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THE IOWA ORTHOPAEDIC JOURNAL

Published by the Residents, Faculty, and Alumni of the Department of Orthopaedics, The University of Iowa

IOWA ORTHOPAEDIC JOURNAL

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INSTRUCTIONS FOR AUTHORS

Any article relevant to orthopaedic surgery, orthopaedic science and the teaching of either will be considered 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. We request that all illustrations be 5 x 7 inch black and white glossy prints for reproduction purposes. The journal will be published annually in April or May. The deadline for receipt of articles for the 1982 journal is February 1, 1982.

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The Iowa Orthopaedic Journal

The University of Iowa
Department of Orthopaedics

This journal has as its primary purpose education. Those who participate in the production of each volume will undoubtedly learn the most. The challenges of such a task include in part, the critical and constructive review of articles, organization and editing of the journal, and the production and distribution of the "final product." The residents in the department have been given the opportunity and responsibility to participate in and accomplish these goals.

We intend to publish one volume annually and hope that this journal will reflect the activity of residents, alumni, visitors to our department, and, to some extent, the faculty. This journal should be the vehicle for the dissemination of thought. As such, we will include historical and "philosophic" articles as well as scientific and general review articles. This will provide a forum somewhat different from most periodicals now extant.

We thank the entire faculty for their help, and in particular, Drs. Pontarelli, Clark, and Cooper for providing the strong enthusiasm to initiate this endeavor. The clerical and secretarial staff have worked unselfishly to aid us and we thank them. We thank Mr. Dale Clark and Mrs. Sandra Bredman for contributing their administrative skills. We appreciate the cooperation of the authors and also the advertisers, who provided the necessary financial support. Our departmental creative ventures, such as this journal, are facilitated by outstanding administrative support from University Hospitals and Clinics, the College of Medicine, and the University of Iowa.

We hope that you, the reader, benefit from our efforts, and we welcome your response and constructive criticism.

F. R. D. and R. F. D.

ARTHUR STEINDLER: FOUNDER OF IOWA ORTHOPAEDICS

Joseph A. Buckwalter, M.D.*

ARTHUR STEINDLER
the physician, scholar and teacher

whose influence spread from a small midwestern city to the far reaches of the world,

whose compassion fused a kindred bond with the saddened or fearful patient,

whose humility often withered the prideful countenances of lesser men and instilled humbleness in many of his students and colleagues,

whose dedication and vision helped to shape a state's system of medical care for the poor,

and whose name was honored in many foreign lands, bringing honor to his own state and country.

–author unknown

As we publish the first *Iowa Journal of Orthopaedics,* it is appropriate to honor Arthur Steindler (Figure 1). He founded the Department of Orthopaedic Surgery at the University of Iowa and directed its growth for thirty-four years. During that time his scholarship, teaching, and clinical work helped Iowa develop into a nationally and internationally recognized orthopaedic center. He personally cared for over 70,000 patients, many of them children crippled by polio, spastic paralysis, scoliosis, congenital deformities, and degenerative neuromuscular diseases. To improve the function of their weakened and deformed limbs, he developed and evaluated many innovative operations. He wrote over 130 papers and 9 books in several languages on the natural history, etiology, and treatment of musculoskeletal diseases and the science of kinesiology. He taught over 250 orthopaedists, including Drs. Albert, Finder, Friedman, Luck, Milgram, Obletz, O'Donohue, Ponseti, Slocum, Soto-Hall, Thornton, and Willis. Thus, through his work and his students, Steindler contributed significantly to the growth of orthopaedics and the scientific foundation of the specialty.

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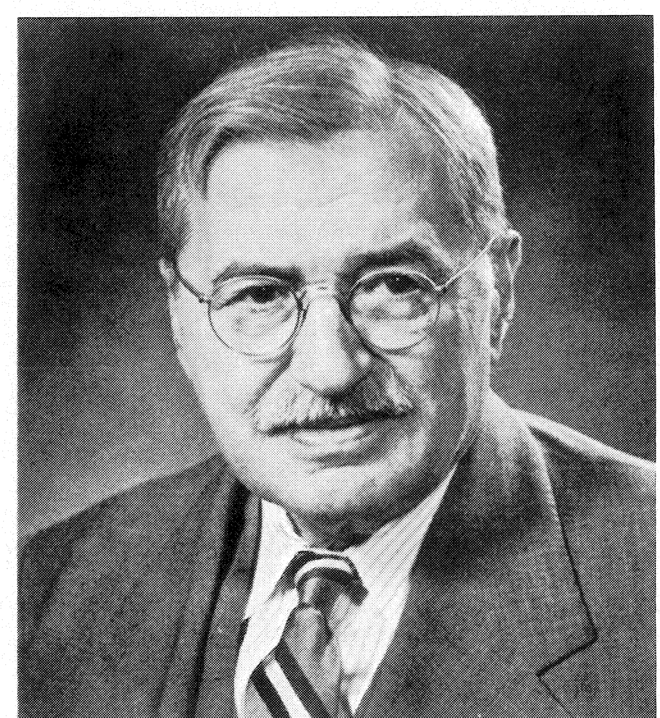

Figure 1. A posed portrait of Arthur Steindler in his later years.

Arthur Steindler was born June 22, 1878, in Graslitz, Czechoslovakia. Shortly thereafter his family moved to Vienna where he spent the early years of his life. His father was a lawyer who valued rigorous classical education. Thus, Arthur's education emphasized literature, language, philosophy, and music. He learned seven languages which enabled him to follow the world orthopaedic and scientific literature closely, translate important papers for others, write for foreign publications, and teach students from many countries. As a young man, Steindler demonstrated considerable musical talent, and expressed an interest in becoming a professional musician, but with his father's advice he chose a career in medicine and entered medical school at the University of Vienna.

In 1902 Steindler graduated from the University of Vienna. After his internship, he focused his attention on the study of orthopaedic surgery. Two European schools influenced his orthopaedic education: initially, the Vienna School through Edward Albert and Adolf Lorenz; and, later, the Liverpool School through John Ridlon. Ridlon also gave Steindler the opportunity to learn the evolving American approach to orthopaedic problems.

Edward Albert had been professor of surgery at Innsbruck, but in 1873 he transferred to Vienna. An eager teacher and innovator, Albert is perhaps most famous for developing and advocating arthrodesis to improve the function of flail limbs. He emphasized that arthrodesis could eliminate bracing and improve function of limbs that might otherwise be useless. Correcting deformities and stabilizing joints by arthrodesis in patients crippled by polio and other neuromuscular diseases became an important part of Steindler's work. During his years in Vienna, Arthur Steindler was also exposed to the work of Adolf Lorenz. Lorenz was interested in children's problems, including club foot correction, treatment of congenital dislocation of the hip, and management of scoliosis. In 1886 Lorenz had published an extensive monograph summarizing theoretical conceptions of scoliosis, including the effect of posture and assymetrical weight-bearing. Lorenz also challenged the concept that corsets and braces could correct scoliosis. Steindler later incorporated these ideas into his own approach to scoliosis.

In 1907, five years after medical school, Steindler left Vienna for Chicago to become an assistant to John Ridlon at the Home for Crippled Children. Ridlon was born in Vermont, graduated from the College of Physicians and Surgeons in New York, and worked with Newton Shaeffer in New York. In addition to his American education, Ridlon was profoundly influenced by Hugh Owen Thomas. Thomas' skill in constructing and using braces and splints, such as the Thomas splint, the Thomas collar, and a number of foot orthoses, had earned him considerable fame and a large group of patients. Thomas also taught that most deformities should be corrected by manipulation, rather than surgery, and that the prime method of treating tuberculosis and other conditions must be rest, "enforced, uninterrupted, and prolonged." Ridlon visited Liverpool twice and adopted many of the practices and devices advocated by Hugh Owen Thomas. Ridlon also worked with Thomas' nephew, Sir Robert Jones, and collaborated with Jones on a number of articles describing the principles of orthopaedics expressed by Hugh Owen Thomas. Ridlon considered these principles to be the basis of good orthopaedic practice and stressed their importance to Arthur Steindler.

In 1910, on Ridlon's advice, Steindler accepted the position as professor of Orthopaedic Surgery at the Drake Medical School and began his practice in Des Moines, Iowa. During his years in Des Moines, Steindler formed friendships with a number of people in state government. These friendships facilitated Steindler's later efforts to promote the development of the University of Iowa Hospitals, including Children's Hospital, and state funded services for crippled children and indigent patients. In 1912 he joined the faculty at the University of Iowa and began traveling to Iowa City by train at least once a week to hold orthopaedic clinics and act as an instructor in orthopaedic surgery at the University of Iowa Hospital.

The years 1914 and 1915 brought significant changes in Steindler's life. In 1914 he married Louise Junk, a nurse he had met when they both worked at the Chicago Home for Crippled Children. Although Louise met Arthur Steindler in Chicago, her family was from Dixon, Illinois. In the same year as his marriage, Steindler became an American citizen. At the age of thirty-seven, in 1915, Arthur Steindler moved to Iowa City to become the first professor of Orthopaedic Surgery at the University of Iowa. At that time, he was the only orthopaedist. When Steindler moved to Iowa City, the University Hospital (Figure 2) was located on

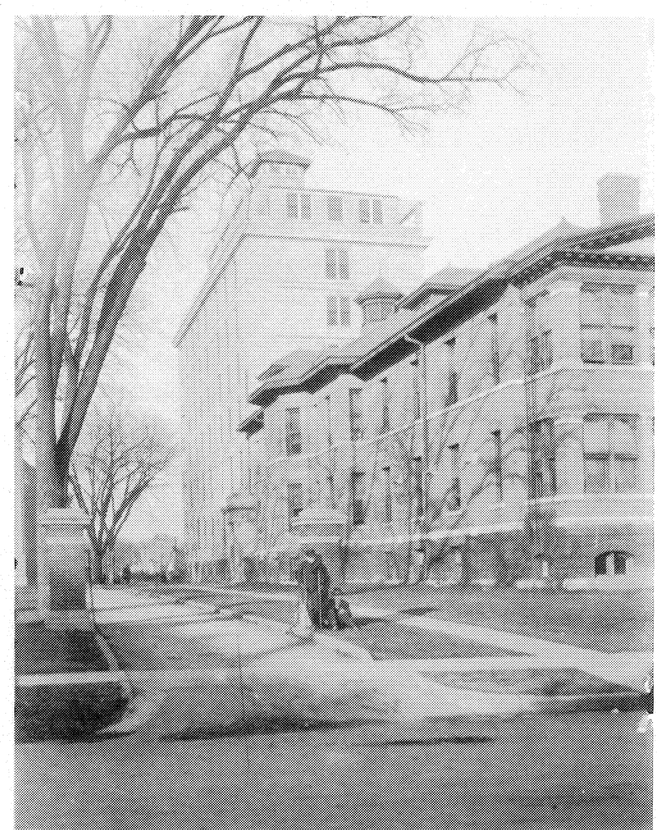

Figure 2. The entrance to the first University of Iowa Hospital (now East Hall). A patient with crutches is standing near a brick pillar. St. Mary's Catholic Church is visible in the background to the far left. (F. W. Kent)

the east side of the Iowa River and consisted of clinics, laboratories, operating theaters (Figure 3), and about 240 inpatient beds. This building was the first University Hospital and had been opened in 1898. While commuting from Des Moines, Steindler had recognized that many people with serious orthopaedic problems could not reach Iowa City. Since only two other physicians in the state practiced orthopaedics, many crippled adults and children did not receive treatment. These observations and his interest in crippled children led Steindler to encourage the state to provide support for the medical care of these children. Iowa was fortunate to have a progressive legislature, and in 1915 the Iowa General Assembly approved the Perkins Act which authorized medical treatment for children under sixteen. This led to the development of field clinics throughout the state for the evaluation of crippled children. Those children needing hospital care, therapy, or surgery were transported to University Hospital. Today the State Services for Crippled Children continues to provide field clinics for children in all parts of the state. Arthur Steindler also advocated providing medical care to needy adults. In 1919 the state legislature approved the Haskell-Klaus Act extending state supported medical care to all indigent adults. To facilitate the transportation of patients benefiting from these acts, Steindler helped organize the hospital car and ambulance system that allowed patients to be picked up at their homes, brought to University Hospitals, and returned to their homes following treatment (Figure 4). The hospital car system still serves orthopaedic and other medical patients today.

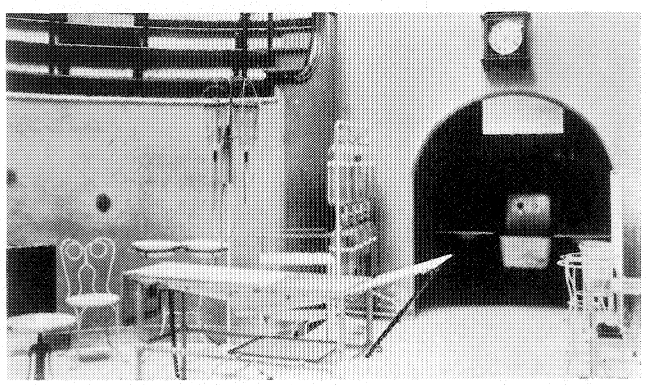

Figure 3. The operating theater in the first University of Iowa Hospital. The scrub sinks, operating table, basins, and seats are visible. (F. W. Kent)

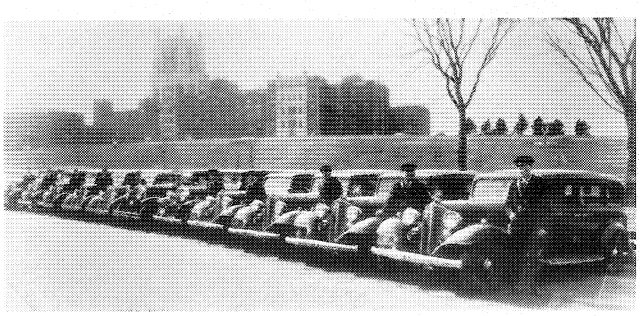

Figure 4. The 1934 fleet of hospital cars and ambulances. The University Hospitals, dedicated in 1928, are in the background.

