteoid osteoma involving the pisiform were reported by Kernohan, et al.[5] Because of the rarity and unusual clinical presentation of osteoid osteoma involving carpal bones, this case is being reported.

CASE REPORT

A 17-year-old male "injured" his right wrist during the spring of 1985. He consulted an orthopedic surgeon in January 1986, because of persistent, progressive pain over the hypothenar region of his palm. The hand was swollen and tender over the pisiform area; however, no erythema or systemic symptoms were noted. Wrist range of motion was significantly restricted. AP and oblique radiographs are depicted in Fig. 1 and 2. Tomograms demonstrating a lucent area with a thin sclerotic border were interpreted as "a pisiform fracture." A previous radiograph of the wrist was normal. The patient was placed in a short-arm cast, but after 10 weeks of immobilization, the radiographic appearance of the pisiform was unchanged.

Four months later, examination revealed a tender, swollen, erythematous and warm hypothenar area. Radiographs showed the pisiform to be enlarged and porotic with an irregular cortex suggesting osteomyelitis (Fig. 3). Complete blood count, sedimentation rate, and C-reactive protein were normal.

Because of persistent and progressive symptoms and the significantly abnormal radiographs, the pisiform was excised. At the time of surgery, the pisiform was irregular, roughened and enlarged. The pisotriquetral joint was filled with rust-colored fluid. Minimal articular cartilage could be identified on either surface of the pisotriquetral joint. Erosions into the subchondral cortex of the triquetrum were noted. Gram stain and cultures of the fluid and bone were negative. An uneventful recovery ensued. Two

Figure 1
Initial AP radiograph with an enlarged, osteoporotic, granular pisiform having a small area of lucency with a thin sclerotic border.

Figure 2
Oblique radiograph showing widened pisotriquetral joint space and a pisiform of irregular density with a small lucent area.

Figure 3
Three months after the initial films, this oblique radiograph shows an enlarged, irregular pisiform with an indistinct cortical border. The pisotriquetral joint is widened and incongruent. Similar bony changes are noted in the adjacent triquetrum, and an erosion into the lunate is also present.

years later he was asymptomatic, had full wrist range of motion, and demonstrated normal wrist power and endurance with Cybex testing.

The samples of bone and soft tissue from the pisiform specimen demonstrated histology typical of osteoid osteoma including a partially mineralized subperiosteal nidus, proliferative osteoblasts and frequent osteoclasts, in a richly vascular fibrous stroma (Fig. 4).

DISCUSSION

Osteoid osteoma of the carpal bones is uncommon with approximately forty-five cases reported.[6–12] These case reports outline the frequent delay in diagnosis because of the uncommon occurrence and atypical presentation.[9,12,13]

Osteoid osteomas are most commonly seen between ages ten and thirty.[6,12,13] Frequency of occurrence is usually 2:1, male:female.[6,13]

As with osteoid osteomas elsewhere in the skeleton, progressive pain is the most common presenting complaint of carpal lesions[6,12,13], although painless osteoid osteomas have been reported.[14–16] Usually this dull, boring pain is most severe at night, with aspirin frequently giving dramatic relief.[3,6,15] Exam findings include swelling, erythema, warmth, tenderness and occasionally a palpable mass. Systemic signs and symptoms are uncommon.

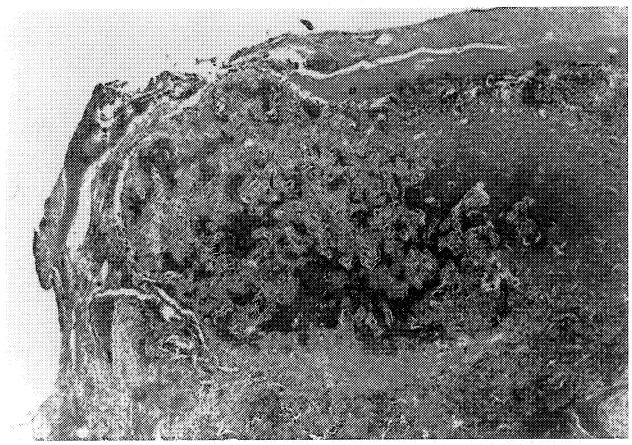

Figure 4
Photomicrograph of the excised pisiform with a typical nidus.

The classical radiographic appearance of osteoid osteoma is radiolucency with a peripheral ring of dense bone and a well-defined central nidus of calcification.[6]

However, the radiographic appearance with carpal bone involvement frequently differs from the classic presentation.[17] A granular opacity with a perimeter of radiolucency, described as a "ring sequestrum," is the frequent radiographic appearance in an affected carpal bone.[3,4,6,9,11] Other reported radiographic appearances of carpal osteoid osteoma include osteoporosis with adjacent degenerative changes[8], carpal enlargement with slight increased density[5], or only focal areas of increased density.[6,7,10] The radiographs can be normal for several months after the onset of symptoms.[18] Other studies may be helpful in establishing the diagnosis, including tomograms[6,12,19,20], bone scans[12,21], angiograms[22], or computed tomograms.[20] Synovitis is common if the lesion is near a joint, resulting in a radiographic appearance of joint space narrowing, joint irregularity and erosion.[7,8,23,24] Adjacent new bone formation may also be noted.[23] The differential diagnosis of carpal osteoid osteoma includes osteomyelitis, septic arthritis, synovitis, avascular necrosis, osteochondritis, tuberculosis, rheumatoid arthritis, and malignant bone tumor.[9,13,23,24]

The radiographic changes of carpal bones are not as helpful as in long bone osteoid osteoma. A typical clinical feature of pain is invaluable information. The pathologist must be aware of the clinical picture, think of osteoid osteoma, and then search diligently for the typical histology including the nidus.

Treatment of osteoid osteoma is complete excision of the lesion to avoid recurrence.[12,13,17,23,25] For the pisiform, complete excision of the bone is most effective.[5]

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SCOLIOSIS CARE TODAY: THE PRODUCT OF CLINICAL AND BASIC RESEARCH

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INTRODUCTION

Current scoliosis care is a combination of quality observation, orthotics and surgery. The responsible surgeon must know the indications and contraindications for each. Once a specific pathway of management has been chosen, then that pathway must be skillfully executed. Painstaking *clinical* research has provided the knowledge base on which critical treatment decisions are made.

OBSERVATIONAL CARE

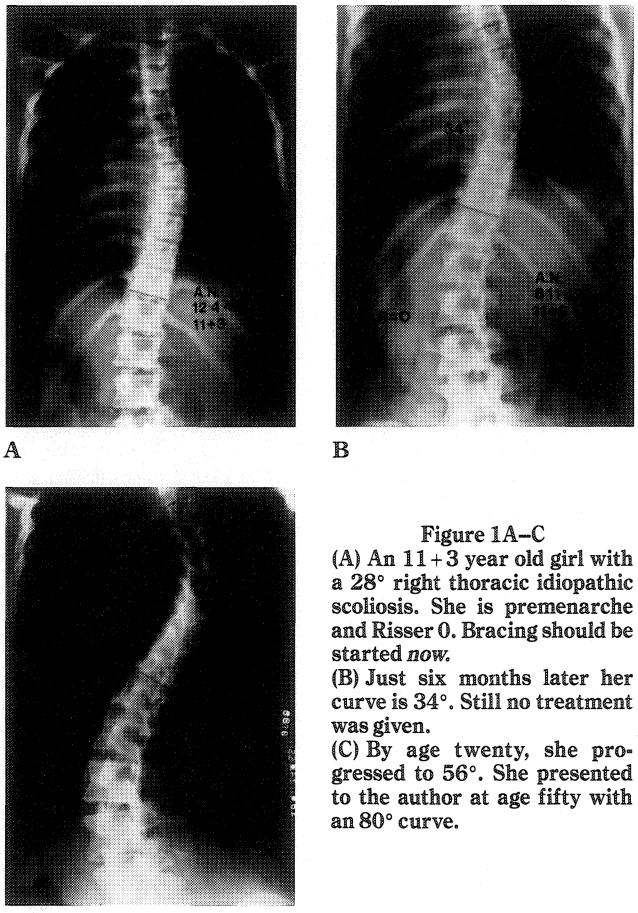
When a thirteen-year-old girl presents with a 20° idiopathic scoliosis, what should an orthopaedic surgeon do? When I was a resident, I was taught that all growing children with a 20° curve must be braced. This thinking was not based on any research, but rather on my professors' "empiric" knowledge.