Increasing numbers of patients and an expanding staff required newer and larger orthopaedic facilities, and in 1917 construction of Children's Hospital began on the west side of the Iowa River (Figure 5). This building was the first part of what became the University of Iowa Health Sciences Complex. Steindler was influential in both obtaining financial support and designing Children's Hospital. When the building was completed about 1920, he became chief surgeon and head of the growing Orthopaedic Surgery Service. The new facility incorporated many features to facilitate the care of orthopaedic patients. The arrangement of inpatient units allowed patients to be moved outside during favorable weather (Figures 5 and 6). The basement

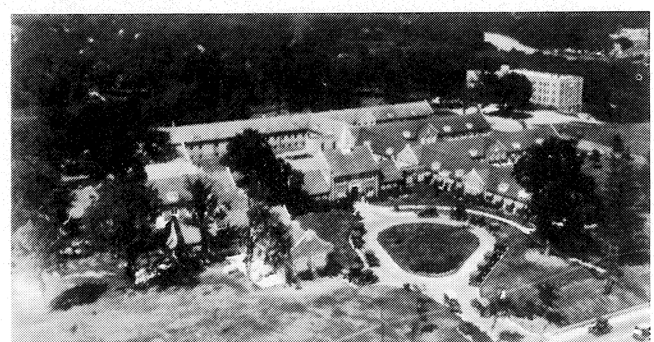

Figure 5. Children's Hospital. The Iowa River is visible in the upper right corner. Patients have been moved onto a patio on the left. The structure with the U-shaped roof projecting into the central courtyard is a ramp which allowed patients in wheel chairs or beds to be easily transported to the "gymnasium" in the basement. (F. W. Kent)

Figure 6. Children on a patio next to Children's Hospital. (F. W. Kent)

Figure 7. Children's Hospital brace shop showing the fitting of an orthosis. (F. W. Kent)

Figure 8. Children's Hospital brace shop showing casts of patients' torsos and limbs, scoliosis braces, as well as other orthoses. (F. W. Kent)

floor housed a large brace shop (Figures 7 and 8) and a "gymnasium" for physical therapy (Figure 9). A ramp (Figure 5) allowed transport of patients in wheel chairs and beds between the first floor and the basement (Figure 9.) The operating rooms in Children's Hospital (Figure 10) were located at the north end of the hospital. Figure 10 shows one of the Children's Hospital operating rooms in the 1920's (the schedule written on the blackboard indicates that a shoulder arthrodesis and a shoulder stabilization were to be performed). The Orthopaedics Department was located in Children's Hospital until 1978 when it moved to the Carver Pavilion (Figure 11).

Figure 9. Patients in the basement "gymnasium" of Children's Hospital.

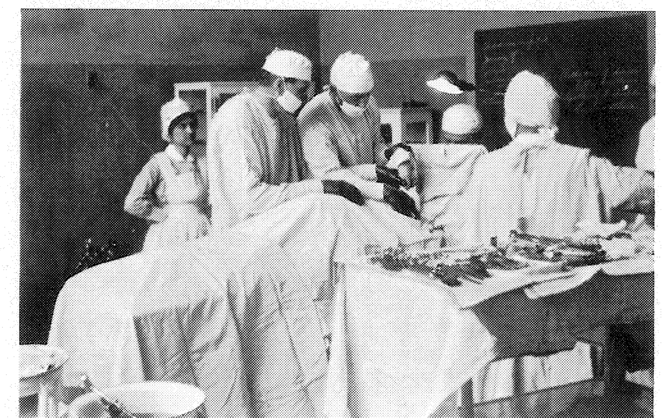

Figure 10. Operating room in Children's Hospital in the early 1920's. The operating schedule on the blackboard indicates that a shoulder arthrodesis and a shoulder stabilization were scheduled. (F. W. Kent)

Figure 11. Carver Pavilion. The Carver addition is located to the right of the fountain and behind the flag, and the Orthopaedics Department occupies the first, third, and fourth floors. (Medical Photography)

Soon after the approval of the Haskell-Klaus Act, other medical departments, still located in the first University Hospital, felt the strain of increasing numbers of patients and the need for more modern facilities. In 1924 the state legislature appropriated $2.5 million, matching a grant from the Rockefeller Foundation, to build the new 900 bed University Hospital near Children's Hospital. The new University Hospital was dedicated in 1928 and is shown in the background of Figure 4.

In the 1920's, Steindler built his own home on a bluff overlooking the Iowa River. The site he selected provided a view of the river and was located within one-half mile of Children's Hospital. He had Horace's quotation, "Ille terrarum mihi praeter omnis angulus ridet" carved in the stone pediment above his door. He had found "the corner of the earth that smiled to him above all others." Mrs. Steindler directed the landscaping of extensive gardens around the house. The Steindlers entertained frequent visitors and relatives. To manage their large home and provide for their guests, they usually had a cook, two maids, and two students who took care of the maintenance work, some of the gardening, and served as chauffers. Louise Steindler took charge of running the household and organized the social gatherings at the Steindlers' home to allow her husband freedom to work, study, and write.

The new facilities of Children's Hospital, combined with the additional patients and staff, enabled Steindler to develop a strong program for orthopaedic care and the education of medical students and residents. In 1927 he was named head of the Department of Orthopaedic Surgery which became a separate department within the College of Medicine. Together with Ernest Freund he built a laboratory within the department to study orthopaedic pathology. This laboratory, through the work of Drs. Freund, Luck, Ponseti, and Bonfiglio, has provided excellent contributions to teaching and research. Steindler believed residency should be based on systematic, critical education in the basic sciences and clinical orthopaedics rather than on a purely apprenticeship system. His approach to residency education influenced not only his students and residents, but led other departments to organize similar programs. He established a one-year graduate course in orthopaedics with a required series of lectures. Each year he took a group of approximately ten physicians (many from other countries) as graduate students. The physicians paid a tuition of $50 to $100 a year and received at least one lecture a day, many delivered by Arthur Steindler. At the end of each year, Dr. Steindler would accept two or three of the graduate students into a three year residency. Residents participated in daily conferences organized by Steindler (Figure 12) in which he stressed understanding of the lesions underlying orthopaedic problems and the natural history of diseases, as well as critical evaluation of proposed treatment and of results. He remarked that, "There will always be those who are anxious to find a short cut to results and in their hurry pass by the stations of diagnosis and indications, making specific operative techniques their first step. No doubt they will be disappointed" (IVP). To stress the importance of unbiased reasoning he would say, "I would rather be wrong with an impartial reason than right without one" (JVL, JBJS 41A: 1366-1367 [1959]). Thus, although his lectures were didactic presentations, the conferences encouraged students and residents to participate by expressing their ideas. As he said, ". . . no justice can be done to the case by adopting a partisan standpoint. All opinions are needed and must be heard and explained" (IVP).

Figure 12. Arthur Steindler, at right, with residents and visitors. Dr. Ponseti is seated on Steindler's right.

In 1949, at the age of seventy, having served the Department of Orthopaedics at the University of Iowa for thirty-seven years, Steindler became professor emeritus at the University of Iowa and chief of the Orthopaedic Service at Mercy Hospital. At Mercy he remained active in patient care and teaching. During the last years of his life he prepared lectures on the interpretation of pain in orthopaedic conditions and reviewed drafts of this book shortly before his death on July 21, 1959.

In reviewing Arthur Steindler's career, his contributions to the state of Iowa and the University are clear. By founding a strong orthopaedics program, he made possible the orthopaedic education of medical students and residents who later practiced in Iowa. He facilitated the organization of the state services for crippled children and indigent patients, and promoted the development of the University Medical Center. Through these efforts, medical care became available to people who might otherwise have gone untreated.

In addition to his influence on the state and the University, Steindler made important contributions to the field of orthopaedics. He wrote on almost every orthopaedic problem, including back pain, scoliosis, tuberculosis, polio, congenital deformities of the hand, Dupuytren's contracture, upper and lower extremity reconstruction, and foot deformities. Steindler was able to absorb information and ideas from many sources and organize them. Through this process he reviewed many orthopaedic problems and presented the available information, including his own experience, in a concise, systematic form. He also worked to bring many of the orthopaedic advances from continental Europe to the United States.

Through his teaching, speaking, and writing, Steindler encouraged basic research and incorporation of the basic sciences into orthopaedic education. In his 1933 presidential address to the American Orthopaedic Association, he emphasized the need for basic scientific research in orthopaedics pointing out the need for broad-based study of anatomy, pathology, physiology, and biochemistry (JBJS XV: 567-573 [1933]). In addition to encouraging others in the study of the sciences, Steindler immersed himself in the investigation of human mechanics. He felt that human mechanics represented a virgin field with great potential application and observed that ". . . biomechanics is a powerful and indispensable ally of the orthopaedic clinician" (JBJS XV: 567-573 [1933]). He frequently stressed that orthopaedic progress would not occur through the pursuit of technical perfection, but rather through advances in the basic medical sciences.

In his study of orthopaedic problems and their treatment, Steindler pointed out the importance of understanding the natural history of diseases and critically reviewing the results of treatment. In his publications he presented and critically analyzed his operative orthopaedic experience, even when the results were unsatisfactory. For example, in *Orthopaedic Operations: Indications, Technique, and End Results* (Thomas, 1940) he discussed the indications and surgical techniques for each operation. However, unlike many authors of his time he reviewed the results of each operation and suggested reasons for failure. In analyzing the results of his flexor transposition to restore elbow flexion (one of his best known operations), he found 30 percent poor and fair results. He noted that causes of failure included insecure anchorage of the transposed muscles and errors in the indications.

Two problems that Steindler studied over many years were scoliosis and cavus deformity of the foot. His first article dealt with scoliosis (J Amer Med Assoc 52:1572-1573 [1909]), and he continued to study scoliosis throughout his career. As might be expected from his early training, he felt, ". . . that the proper way of dealing with structural scoliosis is to follow the footsteps of nature and to develop secondary compensating curves, rather than to persist in unsatisfactory attempts at direct correction" (Lancet, July 1, 1926). He described the compensation-derotation treatment of scoliosis (JBJS VIII:570-586 [1926] and JBJS XI:820-830 [1929]) as a three-fold program involving: 1) mobilizing segments of the spine to produce counter curves and restore balance; 2) stabilizing the compensated spine by mechanical support (Figure 7); and 3) developing and

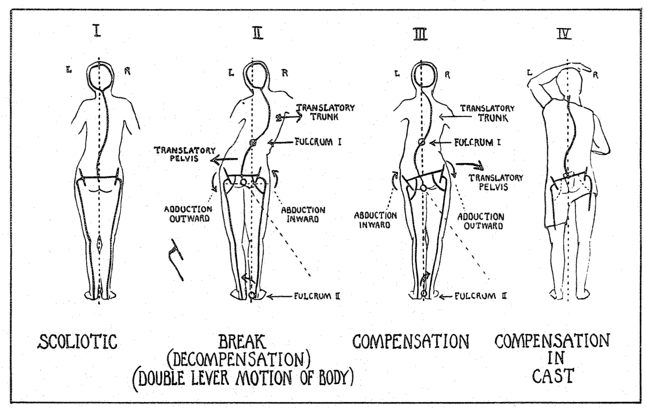

Figure 13. Drawing illustrating the compensation treatment of scoliosis. (J Bone Joint Surg VIII:570-586, 1926, Figure 5)

educating muscles to maintain the new balance of the body (Figure 13). Despite his strong belief that completion of compensation treatment would enable the patient's muscles to balance the spine, Steindler did point out that established curves might prove incurable and that further bracing or surgery might be necessary. In considering surgical treatment of scoliosis he observed that, "In the advanced deformities of non-compensated cases, it will be the only refuge . . . ." However, the maintenance of compensation, ". . . is not a problem that is best solved by totally abolishing the mobility of the spine; in other words, by operative fusion, although in many, if not the majority of cases, one has to accept this compromise. In many other cases, however, we have shown that the return to normal balance by way of mobilization and compensation and ultimate re-development of muscle forces of the back, is possible; and furthermore, that such is the most natural and the more desirable solution of the problem" (AS, Diseases and Deformities of the Spine and Thorax, C. V. Mosby, 1929). However, by the 1940's, Steindler had observed that scoliosis could progress even in patients who had achieved compensation (IVP). Although compensation treatment did not ultimately prove to be a satisfactory answer to the problems of scoliosis, Dr. Steindler's interest in scoliosis and his close follow-up of his patients made possible the landmark paper of Drs. Ponseti and Friedman. This study, reported in the *Journal of Bone and Joint Surgery* (32A:381-395), described the natural history of scoliotic curves, the classification of curves, and their prognosis. These observations significantly advanced understanding of the natural history of scoliosis and made clear the importance of identifying the type of curve to determine the prognosis.