In 1984, Lonstein and Carlson reported an analysis of 725 children with adolescent idiopathic scoliosis, all with curves less than 30°.[7] When subjected to careful analysis, those children Risser 2 or older with a curve of 19° or less, had only a 1.6% chance of progression. If the curve was 20–29°, the chance of progression was only 22%. Thus our thirteen-year-old girl, having a Risser sign of 3, has a 78% chance of *no* progression without treatment. It would be imprudent to apply a brace with such high odds of spontaneous stabilization. Lonstein and Carlson further noted that if a girl was Risser 0 or 1, and if the curve was between 20° and 29°, the chance of progression was 68%! Therefore, our thirteen-year-old girl, if Risser 1, *should* receive a brace.

What should we do if a six-year-old girl presents with a 36° scoliosis due to a T_{11} hemivertebra? To answer this we need, of course, a study on the natural history of such congenital anomalies. The classic work of McMaster and Ohtsuka reveals that some, but not all, hemivertebrae progress.[12] Thus, we should not immediately recommend surgery, but rather we should observe with care.

For such a congenital anomaly, careful observation means a checkup with high quality radiographs every six months. This radiograph must be measured with precision; failure to appreciate progression is a common problem.

Observational management is thus a true form of patient care based on high-quality clinical research. Conversely, basic research has been of little value. (Fig. 1)



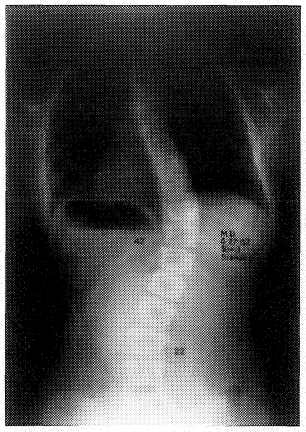
A B C

Figure 1A–C
(A) An 11+3 year old girl with a 28° right thoracic idiopathic scoliosis. She is premenarche and Risser 0. Bracing should be started *now*.
(B) Just six months later her curve is 34°. Still no treatment was given.
(C) By age twenty, she progressed to 56°. She presented to the author at age fifty with an 80° curve.

ORTHOTIC CARE

Though there are skeptics, bracing is the only method to pass the scrutiny of good clinical research. In 1988, Lonstein presented his analysis of 1030 adolescent idiopathic scoliosis patients treated with a Milwaukee brace.[8] Drawing from his previous natural history study, he knew that the critical group was the adolescent with thoracic scoliosis of 20–29°, who was Risser 0 or 1, and thus had a 68% chance of progression. This same group, placed in a Milwaukee brace, had only a 33% chance of progression. On the other hand, patients treated with electrical stimulators showed curve progression in 72%, no different from the natural history.[9]

As a result of these classic studies, we know now that if we wish to treat a child with idiopathic scoliosis non-operatively, bracing is the method of choice. Once again, all of our knowledge is based on clinical research; basic research has been of no value. (Fig. 2)



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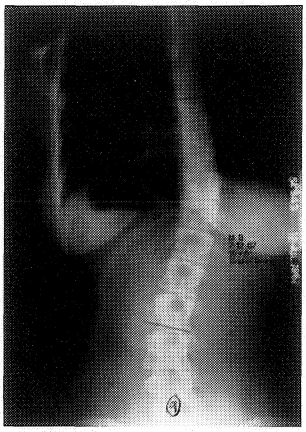

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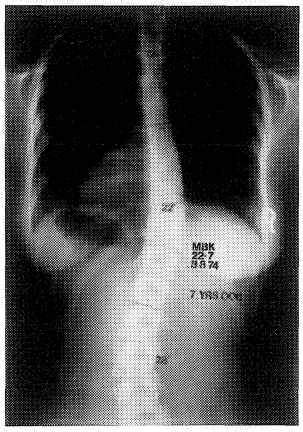

C

Figure 2A–C
(A) An 10+3 year old girl presented with a 42° idiopathic scoliosis. A Milwaukee brace was started immediately.
(B) At age 15+6 her brace treatment ended. Her curve was 21°.
(C) At age twenty-two, seven years after brace removal, her curve was 22°. Brace treatment *can* be effective!

SURGICAL CARE

The surgical treatment of scoliosis is spine fusion in a corrected or partially corrected alignment. Thus the questions are 1) when is surgery indicated?, 2) what part of the spine needs to be fused?, 3) should the fusion be anterior, posterior, or both?, and 4) what method of correction is best? These critical questions are the same for all patients, but the answers differ widely according to the diagnosis and age.

IDIOPATHIC ADOLESCENT SCOLIOSIS

The indications for surgery in adolescent idiopathic scoliosis are a curve that has progressed to an unacceptable level despite brace treatment, or one that presents already too large for bracing. When surgery is recommended, we must select the fusion area and the methodology to achieve fusion.

Selection of the fusion area was a great mystery to many surgeons for a long time. In 1983, King published a review of patients who had had posterior spine fusion for adolescent idiopathic *thoracic* scoliosis.[6] He showed that if the surgeon was cognizant of five basic patterns of curvature, was able to recognize vertebral rotation, and understood the "gravity central line" (stable zone), proper fusion area selection was possible in every case.

Recently, the popularity of Cotrel-Dubousset instrumentation (CDI) has brought into question King's criteria for selection of the fusion area. Shufflebarger has been the most vocal critic, stating that King's rules no longer apply.[14] Shufflebarger's criteria insist that instrumentation must always cross the thoracolumbar junction, i.e., the fusion must always go down to at least to L_1 or even L_2.

We have recently reviewed our own experience with CDI in adolescents and find that King's rules are satisfactory, and Shufflebarger's criteria often require a longer fusion than is really needed.[11] We feel the pathologic anatomy of the curvature dictates the extent of the fusion, not the instrumentation.

While we are on the subject of CDI for adolescent idiopathic scoliosis, we must discuss the problem of surgically-produced decompensation. There is disturbing tendency of patients with King type II curves, the false double major pattern, to end up with excellent correction in the fused thoracic spine, not much correction in the unfused lumbar spine, and marked torso decompensation. In my opinion, this is simply an overcorrection of the primary curve beyond the ability of the lumbar curve to compensate, and reflects the enormous corrective capability of CDI. This problem is not new and was identified by VonLackum in a 1949 discussion of the different types of cast correction.[18]

Others, particularly Transfeldt and coworkers, have done sophisticated multilevel CT studies and feel that decompensation represents an "uncoupling" phenomenon, i.e., a counter-rotation in the compensatory curve in response to the surgical derotation in the primary curve.[17]

Whatever the reason, we must be cognizant of the power of CDI, and use that power with restraint. Sometimes surgery must stop short of maximal correction so that the patient remains in balance. (Fig. 3).

ADULT SCOLIOSIS

The spectacular success of Harrington instrumentation and fusion in adolescent idiopathic scoliosis in the early 1960's led to the surgical treatment of adults with scoliosis. I vividly remember assisting Dr. Moe in the first adult scoliosis surgery in Minneapolis in the late 1960's.