Arthur Steindler found deformities of the foot and resulting problems particularly interesting, and his name is still mentioned frequently in papers dealing with cavus feet. In 1917 (Surg Gynec Obstet, May 1917, pp. 612-615) he published his first description of what has become known as the Steindler stripping operation (Figure 14). At that time, he felt that the short muscles of the foot were responsible for the cavus deformity, and he recommended release of the plantar soft tissues. In 1921 (Arch Surg II:325-337) he returned to the problem of the cavus foot and noted that the results of some of his soft tissue releases were not satisfactory. He suggested that these unsatisfactory results were due to failure of complete correction of the deformity and indicated that complete correction should result from

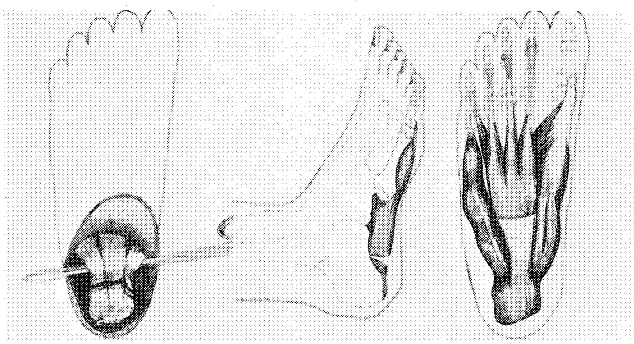

Figure 14. Drawings illustrating Arthur Steindler's release of the plantar soft tissues for cavus deformity of the foot. (Surg Gynec and Obstet, May 1917, pp. 612-615)

release of the plantar soft tissues combined with correction of the skeletal deformities by cuneiform osteotomy (Figure 15). In 1928 (Surg Gynec Obstet, Oct. 1928, pp. 523-562) he again discussed problems in his patients with treated cavus deformities of the foot. He stated that the poor results of his previous procedures might be due to failure to stabilize the foot after correction of the deformity and recommended combining correction of the deformity (by soft tissue release and osteotomy, if necessary) with stabilizing procedures, such as tendon transfers or arthrodesis.

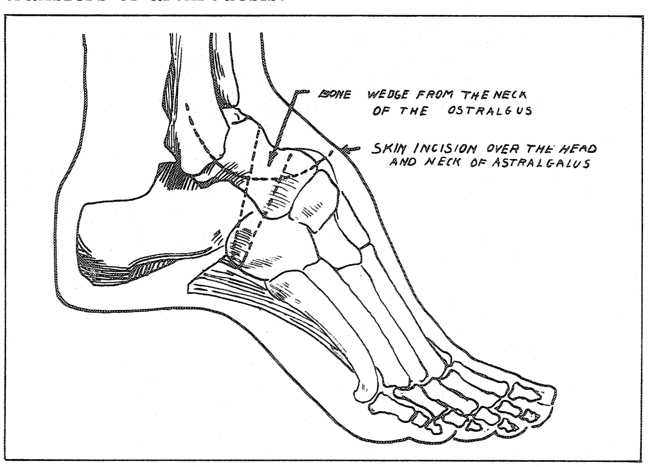

Figure 15. Drawing illustrating Arthur Steindler's relase of the plantar soft tissues combined with a cuneiform osteotomy. (Arch Surg II:325-337, 1921)

Certainly, Steindler's close follow-up of his patients and long-term review of the results of treatment were not common practices during his time.

Arthur Steindler was clearly an exceptional orthopaedist, but study of his many contributions does not reveal his personality, nor the talents and abilities that enabled him to immigrate to the United States and rapidly become an enthusiastic and successful Iowan and American.

He enjoyed refining and developing his own mind and stimulating others to do the same. He had a striking ability to assimilate and remember large amounts of information coupled with a genuine love of learning. His facility with languages clearly proved an asset in learning of new developments in other countries and in writing for orthopaedists outside of the United States. He continually sought comprehensive understanding of problems, and this search brought him to recognize the importance of scientific investigation and reasoning for future advances in clinical practice. Through his teaching and his example, he encouraged his pupils to seek broad education and develop the habit of life-long learning. When he began his classic studies of human movement in the 1920's, he recognized the importance of higher mathematics and took courses in basic calculus, physics, and engineering. In his last year of life, while seriously ill, he continued to participate in the educational activities of the American Academy of Orthopaedic Surgeons, giving his instructional course and avidly taking notes during the talks of others.

In addition to his interest in learning, Arthur Steindler had unusual energy, a remarkable capacity to organize his efforts, and the will to demand the best efforts from himself and others. Well into his 70's he would arise before 5 a.m. and take a walk to watch the first train of the day pass through the countryside. He then studied until 7 a.m. and usually was in his office by 7:30. At 5:30 he returned home and dinner was at 6:00. He rested until 7:00 and then worked, studied, or wrote until 10:00 when he retired to read in bed. By organizing his time and demanding his own best efforts, he gained the maximum from his talents and opportunities. Undoubtedly, his ability to command his time was aided by his wife, Louise, who protected his time for work and study.

Despite his strenuous work habits and the demands he placed on himself, Steindler was not aloof nor removed from people and events around him. After his immigration from Vienna, he followed the changes in Europe with great concern. Before and during World War II, he brought many friends and relatives to the United States to escape the war and persecution. To his friends, colleagues, and family he was lively, outgoing, and warm. He was deeply loyal to his students and followed their careers with great interest. To his patients he was a concerned and caring physician. His affection for children was especially strong, perhaps partly because he did not have children of his own. He possessed a great and kindly sense of humor in both telling and enjoying jokes. His after-dinner speeches usually included humorous anecdotes. Occasionally, he took the role of a part of the body, such as the neck of the femur or the intervertebral disc, and defended this part against its bad reputation in orthopaedic circles.

Figure 16. Arthur Steindler with a group of residents.

For relaxation, Arthur Steindler enjoyed walks in the country, reading, music, and conversation with friends. His interest in literature included Virgil, Horace, and Lucretius in Latin, as well as classical and modern German, French, Spanish, and Italian works. In his early years in Iowa City, he was fond of playing the piano and spending a musical evening with friends. During these evenings, he played duets with Professor Clapp who was the head of the Department of Music or Beethoven sonatas with Dr. Byfield who was the head of the Department of Pediatrics and an accomplished violinist. Arthur Steindler also belonged to two dinner clubs where he eagerly engaged in discussions of literature, history, and philosophy. His broad knowledge, retentive mind, and sense of humor made him an especially valued member of these clubs.

Arthur Steindler's documented accomplishments confirm his position as a great orthopaedist, scholar, and teacher (Figure 16). He cared for patients with many types of challenging and complex problems, helped the state of Iowa and University of Iowa Hospitals establish a system of patient care for the poor in advance of other institutions, authored many influential papers and books, and personally taught a number of outstanding orthopaedists. Through his scholarly work and the orthopaedists he educated, his influence spread from the University of Iowa throughout the United States and to many other countires. More difficult to measure are the values he inculcated in his students and established as traditions in his department—excellence in patient care, unbiased review of treatment, study of the sciences, and critical broad-based orthopaedic education.

Acknowledgments

This brief review of Arthur Steindler's life and contributions was made possible by the kind help from the following people: Ignacio Ponseti, Hans Ehrenhaft, Pat Hicks, Eberly Thornton, Reginald Cooper, William Bean, and Carl Gerbhour.

Despite Arthur Steindler's wide influence and prolific writing, many of the details of his life and work are not easily available. I would greatly enjoy hearing from anyone who would like to correct, confirm, or expand upon the information and ideas presented in this article.

THE DECOMPRESSION PRINCIPLE OF JOINT SURGERY AND ITS APPLICATION TO THE KELLER BUNIONECTOMY

John V. Ioia, M.D., Ph.D.*
Richard L. Jacobs, M.D.*, +

Introduction

As this issue is dedicated to the memory of Arthur Steindler, we would like to use this occasion to reiterate one of the principles which he often stressed in his teachings. In the 1950's, he addressed the Robert Jones' Club on the subject of the Decompression Principle of Joint Surgery. These thoughts, although still true, are often neglected in the practice of orthopaedics. This paper will present an illustrative case and discuss the general principles of successful bunion surgery.

Case Presentation

B. D., a fifty year old white female, presented with a complaint of decreasing range of motion of her left great toe, associated with pain and alteration of gait. She had been under the care of a podiatrist. Eighteen months earlier, simple excision of a dorsal osteophyte was performed. When this failed to give relief, a Keller bunionectomy was attempted, but only the proximal few millimeters of the base of the proximal phalanx was excised.

She still had great pain in the first metatarsophalangeal joint, had to walk with her extremity in external rotation, and complained of knee pain when she was referred to us one year later.

Continuing pain and stiffness of the first metatarsophalangeal joint was now accompanied by pain beneath the second metatarsal head.

On physical examination, there was a well-healed incision over the left first ray. There was almost no active plantar or dorsiflexion of the first metatarsophalangeal joint, and any passive motion produced pain.

Radiographs supplied by the patient documented the attempted Keller type bunionectomy with minimal excision of the proximal phalangeal base. Impingement of the residual base on the metatarsal head was evident.

After persistent complaints with conservative therapy, a revision of her Keller bunionectomy was performed with a much more generous resection of the phalangeal shaft.

Three months post-operatively, her incision was healed, and there was 45° of dorsiflexion and 35° of plantar flexion passively with no pain. She walked comfortably in low-heeled, broad-soled shoes, had no complaints of gait alteration, and her knee pain was gone.

Discussion

Operative treatment of bunions may be divided into three general types: Procedures of soft tissue, procedures of bone only, and mixed procedures. Although numerous surgical arthroplastic techniques have been published,[2] Steindler recommended three specific techniques applied according to the merits of each case.[6]

In milder cases he advocated the technique of Silver.[5] When more extensive disease and a hallux valgus deformity existed, the McBride operation[4] was performed. When arthritic changes of the metatarsophalangeal joint were present, the Keller-Brandes operation[1,3] was employed with resection of one-quarter to one-half the basal phalanx.

Specifically, Steindler stated, "If one-half the basal phalanx is removed, the risk of a post-operative rigidity of the joint is avoided."[6]

Our case illustrates this point precisely. The incomplete resection of the proximal phalanx predisposed the patient to rigidity, arthritic change, and further pain in the first metatarsophalangeal joint. Furthermore, the resulting hallux rigidus disturbed the kinetics of gait and caused secondary knee pain.

Based on his accumulated experience, Steindler realized the importance of adequate release of tension on a painful joint.

The principle of joint decompression is applicable to any surgery involving an arthritic joint. Whether one is dealing with resection to a Girdlestone hip, a radial head resection for relief of arthritic pain, or a metatarsophalangeal arthroplasty, inadequate resection and inadequate decompression lead to failure of the procedure.

Summary

Adequate pre-operative evaluation gives the correct indication for surgery. The appropriate surgical tech-

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nique may still give poor results if basic principles are not followed. A case illustrating the decompression principle in joint surgery is presented.

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LARGE TOE ULCERS IN THE DIABETIC: AN ALTERNATIVE APPROACH

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Introduction

Foot infections continue to be a frequent cause of hospitalization in the diabetic.[4] A common problem is great toe plantar ulceration. Fortunately, these usually respond to conservative treatment. However, approximately 15 percent of the ulcers will recur. This report presents an alternative for the management of recurrent ulcers.

Pathology

Diabetic foot lesions are a composite of complications encountered by the diabetic including relative or absolute insensitivity of the distal extremity, amyotrophy, vascular insufficiency, and susceptibility to bacterial infections. The first two factors allow repeated mechanical trauma to the foot, and the latter two place the foot in a compromised state such that it cannot heal following trauma.

The plantar surface of the great toe is a frequent location for ulcers. The weight distribution across the metatarsal heads and the function of the great toe in push-off are major factors. Weight distribution to the metatarsal heads is divided into six equal parts: two parts are applied to the first ray, and one part is applied to each of the lateral four rays.

Force plate analysis shows that prior to toe-off, the weight is transferred to the medial side of the foot.[3,5] Consequently, the plantar surface of the large toe bears the brunt of the weight at push-off.[1]

Without meticulous shoeing and foot care, the plantar surface of the great toe suffers repeated shearing stresses while being loaded during push-off. This stress, when combined with the four previously mentioned factors, results in persistent ulceration. Conservative treatment usually suffices (debridement of the lesion with subsequent splint thickness skin graft [Figures 1a, 1b, and 1c] or extra depth shoes with aliplast or neoprene insoles).[2] If these measures fail,

Figure 1. Early stage of large toe plantar ulcer.

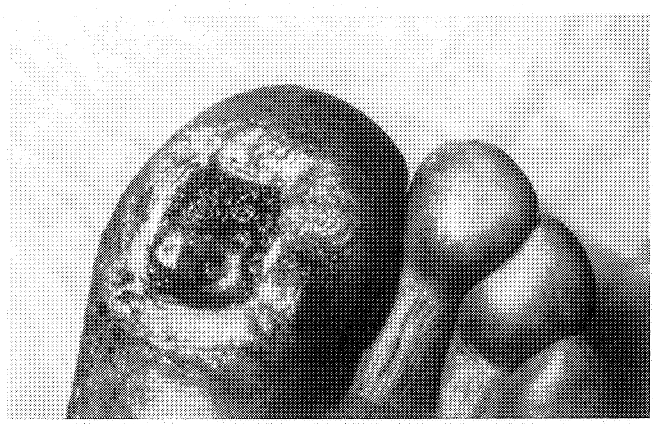

Figure 1b. Toe ulcer after debridement and dressing changes prior to split thickness skin graft.

Figure 1c. Toe ulcer after split thickness skin graft. This subsequently went on to heal without further surgery. The majority of these lesions will heal with only conservative treatment. The more severe problems, because of mechanical factors and perhaps poorer patient compliance, need further treatment, such as excision of the proximal one-half of the proximal phalanx with subsequent split thickness skin graft.

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altering the functional nature of the great toe will help heal these lesions. We have accomplished this by resecting the proximal one-half of the proximal phalanx of the great toe. This functional shortening of the great toe flexors diminishes much of the weight and shearing stress on the plantar aspect of the great toe during toe-off.

Case Reports

Two cases illustrate this principle.