The first publication on the surgical treatment of adult scoliosis was by Gui and Savini in the Italian literature in 1975.[4] They reported on sixty-five patients, forty having curves greater than 100°. The most important results of

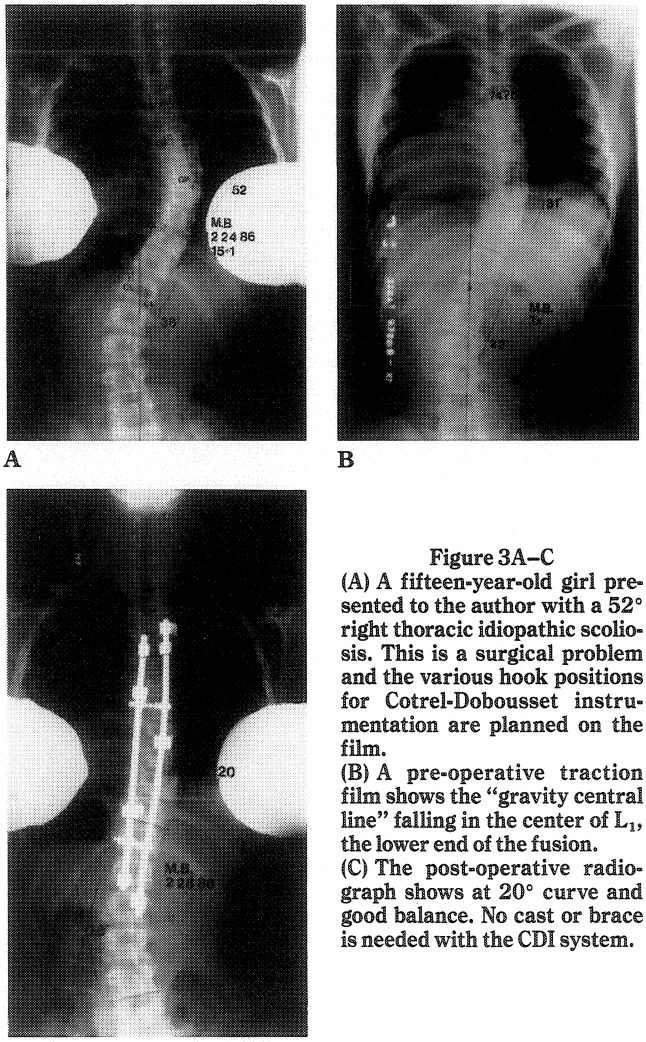

Figure 3A–C
(A) A fifteen-year-old girl presented to the author with a 52° right thoracic idiopathic scoliosis. This is a surgical problem and the various hook positions for Cotrel-Dobousset instrumentation are planned on the film.
(B) A pre-operative traction film shows the "gravity central line" falling in the center of L_1, the lower end of the fusion.
(C) The post-operative radiograph shows at 20° curve and good balance. No cast or brace is needed with the CDI system.

their analysis was an average of five cm. height gain and an average of 11% increase of pulmonary vital capacity following surgery.

In 1978, Stagnara reported on 301 surgically treated adults with curves greater than 100°.[15] The critical points were his concepts of 3-dimensional spine deformity—i.e., "kyphosing scoliosis", and the need for combined anterior and posterior fusion.

The same year, Swank, et al., presented the first paper in the English literature on the surgical treatment of adult scoliosis.[16] 118 of their patients (53%) had one or more complications, a much higher rate than seen in the surgical management of adolescent idiopathic scoliosis. Additionally, the study showed that the pre-operative halo traction was useless except in those patients presenting with cor pulmonale.

NEUROMUSCULAR SCOLIOSIS

Scoliosis secondary to poliomylelitis led Dr. Paul Harrington to develop the rods which bear his name.[5] In this day of CD's, Zielke's, Luque's, and other instrumentation systems, we tend to forget the monumental contributions of Dr. Harrington. Confronted with a large number of patients with post-polio scoliosis, Dr. Harrington quickly realized that traditional methods of cast correction were often lethal. He therefore developed the Harrington posterior instrumentation system.

The Harrington system went unchallenged from 1960 to 1978, when Luque developed his concept of segmental fixation based on sublaminar wiring of rods having no hooks or distractive component.[10] Luque's system was initially based on clinical experience; years later, basic science analysis of his system was done.