Case I

A sixty-three year old male with a thirty-year history of insulin dependent diabetes mellitus suffered numerous complications from the disease. The most significant complication was a severe polyneuropathy. On examination he exhibited typically cool, dry skin in his lower extremity with diminished pulses. Ankle reflexes were diminished bilaterally. There was marked sensory and motor nerve impairment. An ulcer on the plantar aspect of the great toe measured 10 x 10 millimeters. The base of the ulcer was necrotic with surrounding hypertrophic skin and marginal erythema. Pulse volume recordings showed good pulsatile flow to the transmetatarsal level. He was placed on oral Cephalosporin. The ulcer was debrided. After the marginal erythema had subsided, the ulcer was covered with split thickness skin grafts (Figure 2a). The ulceration did heal, but upon resumption of ambulation, it recurred despite the use of extra depth shoes and aliplast insoles. The ulcer, then 10 x 10 millimeters, remained clean for one month, but did not diminish in size (Figure 2b). Nine months following the appearance of the ulcer, we admitted the patient to the hospital for a proximal phalangectomy. Preoperatively, intravenous Cephalosporin was given. We then resected the proximal half of the proximal phalanx of the great toe through a dorsal medial incision (Figure 2c). Postoperatively, saline wet-to-dry dressings were applied to the ulcer four times a day. A split thickness skin graft was applied on the third postoperative day. He remained at bed rest for seven days. Intravenous Cephalosporin was given for a full week followed by oral Cephalosporin. At one week, heel weight bearing was allowed. On the tenth day he was discharged. The toe lesion healed in 70 days (Figure 2d).

Case II

A forty-nine year old male had a thirty-one year history of insulin dependent diabetes mellitus. Despite multiple complications from the diabetes, including

Figure 2a. Large toe ulcer with split thickness skin graft. This subsequently sloughed.

Figure 2b. After ambulation, the split thickness skin graft was lost. The ulcer was treated with saline soaks. The ulcer became indolent and poorly granulating but with no active infectious process.

Figure 2c. Surgical procedure was performed. Note the position of the incision on the dorsum of the toe medial to the extensor hallux longus.

Figure 2d. (At Right) Ulcer after partial phalangectomy and split thickness skin graft ready to start ambulation and footwear with extra depth shoes and aliplast insoles.

severe retinopathy, foot ulcers, peripheral neuropathy, autonomic neuropathy, left-sided cerebral vascular accident with a residual right hemiparesis, and severe peripheral vascular disease, this gentleman continued to work as a college professor. He first presented with a 25 x 22 millimeter ulcer on the plantar aspect of the large toe that had been present for two months. He had been treated previously with appropriate antibiotics which eliminated an acute infection. The patient gave a history of severe claudication, and there were no palpable distal pulses in the involved extremity. A successful vascular reconstruction with vein bypass graft was performed. The ulcer was widely debrided. The patient was discharged on Betadine dressing changes and oral Cephalosporins.

The toe lesion remained clean, but granulated slowly. Four months after the onset of the ulcers, the proximal one-half of the proximal phalanx of the large toe was resected through a dorsal medial incision. Swelling and mild erythema of the incision subsided with elevation, bed rest, and intravenous antibiotics. A split thickness skin graft to the toe ulcer was done under local anesthesia on the sixth day. He remained at bed rest with intravenous antibiotics for nine days and was subsequently discharged on the tenth postoperative day on heel weight bearing and oral antibiotics with saline wet-to-dry dressing to the split thickness skin graft. The incision healed without problems. Two months post-surgery the ulcer and split thickness skin graft had completely healed. Antibiotics were stopped, and the patient was allowed to resume use of prescribed extra depth shoes and full weight bearing.

In the last three years, six such procedures have been performed (Chart I). The age range was thirty to sixty-three years. Each patient was an insulin dependent diabetic. Each patient had persisting plantar ulcerations despite conservative treatment. The Infectious Disease Service and Vascular Surgery Service evaluated each

CHART I, PATIENT DATA

	Age	Diabetic Complications	Previous Treatment for Ulcer	Initial Ulcer Size	Duration of Ulcer	Days Hospitalized	Vascular Assessment	Antibiotic Coverage	Complications	STSG Required	Days to Heal
J.P. (case 1)	63	RET (1) PVD (2) AN (3) SN (4)	STSG (7) Extra Depth Shoes Onsoles	5mm. x 11mm.	8 mos.	11	small vessel disease	Cephalosporin	none	Yes	70
W.C. (case 2)	49	RET RD (5) PVD AN SN	Control of acute infection	25mm. x 22mm.	4 mos.	11	femoral-popliteal bypass.	Cephalosporin	none	Yes	65
J.B.	49	PVD SN	TIR Splint Extra Depth Shoes STSG	10mm. x 10mm.	22 mos.	19	small vessel disease	Cephalosporin	none	No	less than 120
R.G.	30	Blind KID/TPT PVD (6) AN SN	Debridement STSG Shoes TIR Splint	15mm. x 10mm.	8 mos.	(8)	small vessel disease	Cephalosporin	none	Yes	25
V.R.	65	PVD SN	Debridement Extra Depth Shoes Insoles	12mm. x 11mm.	unk.	19	small vessel disease	Cephalosporin	none	Yes	less than 30
P.H.	44	Blind RD PVD AN SN	Debridement STSG Extra Depth Shoes Insoles	20mm. x 22mm.	10 mos.	20	small vessel disease	Cephalosporin	delayed healing incision	No	23

(1) RET = Retinopathy
(2) PVD = Peripheral Vascular Disease
(3) AN = Autonomic Neuropathy
(4) SN = Somatic Neuropathy
(5) RD = Renal Disease
(6) KID/TPT = Kidney Transplant
(7) STSG = Split Thickness Skin Graft

patient prior and subsequent to the procedure. In each instance, the ulceration healed following the procedure in a relatively short period. Delayed healing of the incision in one case was the only problem. No ulcerations have recurred.

Discussion

Large toe ulceration is a problem which can lead to prolonged disability. If allowed to persist, it can result in the spread of infection to the forefoot. Long term sequelae include the loss of the extremity. Where there is only minor vascular embarrassment, simple excision of necrotic tissue with subsequent split thickness skin graft suffices.[2] Wagner advocates condylectomy or removal of any bone prominence, in addition to debridement of the necrotic tissue. Despite these measures, approximately 15 percent of cases are refractory and require further intervention. In each of these cases we have obtained vascular surgery consultation. Some patients have benefitted from revascularization procedures to augment distal blood flow. A lesser number (after studies which include Doppler pressures, pulse volume recording, and, if indicated, angiography) are deemed to have sufficient blood flow to allow corrective surgery to the large toe. Aerobic and anaerobic cultures are obtained and the patient is given appropriate antibiotics. All surgery is delayed until infection is controlled. The proximal one-half of the proximal phalanx of the great toe is excised through a dorsal medial incision located just medial to the extensor hallux longus. No capsular flaps are developed and soft tissue dissection is kept to a minimum. The cartilagenous cap of the metatarsal head is debrided. The large toe is splinted with a soft dressing between the great toe and the second toe. No plaster slipper or K-wire fixation is used. This procedure decompresses and shortens the toe. The area of the ulcer decreases by at least 15 to 20 percent immediately. Postoperatively, saline dressing changes wet-to-dry four times a day encourage granulation in the ulcer. When good granulation has been obtained, a split thickness skin graft can be placed (preferably without sutures) across the ulcer and dressed with a Xeroform dressing (fine mesh gauze impregnated with Bismuth Tridromophenate in a petrolatum blend) and stented with a soft dressing. Occasionally the ulcer shrinks to a size that split thickness skin graft is not required. If a split thickness skin graft is applied, the wound is checked in four days. When the incision and ulcer are clean and healing, the patient is mobilized with protective weight bearing and discharged from the hospital on oral antibiotics.

With a decrease in the weight bearing function of the large toe, these deeply ulcerated, inflammed, and often infected wounds heal. The patients are refitted with extra depth shoes with aliplast or neoprene insoles. One-hundred percent of the ulcerations have healed in a short time – the average time being less than sixty days. Hospitalization was frequently prolonged from other diabetic complications, but averaged only twenty days. No toes have been lost to gangrene.

This procedure has several advantages. The patients maintain a relatively intact foot, the great toe is not amputated, and the necessity for shoe fillers is avoided. Importantly, the foot is not dismembered, and the cosmetic deformation feared by most diabetics is avoided. In most instances, patients resume the same activity level and employment they pursued prior to development of toe ulceration. No longer do they have to do continuous dressing changes. The occurrence of future foot problems is reduced. While the large toe loses most push-off strength, some is maintained and the gait pattern is not appreciably altered. Additionally, by maintaining some of the push-off, the first metatarsal head is partially unloaded,[1] protecting this site of potential problems.

The procedure does require hospitalization. Complete healing of both the ulcer and the operative site may take several months. There is a risk of complications resulting in amputation. We try to minimize the risk with careful evaluation of the vascular status, intelligent use of antibiotics, and careful management of the hyperglycemic state. Each patient should be apprised of the potential risks.

Summary

Certain patients have severe ulcerations on the plantar surface of the large toe that debridement and split thickness skin graft will not heal. After careful vascular and medical evaluation, resection of the proximal one-half of the proximal phalanx of the great toe, at times followed by split thickness skin graft to the toe ulcerations, has resulted in healing of these lesions.

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PRENATAL AND POSTNATAL DEVELOPMENT OF HUMAN KNEE JOINT MENISCI+

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Introduction

The menisci are important primary stabilizers and weight transmitters in the knee. A thorough understanding of their basic form (i.e. gross anatomy and histology) is a prerequisite to understanding function. Previous studies have analyzed the microscopic structure and biomechanics of adult menisci[7,36] but no parallel study of developing menisci has been reported.

Gardner and co-workers,[15] as well as McDermott,[25] Mitrovic[27] and others[1,3,11] have provided detailed studies of the prenatal development of the knee joint, however, they concentrated largely on embryologic development (i.e., prior to three gestational months). No similar longitudinal fetal and postnatal development study of the human menisci, correlating anatomy (gross morphology) and histology is currently available. It is the purpose of this study to expand upon these works and to concentrate on changes occurring during the *fetal* period. More importantly we will look at the postnatal development. While studying the development of the meniscus, we will also investigate the topic of discoid meniscus.

Meniscal injuries are extremely unusual in children, but become increasingly prevalent in adolescence. Traumatic rupture of previously intact normal medial menisci in children before the age of 10 is exceedingly rare.[4,6,10,34,35,38,39,40] In this study, we will correlate this clinical observation with the changing developmental architecture.

Further, with increased emphasis on repair of partial and peripheral tears rather than total meniscectomy, understanding the histological structure of the immature meniscus may allow greater chance of success. However, the exact histologic nature of menisci at different ages is unknown. A chronological anatomic and histologic study of prenatal and postnatal cadaver knees was undertaken to critically analyze and elucidate the changes that occur in the developing meniscus with growth. In this paper, we will correlate the morphologic changes with the evolving physiology and function.

Materials and Methods

Specimens were obtained from the Yale Human Growth and Development Laboratory. One hundred nine specimens from fetuses ranging in age from fourteen to thirty-four weeks gestation (80-285 mm. crown-rump length) and twenty-eight specimens from cadavers ranging in postnatal age from three months to eleven years were studied providing a total of 548 menisci (Table 1). For comparative purposes, three menisci were obtained from adult autopsies.

Table I

Speciman Studied (Parenthetical Numbers Indicate Number of that Length or Age Group Studied)

Prenatal (In Millimeters, C-R Length)	Post Natal (By Age)
80 (7)	3 Mo. (4)
90 (2)	3 Yr. (2)
100 (11)	6 Yr. (4)
110 (10)	7 Yr. (4)
120 (4)	9 Yr. (4)
130 (16)	10 Yr. (4)
140 (16)	11 Yr. (6)
150 (2)	Adult (3)
160 (5)	
170 (7)	
180 (4)	
190 (2)	
200 (5)	
210 (4)	
220 (4)	
230 (4)	
240 (2)	
250 (1)	
285 (2)	

All specimens were studied according to the following protocol:

(1) Gross studies: the intact specimens were roentgenographed, photographed, and measured. The joints

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were carefully dissected with a dissecting microscope with attention directed to gross morphologic patterns, capsular and ligamentous insertions and gross vascular contributions. The proximal one-fourth of the tibia with attached menisci was removed and slab specimens were prepared. Since it was possible to get matching (right/left) specimens from many cadavers, most specimens were sectioned in at least two planes: sagittal and transverse (Figure 1). For descriptive purposes, the portions of the menisci were divided into internal, intermediate and external thirds by measurement (Figure 2), as suggested by Wilson, et al.[44]

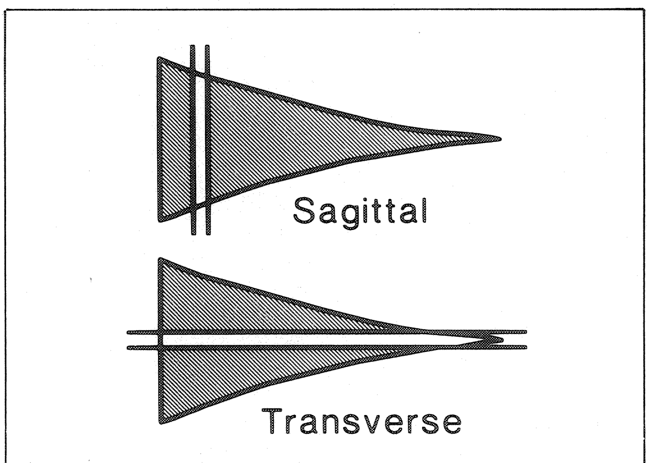

Figure 1.

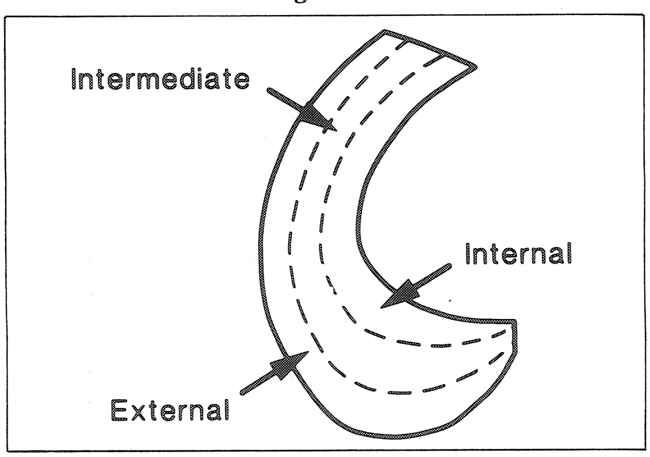

Figure 2.

(2) Meniscal area: all slab specimens were photographically documented using a standard technique. A Nikon-F camera with a macroscopic/microscopic lens system was utilized. Photographs of the tibial plateau with attached menisci were obtained and were subsequently converted to line drawings on graph paper. A Kontrin Messgerate Quantitative Image Analyzer (model MOP/AMO 1) was used to determine meniscal and tibial plateau areas. Ratios of lateral to medial meniscal area and meniscus to respective tibial plateau area were determined and analyzed.

(3) Histology: when all photographic and roentgenographic documentation was complete, appropriate slab specimens consisting of the proximal tibia with attached menisci were decalcified in five per cent formic acid solution, sectioned in transverse or sagittal planes and embedded in paraffin. They were microsectioned at six microns and stained with hematoxylin and eosin or Bodian silver stain (for nerve fibers). The sections were examined under ordinary and polarized microscopy. Study focused on the changing histologic patterns which occurred with growth. Neurovascular structures and attachment sites were carefully analyzed.

Results

Meniscal Area

Ratios comparing the medial meniscus (MM) area to the medial tibia plateau (MTP), lateral meniscus (LM) to lateral tibial plateau (LTP) and medial meniscus to lateral meniscus were calculated and recorded in Tables 2 and 3. These values were graphically analyzed and plotted in Figures 3, 4, 5, and 6.

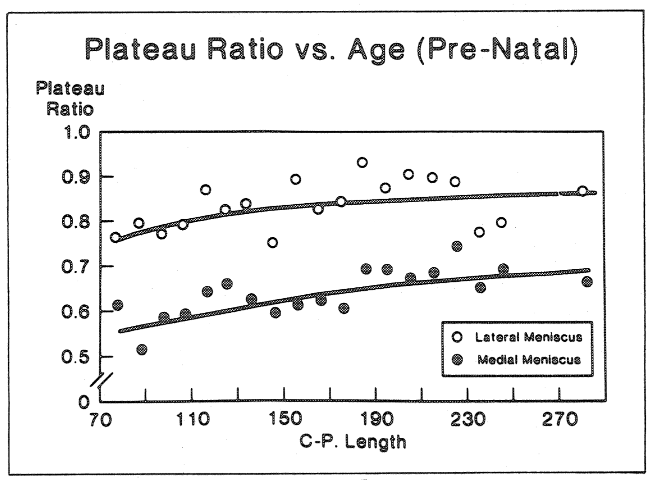

Figure 3.

Table 2 contains a tabulation of the meniscal areas of the prenatal specimens. The ratio of meniscus area to its respective tibial hemiplateau describes the percentage of the plateau covered by meniscus. As this ratio approaches one the meniscus covers more of its hemiplateau and assumes a more discoid appearance. None of the prenatal specimens were discoid. The medial meniscus covered from 51% to 74% of its hemiplateau with a mean of 64%. The lateral meniscus consistently covered a greater portion of its plateau with a mean meniscus-plateau ratio of 0.84. The surface area of the medial meniscus was compared to that of the lateral

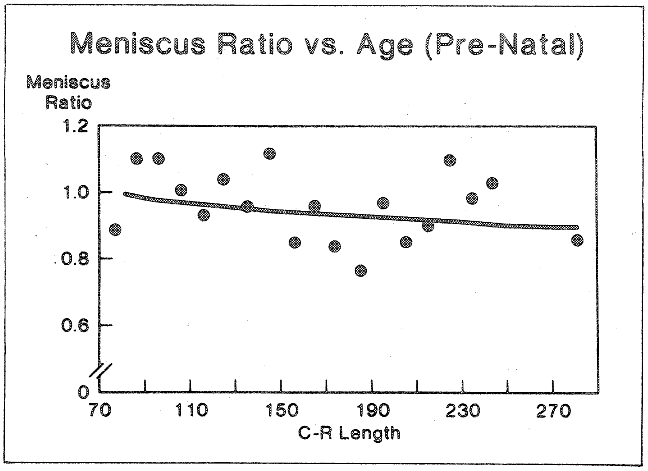

Figure 4.

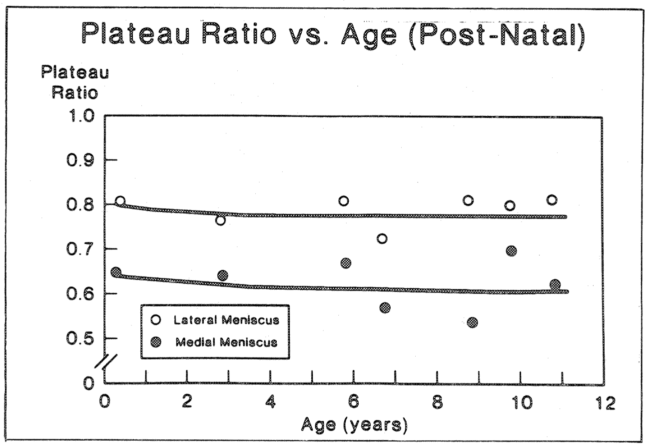

Figure 5.

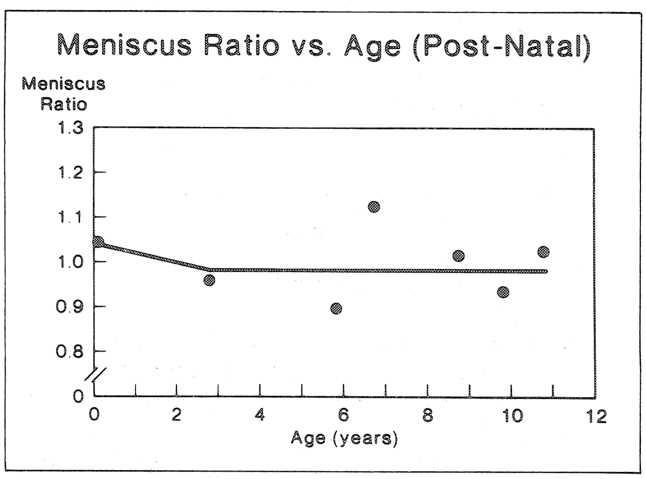

Figure 6.

meniscus and a ratio was determined. The medial and lateral menisci were about equal in total surface area.

The plateau ratio was plotted against age for the prenatal specimens (Figure 3). The ratios tended to slightly increase during the early fetal period but leveled off by

Table II

Meniscal Areas (Pre-Natal)

C-R Length	(MM/MTP)*	(LM/LTP)**	(MM/LM)***
80	0.61	0.78	0.87
90	0.51	0.80	1.09
100	0.59	0.77	1.09
110	0.60	0.80	0.99
120	0.64	0.87	0.91
130	0.66	0.83	1.03
140	0.63	0.84	0.95
150	0.60	0.75	1.11
160	0.62	0.89	0.83
170	0.63	0.82	0.95
180	0.60	0.84	0.80
190	0.69	0.93	0.75
200	0.69	0.87	0.95
210	0.67	0.90	0.83
220	0.68	0.89	0.90
230	0.74	0.88	1.09
240	0.65	0.77	0.96
250	0.69	0.79	1.02
285	0.66	0.86	0.84
Mean	0.64	0.84	0.95

approximately 28 weeks gestation. The meniscus ratio was also compared with age, but no consistent trend was established (Figure 4).

The meniscal areas of the postnatal specimens are similarly recorded in Table 3. As can be seen in the chart, these values are quite similar to the prenatal specimens. Once again, the medial meniscus covered a smaller percentage of its respective hemiplateau than did the lateral. The mean values for the medial and lateral menisci were also similar to the prenatal condition.

Table III

Meniscal Areas (Post-Natal)

AGE	(MM/MTP)	(LM/LTP)	(MM/LM)
3 Mo.	0.64	0.81	1.04
3 Yr.	0.63	0.76	0.96
6 Yr.	0.66	0.80	0.89
7 Yr.	0.56	0.72	1.12
9 Yr.	0.53	0.80	1.01
10 Yr.	0.69	0.79	0.93
11 Yr.	0.61	0.80	1.02
MEAN	0.62	0.78	0.99

The plateau ratios did not vary significantly with age as depicted in Figure 4. Likewise, the meniscus ratio did not show a significant variance during postnatal growth (Figure 6).

Throughout the fetal period, the lateral meniscus covered a greater portion of its respective tibial plateau compared to the medial side. This same relationship was also seen in the postnatal specimens and appeared to be constant. The plateau ratio curves as depicted in Figures 3 and 5 have the same general configuration for both the medial and lateral meniscus. This implied that the same rate of change occurred simultaneously in both the medial and lateral meniscus.

Histologic Study

Fetal Specimens

Our observations commenced at approximately twelve weeks gestation when the fetus has a crown-rump length of eighty millimeters.

80 millimeters. At this stage the joint cavity had essentially the same contours and relative size as in the adult. The femoral condyles, patella and the tibial plateau were all present. The distal femoral and proximal tibial growth plates had developed into distinct regions between their respective metaphyses and chrondroepiphyses. The tibial tuberosity was not yet evident. The joint capsule, collateral ligaments, cruciate ligaments and coronary ligaments were well defined. Blood vessels were prominent along the perimeter of the menisci, around the cruciate ligaments, and in the areolar tissue of the posterior aspect of the joint.

The meniscus was a distinct structure and was well separated from the articular surface of the tibial plateau. It demonstrated the same capsular and tibial attachments as in the adult. At this stage, the meniscus was densely cellular consisting of fibroblasts. These cells appeared plump in the intermediate region of the meniscus and were more compact at the edges. Vascular channels penetrated the entire meniscus, including the internal third. Vessels were particularly numerous and appeared to enter the meniscus at the sites of attachment to the plateau along the circumferential aspects of the meniscus. There was no evidence of chondrification within the meniscus.

The meniscal attachment sites were characteized by a gradual transition from fibroblasts in the meniscus to hyaline cartilage in the tibial plateau. The zone between these two areas was comprised largely of fibrocartilage. Fibrocartilage was also evident surrounding the attachment sites of the coronary ligaments.

The cells comprising the meniscus were characterized by a large nuclear to cytoplasmic ratio. There was no definite arrangement of cells at this stage. The cells were somewhat compacted at the priphery, and no synovial lining membrane was evident.

The tibial spines were well defined and the cruciate ligaments present. The cells comprising the cruciate ligaments were arranged in a somewhat regular fashion, being largely parallel to the long axis of the ligament. The ligaments were composed of fibroblasts with chondroblasts identifiable at the points of attachment. Blood vessels were prominent peripherally at the attachment sites of the tibia, however, vessels did appear to permeate throughout the substance of the ligament.

120 millimeters. The capsule, menisci, coronary ligaments and cruciate ligaments appeared more distinct. The tibial tuberosity was beginning to form and the patellar ligament was starting to send fibers into it. The cells comprising the menisci and cruciate ligaments were becoming more differentiated and mature appearing. The matrix was more collagenous. The collagen bundles comprising the meniscal fibers appeared to orient in an organized fashion. In the transverse plane, the fibers were arranged largely in a circumferential fashion, although some fibers were radially directed. The compacted layer of cells at the periphery of the meniscus became more distinct. Numerous blood vessels were present throughout.

150 millimeters. Further maturation of all structures was evident. The vascularity of the meniscus and of the chondroepiphysis was more prominent. The tibial tuberosity was more distally situated in relation to the tibial chondroepiphysis.

The most striking feature at this time was a further differentiation of the peripheral compact layer of fibroblasts to form a distinct synovial membrane. This membrane was approximately five to six cell layers thick, being slightly thicker at the more acute curves of the meniscus.

The arrangement of the collagen fiber bundles was more organized. The predominant alignment of fibers in the transverse plane was circumferential with fibers at the attachment sites being more obliquely oriented with respect to the axis of the plateau. Radial fibers appeared to be more prominent on the tibial surface and woven collagen bundles were seen on the femoral surface.

Vessels continued to permeate the entire meniscus, being more prominent at the peripheral attachment sites to the capsule and along the coronary ligament.

180 millimeters. Blood vessels were more evenly distributed within the chondroepiphysis. The chondroblasts of the epiphysis were more mature appearing, assuming a hyaline character. These changes were most marked immediately adjacent to blood vessels. Fibrocartilage was prominent at points of attachment of the meniscus to the chondroepiphysis.

The surrounding synovial layer was more distinct, completely enveloping the meniscus except at attachment sites. The nuclear/cytoplasmic ratio was greater in these lining cells, compared to the cells comprising the body of the meniscus which were becoming increasingly collagenous.

240 millimeters. Grossly, the cruciate ligament, ligament of Wrisberg, ligamentum transversum, alar ligament and ligamentum mucosa were well defined. The infrapatellar fat pad was also evident.

The tibial tuberosity had continued its distal migration with respect to the tibial plateau and the proximal tibial physis was now proximal to it.

The meniscal fibers were becoming further organized in their arrangement. Discrete bundles of fibers were evident on sagittal views.