The Luque concept of segmental fixation with sublaminar wires is now widely accepted as the procedure of choice for patients with neuromuscular scoliosis. (Fig. 4) The excellent results of this system have been reviewed in several clinical studies.[1,3] Additionally, basic research studies support the use of the Luque system in selected cases. One example is a recent biomechanical study by Coe and McAfee which evaluated the load-to-failure strengths of various spinal implants in osteoporotic vertebrae.[2] Because the laminae are stronger than other parts of the vertebra in osteoporosis, sublaminar hooks had almost twice the resistance to pull-out compared to pedicle screws. We have known this clinically since scoliosis in osteogenesis imperfecta can be successfully corrected with a Luque system.

SUMMARY

There have been enormous strides made in the treatment of scoliosis, especially since 1970. A condition which was once considered the "cancer" of orthopaedics is now successfully treated around the world.

The absence of an experimental animal with scoliosis has forced us to depend on our own patients as the model. Clinical research has led the way in treatment, both non-surgical and surgical.

Unfortunately, the etiology of idiopathic scoliosis remains a mystery; only good *basic* research will discover the answer to this problem.

Good clinical research has provided us with a system for the management of scoliosis in the 1990's. We can observe with skill when necessary. We can non-operatively treat our patients with good orthoses. If necessary, we can perform surgery with a high degree of success and a low degree of risk or failure.

There are several different surgical techniques and a multitude of instrumentation systems including Harrington, Zielke, Luque, and Cotrel-Dubousset. No one method is best for all problems; the skilled surgeon must know when and how to use each.

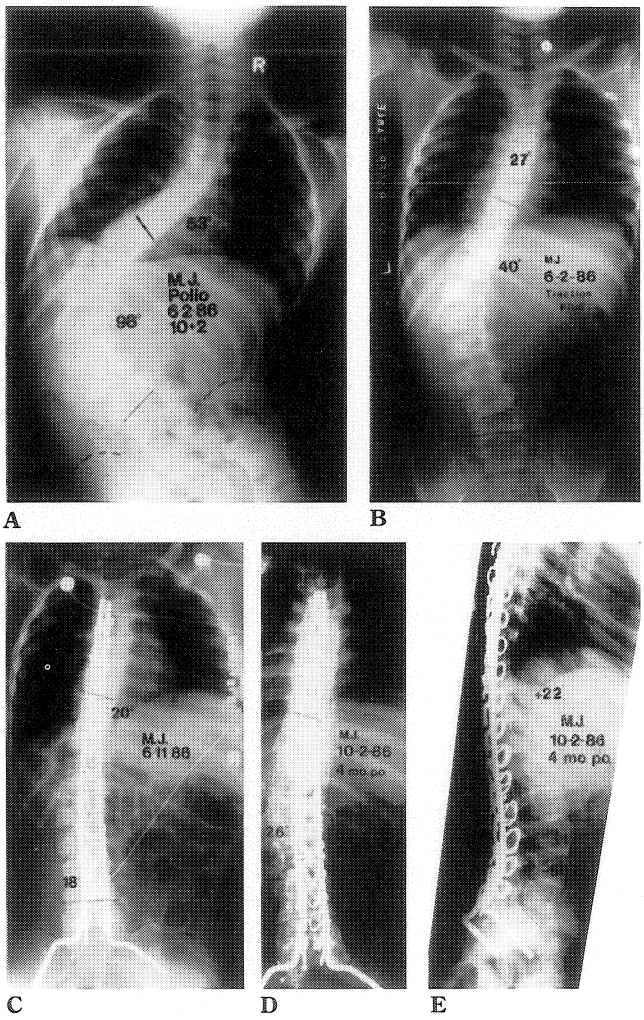

Figure 4A–E
(A) A ten-year-old boy has a 98° scoliosis due to poliomyelitis. Surgical treatment is obviously the answer, but what surgery?
(B) His traction film (on a Risser table) shows correction to 40° and a level pelvis. Should he have only a posterior procedure or both anterior and posterior?
(C) An anterior discectomy and interbody fusion was done, not because better correction was critical, but because he was only ten and a posterior fusion alone was inevitably going to bend ("crankshaft effect") due to growth forces.
(D) In only four months, his fusion was solid.
(E) The lateral film at four months shows totally normal, harmoninous sagittal contours accomplished by Luque instrumentation.

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