The cytoplasm of the fibroblasts was becoming more collagenous and subsequently the nuclear/cytoplasmic ratio was decreasing.

285 millimeters. No significant structural change was noted, however, further growth had occurred. The synovial membrane appeared to line the entire joint except for the articular surfaces of the distal femur, proximal tibia and patella and at attachment sites.

Post-Natal Development

No abrupt change in development was noted at birth, rather there was a gradual transition from the prenatal stage.

3 months. Morphologic growth commensurate with enlargement of the distal femur and proximal tibia had occurred, accommodating the changing femorotibial contact. Anterior extensions from both menisci to the anterior cruciate ligament as well as to each other were commonly present in specimens. The more fixed medial meniscus possessed important peripheral capsular attachments, including the thickened medial capsular ligament and posteromedial capsular complex. The lateral meniscus appeared to be more mobile, having no attachment posterolaterally, particularly in the area of the popliteus tendon recess. The menisco-femoral ligaments of Humphrey and Wrisberg were variable, both as to size and presence.

Microscopically, the meniscus appeared to be less cellular. A relative decrease in nuclear size was noted with an increase in collagen content. The cells were more mature in appearance and were arranged in an orderly fashion. No cartilage matrix was identified. Blood vessels could be identified throughout the entire substance of the meniscus, but were predominantly located in the external and intermediate regions.

9 months. The knee joint had a striking resemblance to the adult at this stage. Further growth had continued. The nuclear/cytoplasmic ratio of the meniscal cells continued to become progressively smaller and there was a steady increase in the amount of collagen present. Once again, no evidence of cartilage matrix was noted. The internal zone appeared relatively avascular but an occasional blood vessel was identified in this region.

3-9 years. Morphologic growth was the major process at this time. The progressive decrease in vascularity continued.

Microscopically, the collagen fiber alignment appeared highly organized. The majority of fibers were arranged in a circumferential fashion in the long axis of the meniscus, with occasional fibers traversing the circumferential ones in a radial direction. The radial fibers were located mainly on the surfaces of the meniscus, more on the tibial side than the femoral side. A few of the radial fibers changed direction and ran in a vertical fashion through the body of the meniscus.

The synovium appeared thin over weight-bearing portions of the meniscus, and was absent at the inner edge of the meniscus.

11 years. The meniscus at this stage was similar in appearance to the adult. Blood vessels were located primarily along capsular and coronary ligament attachment sites. Weight bearing regions of the meniscus lacked a synovial covering. The meniscus appeared more avascular, particularly the internal region. No evidence of cartilage matrix was present.

Discussion

The development of the human knee joint meniscus has been examined from the fetal stage to the adolescent period. Studies by Gardner,[15] McDermott[25] and others[1,3,5,11] concentrated on the embryonic and early fetal development. Several longitudinal developmental studies of non-human vertebrate knees exist,[12,14,16,27,30,42,43] however, similar human studies are virtually nonexistent.

The blastemal appendicular skeleton of the human embryo is initially formed as a continuous structure, with no spaces or joints separating the major anlagen from each other. But as the mesenchymal model begins chondrification, concomitant changes occur in the region of the presumptive joint to create the interzone. This structure has three layers – two parallel chondrogenic layers and an intermediate, less dense layer. The interarticular structures (e.g., menisci and cruciate ligaments) appear as further condensation in this intermediate layer.[28] The formation of the coordinated menisco-ligamentous complex in the knee is well established in the eight week embryo. The meniscus assumes its characteristic gross shape during prenatal development. At this stage it is highly cellular with a large nuclear/cytoplasmic ratio. Blood vessels are numerous and are most prominent along capsular and tibial attachment sites, however, vessels are identifiable throughout the substance of the fetal meniscus.

No abrupt change in development is noted at birth, rather there is a gradual transition from the prenatal state. The only major postnatal changes are progressively decreased vasularity, morphologic growth commensurate with enlargement of the distal femur and proximal tibia, and accommodation of this growth to changing femorotibial contact. The cellularity of the meniscus greatly decrease with a marked increase in collagen content. Blood vessels are primarily located in external regions of the meniscus along attachment sites.

The lateral meniscus tends to have more developmental variation, but at no time does it normally appear to have a discoid shape. The etiology of discoid meniscus and the mechanics of the clicking sound have only been partially explained. Smillie reported twenty-nine cases of congenital discoid meniscus in a series of thirteen hundred menisectomies, and has written extensively on this topic.[37] He felt that the condition was simply a reflection of persistence of the normal fetal state of development from a cartilaginous disc. Kaplan studied human fetal material, stillborns, premature and full-term infants, and conclusively demonstrated that the discoid meniscus was a definite pathologic entity that developed under specific conditions and was influenced by mechanical factors.[27] Ross observed that it is only at the very earliest phase of development during the embryonic period that the plate of undifferentiated mesenchyme from which the cartilage is developed can be said to resemble a disc in any way.[33]

Our study complements several embryologic studies which show that the meniscus does not normally assume a discoid configuration during its development.[21,22,23] Throughout growth the ratios of meniscal area to tibial plateau area and lateral meniscus area to medial meniscus area are fairly constant. This implies a uniform relative growth rate of the menisci.

Bullough and others have theorized that the microscopic structure of the meniscus is related to weight bearing function. The collagen fiber alignment has been studied by polarized light microscopy as well as electron miscroscopy.[7,8,20] The majority of the fibers are arranged in circumferential fashion in the long axis of the meniscus. Other fibers transverse the circumferential ones in a radial direction. The radial fibers are located mainly on the surfaces of the meniscus, more on the tibial than the femoral side, and probably act as tie rods resisting logitudinal splitting. A few of the radial fibers change direction and run in a vertical fashion through the substance of the meniscus. These patterns undergo the most significant development as the child begins ambulation.

The collagen fiber arrangement of the meniscus appears to be bio-mechanically advantageous. The meniscus has an important weight bearing role. It functions to transmit approximately forty to sixty per cent of the total load applied across the joint, thereby requiring significant internal strength.[41] The shape and attachments of the meniscus are such that under normal loading conditions tension will be generated in them. Bullough states that most of the fibers are arranged in a circumferential manner to withstand tension and the radially dispensed fibers probably act to resist longitudinal splitting of the meniscus.[7]

Meniscal injuries are extremely unusual in children, but become increasingly prevalent in adolescence. Ritchie described a total of thirty-nine meniscectomies in children.[32] He felt that the meniscus lesions were quite rare in children and concluded that the lateral meniscus was the prime site of pathology in children. Zaman and Leonard reported the results of meniscectomy in fifty-nine knees of forty-nine children.[45] They stressed that the results showed meniscectomy in children was *not* a benign procedure. A definite relationship existed between poor results and the removal of normal menisci. They recommended that every child have arthroscopy before arthrotomy. If a normal meniscus is found, it should not be removed; another source of joint derangement such as chondromalacia, patellar subluxation or plica syndrome must be sought.

Ingman, et al., have studied the variation of proteins in the human knee meniscus with age and degeneration.[19] They demonstrated that the ratio of collagenous to non-collagenous proteins decreased with age, resulting in a decrease of tensile strength. These changes were most marked between the neonatal and childhood meniscus. The biochemical nature of the meniscus is probably related to its vascularity. The biochemical and vascular environment of the young meniscus may be responsible for the low prevalence of meniscal injuries in children. Also, because of its vascularity and biochemical properties, the young meniscus may have greater reparative ability than the adolescent or adult.

Derangements occur in the adolescent meniscus and can cause problems typical of any older age group. A recent review of patients undergoing meniscectomy prior to the age of seventeen shows sixty percent having some type of difficulty up to nine years after surgery.[13,23] The meniscus has an important biomechanical function and there should be extremely well-defined indications for its removal, particularly in an adolescent or child. In adults the concepts of meniscal preservation and partial meniscectomy are gaining acceptance due to the decreased incidence of subsequent degenerative joint disease and the maintenance of joint stability.[2,9,17,18,24,26,29,31] In children and adolescents every effort should be made to preserve peripherally detached menisci by careful reattachment.

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SPHEROCENTRIC KNEE ARTHROPLASTY: DEVELOPMENT AND CLINICAL EXPERIENCE+

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Almost twenty years ago, John Charnley[3] proclaimed the three most important factors in the subsequent development of total joint replacement arthroplasty. (1) Low friction between the prosthetic components at the bearing surface assured minimal mechanical toggling effects at the all important prosthesis-cement-bone interfaces. (2) The selection of biocompatible metals and plastics assured an acceptable relationship with the patient's tissue, even in the face of a significant amount of particulate wear debris. (3) The use of methylmethacrylate bone cement assured firm and lasting fixation of the components to the patient's bone. These factors, together with the emphasis on operative sterility, complete patient follow-up, and responsible dissemination of information, set the foundation for an explosive development of total hip arthoplastly. This development and subsequent use of the principles involved has probably been the greatest advance in orthopaedics in at least several decades. More than ten years ago, Frank Gunston[4] studied with Charnley and developed the four-component polycentric knee. The Gunston knee components were difficult to align so that they would function harmoniously with each other and with the all important remaining knee ligaments. Because of this technical problem and because of concerns regarding wear, a two part prosthesis, the geometric, was developed. Bridges between the medial and lateral prosthetic condyles of both the femoral and tibial components allowed reproducible, congruent, interaction between these two parts. The major knee joint ligaments, the collaterals and the cruciates, provided the required knee joint stability. The prosthesis offered a smooth, painless, bearing surface and the rapid popularity of geometric arthroplasty attested to generally satisfactory early clinical results.

More than ten years ago, we recognized that many patients with severe knee joint deformity, instability, or loss of significant metaphyseal bone could not be treated with the resurfacing arthroplasty. At that time, only uniaxial hinge prostheses, such as the Walldius[1,2] were available for this patient group. Hinge prostheses had deservedly poor reputations. The all too frequent "clank" at the end of extension brought attention to the impact character of the prosthesis-bone interaction when the joint reached its mechanical, metallic extension stop. The uniaxial nature of the joint allowed for no axial rotation of the tibia on the femur. For these two reasons, the hinge joint prosthesis loosened rapidly, and the patient's pain increased while the activity level diminished. Metallic wear particles were generated at the metal-on-metal bearing surface. They frequently resulted in a serious inflammatory response. These particles and the body's reaction against them may account for a portion of the high infection rate in uniaxial metal-on-metal hinge total knee arthroplasty.

In 1971,[5] we began the development of an intrinsically stable prosthesis which could be used to treat patients with gross deformity, severe knee joint instability, or considerable loss of metaphyseal bone. We planned to utilize the basic tenets of minimal friction, biocompatible materials, and methylmethacrylate component fixation. In addition, intrinsic stability was essential for a hinge substitute. Tri-axial rotational freedom would decrease the torsional loads and minimize loosening. We recognized that end extension impact must be eliminated. A few additional design criteria were felt to be worthwhile. All plastic components should be supported by metal, and plastic should be loaded in compression. The prosthesis obviously should be strong enough to withstand all expected functional loading. Inverted plastic concave surfaces were expected to minimize the body wear. Since most metallic implants fail by fatigue, any intrinsically stable prosthesis should be tested and designed to be maximally fatigue resistant.

A contained, ball-in-socket primary articulation provided the necessary intrinsic stability against translational deformation, but allowed for excessive and uncontrolled rotation in every direction. Outrigger, or side-arm condylar tracks and runners were therefore designed to limit this excessive rotational freedom to approximately that of normal knees. This arrangement of contained ball-in-socket and outrigger track and run-

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ner geometries provided 120° of rotation in the flexion-extension axis, and 20° of unrestricted axial rotation of the tibia in relation to the femur with normal varus-valgus stability in both flexion and extension.

A large number of prosthetic prototype models were modified until in early 1973, the first Spherocentric knee (Figure 1) achieved,[6] in essence, its present shape.

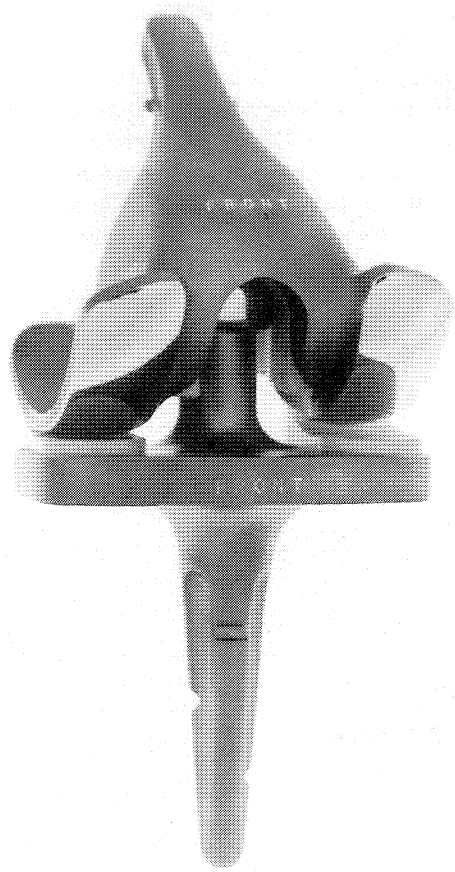

Figure 1. This view of the Spherocentric knee demonstrates the central ball-in-socket in relation to the condylar tracks and runners.

This prosthesis was taken through a series of three point hyper-extension bending tests and was compared to normal cadaver knees and to hinge joint prosthesis-prepared cadaver knees for load to failure and energy to failure. In the test of hyperextension resistance, the Spherocentric prosthesis allowed a greater deformation before failure and a much greater load before failure than did normal control knees. The energy to failure for the prosthesis-prepared specimens was nearly twice that of control specimens. In these same tests, hinge joint prepared specimens failed at very high load levels with very little deformation. The engineering test graphs were documentation of the impact metallic extension stop. Spherocentric prepared specimens, on the other hand, slowly deformed with load, and resembled normal knees in their end extension behavior. When tested for resistance to varus or valgus deformation, control and prosthesis-prepared specimens were equally strong. Although tension is an infrequent failure mode, tensile tests of tibial component stability in bone, femoral component stability in bone, and intrinsic ball-in-socket prosthetic stability were carried out. While the femoral component failed at approximately 390 kilograms, and the tibial component failed at nearly 300 kilograms, the ball-in-socket articulation of the prosthesis failed at a much lower load of 160 kilograms. This load, more than 320 pounds, was felt to represent adequate intrinsic strength. Should an unfortunate tensile event occur, separation at the replaceable ball-in-socket articulation would be preferrable to avulsion of either prosthetic component from its metaphyseal bone. A few tests in pure compression indicated that prosthesis-prepared specimens were as strong as normal specimens. Wear tests of the prosthesis bearing surfaces flooded with serum were carried out utilizing 60° arc with a 200 pound load. After 1,200,000 cycles, the fatigue machine failed. At that time there was minimal prosthesis component wear. While this does not duplicate physiologic knee function, subsequent clinical prosthetic use over many years has not revealed a wear problem.

Most orthopaedic implant failures are due to fatigue. The nature of the knee joint subjects the intrinsically stable prosthesis to high loads. We were concerned that the Spherocentric prosthesis would be vulnerable to the same fatigue problems which plagued the Herbert prosthesis.[7,8] Because of this, prosthetic prototypes were coated with stress coat, a brittle lacquer which predictably and visibly cracks at known strain levels. Coated components were subjected to strains estimated to be in excess of those which would be expected in normal use. Areas where cracks appeared were instrumented with strain gages and direct strain readings obtained. The prosthesis was modified until it was felt that fatigue failure of the metal components would be extremely unlikely under anticipated human use.

When the prosthesis passed these tests, it was approved by the University of Michigan Human Subject Review Committee for clinical trials for patients with severe instability, or deformity of the knee joint, or for those who had lost considerable metaphyseal trabecular bone. All of these patients would otherwise have been considered candidates for knee joint fusion or previously for axial hinge arthroplasty.

Between 1973 and 1977 we performed 84 Spherocentric arthroplasties on 71 patients. Ninety-eight percent of these patients were followed according to protocol consistently until 1980. The follow-up period averaged 48 months and ranged from 24 to 73 months. Approximately half of the patients had rheumatoid arthritis and half had degenerative joint disease with a variety of etiologies.

Thirteen of the procedures were performed for failure of eight types of previous arthroplasty. While uniaxial hinges were dominant in this early group, many revisions were done for failures of resurfacing prostheses. All of these revisions achieved knee joint stability and a functional range of motion. No overwhelming problems were identified in revising either failed hinge or resurfacing prostheses.

Thirty-eight patients had varus or valgus knee joint instability that ranged from 2 to 60 degrees. These patients with an average instability arc of 26° all achieved immediate post-operative stability. At the time of follow-up four knees were unstable. Thirty-seven knees were treated for varus deformity of an average of 25°. They were corrected an average of 23° for a final post-operative knee position of five degrees valgus. The final knee angulation after arthroplasty ranged from five degrees of varus to eleven degrees of valgus. Twenty-nine patients with valgus deformities that ranged from 5 to 50 degrees (average 20°) were corrected 20° for a post-operative knee joint angle of six degrees valgus. The post-operative range was five degrees varus to ten degrees valgus. Thirty-one patients were treated for an average 34° knee flexion contracture. The maximum preoperative knee flexion contracture was 80°. These patients' knees were corrected an average of 30° for a final post-operative knee flexion contracture which averaged three degrees. Corrections of flexion contractures were maintained throughout this long term follow-up period.

Electrogoniometric studies of patients walking, sitting, and turning around indicated that they used 10° of tibial-axial rotation on the femur during these activities. That compares to the 12° measured for normal young adults. These studies appear to indicate that provision of tibial rotation is indeed an important design feature for an intrinsically stable prosthesis.

Flexion-extension range of motion examinations demonstrated an average of seven degrees of improvement with the operative procedure. This minimal change was due to the fact that patients with unstable knees lost motion while patients with stiff knees, or flexion contractures, gained motion. More importantly, these very seriously affected patients achieved an average of 90° of knee motion and were in general able to rise independently from a normal chair using the prosthetic knee joint.

Pain was dependably relieved. The average post-operative patient at the time of follow-up used no pain medication for the knee joint and did not have rest pain. The average patient, however, did have pain when shopping or using the knees excessively. The patient's function was greatly increased. The average preoperative patient rarely could leave the home and usually walked with supports. The average post-operative patient used a cane but could shop at supermarkets, attend special functions, and live independently.

At follow-up, thirty femoral components (37%) demonstrated radiolucent lines around the cement. Twenty-two were non-progressive while eight were progressive. Radiolucent lines were noted around the cement at some location for 34 (43%) arthroplasties. Twenty of these were non-progressive throughout the period of follow-up and 14 were progressive. At the time of follow-up three patients had knee joint infections. One occurred during the initial hospitalization and two were diagnosed after several months. One patient's limb was amputated for infection. Nine knees demonstrated prosthetic loosening. We defined loosening as motion of the prosthesis relative to its bony bed with manually applied maximally tolerable stress, or as documented motion of the prosthesis relative to the bony bed when sequential radiographs were compared.

During the period of follow-up, seven revision operations were done: one for persistent patellar pain, three for loosening, and three for infection. This re-operation rate of nine per cent compares favorably with most other reports for intrinsically stable prosthetic arthroplasty. In fact this re-operation rate is comparable to that seen after the same period of follow-up for revision of resurfacing arthoplasty.

Before Spherocentric arthroplasty, seven patients were non-ambulatory and only two could walk without aids, and at the time of follow-up only one patient was non-ambulatory, and 38 could walk unassisted.

Total joint replacement arthroplasty offers appropriate patients a significant chance for elimination of pain and increased function. Resurfacing procedures should be used for all patients with satisfactory ligamentous stability and sufficient metaphyseal bone for the selected procedure. In cases where ligamentous stability has been compromised by disease or previous surgery, and where there has been considerable bone loss, the Spherocentric prosthesis can substitute and provide good function for many years.

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OBJECTIVE EVALUATION OF THE MEDIAL COLLATERAL LIGAMENT OF THE KNEE

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Introduction

"From the mechanical point of view, the knee is a compromise which sets out to reconcile two mutually exclusive requirements: to have great stability in complete extension, when the knee is subjected to severe stress resulting from the body weight and the length of the lever arms involved; to have great mobility after a certain measure of flexion has been achieved."[1]

The stability of the knee is maintained by the menisci, the capsule and non-capsular ligaments, the musculotendinous structures which traverse the joint, and the shape of the femoral and tibial condyles. The collateral and cruciate ligaments guide the joint through a normal range of motion while preventing abnormal mobility.[2] With injury to one or more of these structures, function is compromised. Precise evaluation of knee injuries is important for accurately planning therapy. "It is not sufficient simply to perceive that some change is present; it is necessary to define how much stability has been altered, and how the pattern of stability of the knee in various positions has changed."[3] Clinical assessment of knee laxity is subjective and depends upon the skill and experience of the examiner. Thus, an objective system for the evaluation of knee ligament injuries would help in establishing the exact diagnosis.

This paper focuses on injuries of the medial collateral ligament (MCL), the most frequently injured ligament in the knee.[4] A brief review of some of the work describing the functional anatomy and pathophysiology of this ligament complex will be presented. This review includes a description of some of the diagnostic aids that have been developed. Finally, the diagnostic apparatus and the data derived from it will be presented.

Historical Review

Hiesch[5] and Trent[6] used fresh cadaver specimens to examine the stabilizing mechanism of the loaded and unloaded knee to determine knee ligament length patterns, strength, and rotational axes. Wang[7] used similar specimens to characterize laxity of the normal knee. He found no discernible correlation with age, sex, race or bodv build.

Selective ligament transection in intact cadaver specimens followed by controlled range of motion testing has been a frequently employed method of study. Martin[8] used this technique with abduction stress roentgenograms to study medial collateral ligament injury. He concluded that an increase of greater than 1.0 mm in medial "clear space" is presumptive evidence of a partial or complete rupture of the medial collateral ligament. Roubichon[9] and Warren[10] concluded that the MCL is the primary stabilizer of the knee against valgus and rotatory stresses. Markolf and co-workers[3] recently concluded that torsional laxity and internal rotational stiffness were most significantly affected by sectioning the MCL. They noted that this structure, along with the posterior capsule, is important in controlling anteroposterior laxity. Crowninshield et al.[11] determined from a mathematical model of the knee that the medial collateral ligament and the middle one-third of the medial capsular ligament provide approximately equal contributions to valgus stability. Radiography has been employed by several investigators[12-15] to evaluate the MCL. In these investigations the thighs were immobilized while a valgus force was applied to the lower leg and a roentgenogram taken. A similar method using serial photographs was described by Spraque.[16] Klein[17] was the first to describe an instrument that could be applied directly to the leg in evaluating ligamentous instability. His apparatus evaluated the knee in full extension by manually applying forces and measuring deflection with a dial indicator. However, the author did report some difficulty in repeatability. Kalenak and Morehouse[18] developed a system for evaluation of medial, lateral and anterior stability. Lowe[19] established a preliminary report in 1970 of a mechanical testing machine. No follow-up was found in the literature. The present authors[20-22] published a series of articles describing knee impedance for evaluating the *in vivo* dynamic behavior of intact and injured human knees in varus and valgus.

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Method

This study was divided into three distinct phases: 1) measurement of the load deflection characteristics of the *in vivo* human medial collateral ligament using a simple testing machine; 2) establishing the relationship of anthropometric parameters (height, weight, and proximal tibial width) to the compliance of the medial collateral ligament, and 3) retrospective analysis of injured skiers to determine the relationship of ligament compliance to actual injuries produced.

Definition of Terms

The testing machine provides a measurement of compliance or stiffness. Compliance is the ratio of elongation of the ligament to the load applied and stiffness is its inverse, the ratio of load to elongation. These entities are thus specific engineering terms describing the relative displacement of the medial collateral ligament when loaded. "Clinical laxity" is a less precise term used to describe the examiner's impression or rating of the medial ligament complex after applying a typical valgus force test.

Phase I: Measurement of Load Deflection Characteristics:

Subjects for the first phase of the study were randomly selected from the hospital staff, medical school and the outpatient orthopaedic department at the University of Vermont Medical Center. Forty-one individuals participated in this study (15 females and 26 males), 18 of whom gave no previous history of knee injury or surgery (7 females and 11 males). Nine patients (4 females and 5 males) had a history of injury or surgery that involved the MCL of one knee but whose opposite knee was "normal" (Table I).

Table I

Subject Population

BOTH KNEES NORMAL:	7 FEMALE + 11 MALES = 18
ONE KNEE INJURED (NOT INVOLVING MCL)	4 FEMALES + 5 MALES = 9
ONE KNEE INJURED (INVOLVING MCL)	4 FEMALES + 10 MALES = 14
TOTAL SUBJECTS	15 FEMALES + 26 MALES = 41
TOTAL NORMAL KNEES:	22 FEMALES + 37 MALES = 59

A brief history relating to any lower extremity injuries was recorded. Measurements of proximal tibial width, tibial length, and thigh circumference were made on each subject.[23] Height, weight and sex were recorded. Both knees were then examined by conventional clinical means including varus and valgus forces at 15° of flexion, anteroposterior forces at 15° and 90° of flexion, and axial torgue with the knee flexed 90°. Particular attention was paid to the valgus force test with which the medial collateral was assessed as to its clinical laxity on a scale of 1 to 9 (1 = very loose and 9 = very tight).

A specially designed portable examining platform was built to attach securely to any conventional office examining table (Fig. 1). It consists of a horizontal portion supporting the supine patient and an angulated portion which supported the leg in 15° to 20° of flexion. The foot of the leg to be examined was secured in a low friction roller mechanism which glided over a plexiglass surface. Around the ankle was attached a spring-loaded tape measure. With a hand-held transducer, valgus force was applied to the leg in five increasing increments (Fig. 2) from the position at which the primary laxity ended. The scale was marked from 0-25, and the displacements on the tape measure were read at each 5

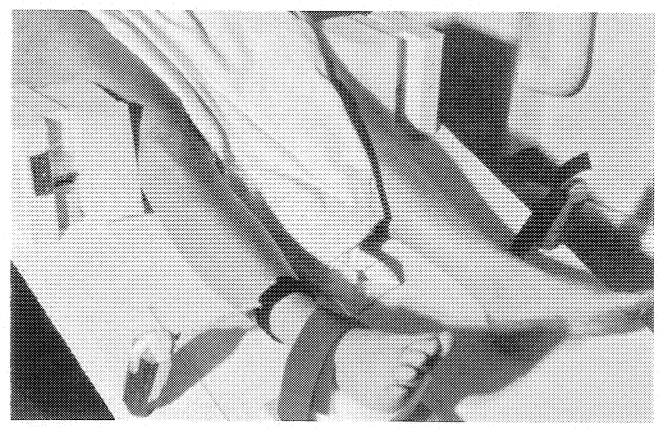

Figure 1. Demonstration of test subject lying on examining table.

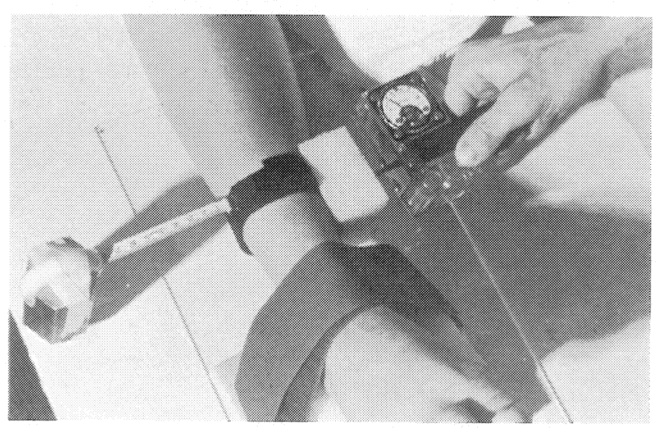

Figure 2. Hand-held displacement transducer being applied to the subject's leg during the valgus stress test.

unit increment. Each such increment was 7.5 N, but this was deliberately left unknown to the examiners. The distance from the knee joint to the point of application of force was the same for all subjects to assure that the moment applied to the MCL of the knee was the same in spite of differing leg lengths. As each additional 7.5 N force was applied, the valgus displacement was recorded in centimeters from the measuring tape. This procedure was performed twice on each leg (Fig. 3).

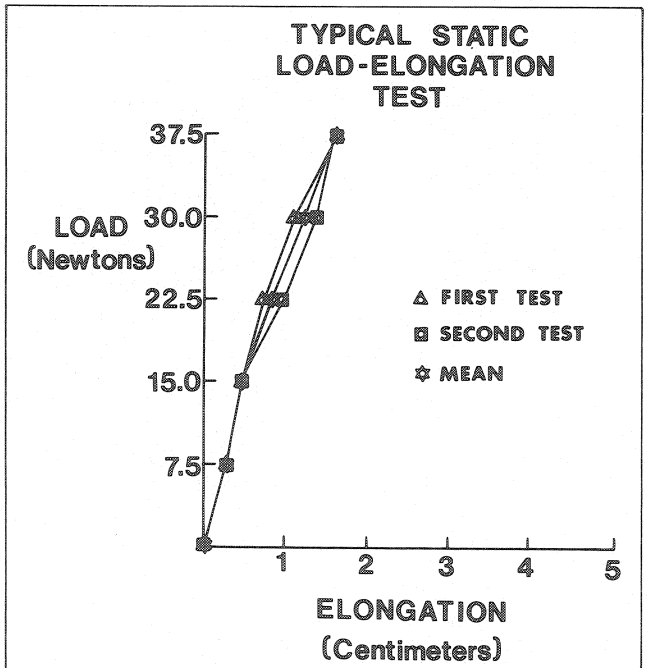

Figure 3. Displays the results of two typical load elongation tests on a single individual. The mean of the two tests is also depicted.

Rotation of the femur was found to be very important in a recent study of ours,[22] but this was found to be minimal due to the low forces involved and to the partial fixation of the tibia in the heel cup. Likewise, upper body motion was assessed and found to be minimal. Two of the authors (RJJ and KHJ) examined the first 15 subjects independently to establish the degree of reproducibility possible using the test method. Reproducibility was dependent upon careful positioning of the patient. Keeping the lateral side of the leg parallel to, and snug up against the lateral pad was particularly important. It was, however, quite easy for the investigators to demonstrate repeatability with a minimum of practice.

Phase II: Compliance Versus Anthropometric Data:

A linear regression analysis of all anthropometric data and ligament compliance was then undertaken. This established a statistical relationship between easily obtained body parameters and ligamentous compliance.

Phase III: Analysis of Injured Skiers

The formula derived from the regression analysis allowed retrospective evaluation of 827 uninjured (control) skiers and 1,052 injured skiers who sustained 195 MCL sprains during the 1972-73, 1973-74, 1974-75 and 1975-76 seasons at a northern Vermont ski resort. Immediately following injury, each skier was asked a series of questions concerning physical characteristics; experience; the causes and mechanism of the accident; and the adjustment, maintenance and previous performance of the ski-boot-binding system. Their height, weight, proximal tibial width, age and sex were recorded. The relationship of the derived ligament compliance to the type of injuries they sustained was established.

Results

For all 41 individuals evaluated on the machine, the mean weight of the males was 79.52 Kg and that of the females 57.65 Kg. The males averaged 1.79 M, while the females averaged 1.64 M. Their ages ranged from 14 to 38 with a mean of 24.7 years. The load-deflection data was plotted by the computer and the slope or compliance computed.

The load-deflection tests attained from the first 15 subjects was evaluated separately by two of the authors and showed a correlation coefficient of .99 and a slope of .99. This indicates that the test produced very consistent results when performed by two different individuals.

The compliance of 37 normal male knees was then compared with the compliance of 22 normal female knees. There was a significant difference between the means of the two groups, females showing greater compliance than males: females = 7.93×10^{-4} M/N, males = 6.38×10^{-4} MN, (t test $p < .0025$). This difference was also detected in the analysis of the clinical laxity obtained by routine examination. The females averaged 4.68 on a scale of 1 to 9 (very loose to very tight) while the males averaged 5.96 (t test $p < .005$).

Even though the difference was also detected by the clinical examination, the possibility existed that the apparent difference in compliance was due to a greater compressibility of adipose tissue over the medial aspect of the female knee in spite of attempts to minimize this by pivoting about the bony prominence of the femure. To eliminate this possibility, we compared the mean compliance of our six lightest normal females with smallest thigh circumferences (mean weight = 45.81 Kg, and mean thigh circumference = 41.7 cm) to our six heaviest females with the largest thigh circumference (mean weight = 68.5 Kg, and mean thigh circumference = 51.7 cm). The increased adiposity of the heavier females did not result in an overall change in compliance, nor a decrease in the initial slope of the load elongation curve, which we would have expected if the soft tissue (with its inherently higher compliance) was responsible for the initial displacement reading.

A linear regression analysis of the anthropometric data (height, weight and proximal tibial width) against compliance was undertaken. The trend of an increasing proximal tibial width, height and weight and a decreasing compliance was noted (correlation coefficient = .54, .55, and .56 respectively). There was no significant correlation between tibial length or thigh circumference and compliance.

We studied the relationship between clinical laxity and the measured compliance. The following regression formula was obtained:

Clinical laxity = −14.55439 (C) +9.978240.

Where C = Compliance

Correlation coefficient = .72

A stepwise regression formula between height, weight, and proximal tibial width versus compliance was obtained, thus providing mathematical descriptions for the relationships:

$$C = \text{Compliance (m/N)} = 5.1 + 14.0\,(hp) + .005\left[\frac{W}{P} + 1.4\,h - .0018\,(hw) - 4.0p\right]10^{-4}$$

Where h = height (m)

w = weight (leg)

p = proximal width (m)

Correlation coefficient = .65

These formulae were then applied to a group of 195 skiers who had sustained medial collateral sprains probably related to the failure of their bindings to release and to 827 uninjured (control) skiers. We used the weight, height, and proximal tibial width measurements obtained at the time of their injury. Analysis of the ski injury population revealed that although females have a higher incidence of MCL sprains than males ($p < .005\ \chi^2$), a disproportionately large number of female's sprains were Grade I.

Tables II and III show the means and standard deviations for height, weight, and proximal tibial width, com-

Table II

Anthropometric Results of Ski Injury Population

		MEDIAL COLLATERAL LIGAMENT SPRAINS			CONTROLS
		Grade I	**Grade II**	**Grade III**	
Height (Meters)	Mean	1.67	1.70	1.74	1.72
	S.D.	0.14	0.10	0.11	0.11
Weight (kilograms)	Mean	59.6	66.9	71.6	67.2
	S.D.	14.7	12.9	18.7	14.5
Proximal Tibial Width (centimeters)	Mean	8.32	8.80	8.70	8.70
	S.D.	0.86	0.70	0.70	0.60

The differences between the three grades of ligament sprains were statistically significant.
Height < .05 chi square
Weight < .05 chi square
Proximal Tibial Width < .07 chi square

Table III

Regression Results on Ski Injury Population

		MEDIAL COLLATERAL LIGAMENT SPRAINS			CONTROLS
		Grade I	**Grade II**	**Grade III**	
Compliance ($\times 10^{-4}$ meters/Newtons	Mean	8.61	8.38	7.70	7.93
	S.D.	2.72	3.40	2.04	2.49
Clinical Laxity (Non-dimensional scale from 1-9)	Mean	4.40	4.80	5.00	4.90
	S.D.	1.60	1.40	1.40	1.40

pliance, and clinical laxity compared to the grade of medial collateral injury. The grade of ligament injury was based on the definitions in the American Medical Association Standard Nomenclature of Athletic Injuries.[24] The height and weight of skiers who sustained medial collateral injuries increased as the grade of injury became more severe ($p < .05$ χ^2 respectively). The proximal tibial width of the individuals with Grade I injuries was less than that of Grade II and III sprains ($p < .07$ χ^2). Controlling for ability of skier; height, weight, and tibia size increased as the grade of injury rose (significant to $p < .05$ for both male and female, except proximal width for females $p < .07$). The foils in our questionnaire regarding mode of injury (direction of fall, weight bearing, windmilling, etc.) showed no differences related to size.

Discussion

The apparatus described quantitates only one functional component of the medial collateral ligament; that being its ability to support the knee against a valgus force. This study does not address the question of the medial collateral ligament's supportive role in axial rotation. The apparatus allows the rapid and repeatable collection of data from which statistically significant conclusions are derived. It requires only 37.5N of force to be applied to the leg and thus can be used even in acutely injured knees without producing significant pain. This small amount of force eliminates the need to control rotation of the lower extremities which invariably occurs if larger increments of force are applied to the leg. Administration of the test requires less than 15 minutes. The entire apparatus is easily transportable and costs less than $150 to construct. It thus has the potential of being a valuable adjunct in knee injury research.

No previous mention has been made in the literature regarding laxity difference between males and females in the *in vivo* human knee. Wang[7] studied rotatory laxity in 27 cadaver knees and found no correlation of laxity with age, sex, race, or body build.

In the ski injury group, we found a lower relative incidence of severe knee injuries in women. In could be that their increased compliance protected them from the more severe injuries, but further work is required to confirm this. Women appeared to have more compliance than men due to anthropometric scaling (size) rather than sex per se. Likewise, it is possible that all individuals who are classified as loose are protected from more severe skiing injuries because of an increased compliance. For a given breaking strength, more compliance means more ability to absorb energy before disruption occurs. The knee injury in skiing may also be displacement limited (load being applied for a finite distance as the ski externally rotates, for example) making laxity more important or at least as important as the strength of the ligament. In such a situation, an individual with a tight knee will sustain a tear before the same amount of rotation produces an injury in a person with more compliance. For two individuals of the same size, increased compliance does not mean decreased breaking load of the ligament.

Nicholas graded relative ligament laxity in professional football players using arbitrary performance tests.[25] He classified the subjects as either loose or tight, but did not grade the knee clinical laxity by direct testing. A high percentage of players sustaining knee ligament ruptures were previously categorized as loose. He thus concluded that there was an increased likelihood of total ligament rupture in loose-jointed football players. Kalenak[18] evaluated college football players using a varus and valgus force apparatus. Each player was rated depending upon the degree of knee adduction or abduction and also using Nicholas' performance tests. The players were classified as tight or loose. There were an equal number of tight- and loose-jointed individuals in his injury group. Kalenak concluded that the subjective joint laxity test and his relatively objective biomechanical tests could not predict knee ligament sprains in football players.

The present study demonstrated that individuals sustaining Grade I medial collateral sprains in skiing were shorter, lighter, smaller in proximal tibial width, and greater in compliance than those who sustained the more severe injuries. Conversely, largely skiers with lower compliance were found in greater proportion in the Grade II and III injury categories. That skiers with "loose joints" have a lower incidence of severe injuries than individuals with tight joints does not mean that the same may be true in football or other sports. The major mechanism of injury of the medial collateral in skiing is external rotation of the tibia on the femur,[26] while in football, valgus force appears to be the more important mechanism. Further studies with apparatus such as the one presented here are needed to learn the relationship of medial collateral ligament complicance to injury in other major sports.

Conclusions

1An apparatus which reliably and accurately determines medial collateral ligament compliance *in vivo* has been developed.

[2]The device is portable, inexpensive and has the potential of becoming an integral part of the routine classical examination in knee ligament research.

[3]Medial collateral ligament compliance is greater in females than in males.

[4]Medial collateral ligament compliance is greater in individuals who are shorter, lighter and have smaller proximal tibia diameters than in larger individuals.

[5]Skiers who sustained Grade III medial collateral ligament sprains were found to have less compliant MCL ligaments and to be taller, heavier and have larger proximal tibial widths than those sustaining Grade I injuries.

[6]It is possible that relative MCL laxity (increased compliance) may protect the ligament from injury in skiing accidents.

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CUPPING OF THE LATERAL TIBIAL PLATEAU ASSOCIATED WITH A DISCOID MENISCUS
A Case Report

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G. Y. El-Khoury, M.D.***

The following case of a patient with a discoid lateral meniscus of the knee demonstrates the unusual radiologic finding of cupping of the lateral tibial plateau. We are not aware of similar previous reports and believe that this finding may be useful in arriving at a diagnosis.

Case Report

B. B., a 22 year old white female, had a three year history of intermittent catching, popping, and swelling in the right knee. There was no history of knee complaints during her childhood, nor was there a history of trauma to the knee. Physical examination was unremarkable with the exception of the right knee. The range of motion was normal. No effusion was present. The ligaments were intact, and there was no rotatory instability. There was a positive McMurray's sign for a torn meniscus at the lateral joint line and a palpable bulge at the lateral anterior joint line as the knee approached full extension and full flexion.

Roentgenograms of the right knee, AP, lateral, sunrise and notch views, revealed an abnormal marked cupping of the lateral tibial plateau with subchondral sclerosis (Fig. 1). A similar view of the nonsymptomatic left knee was normal.

An arthrogram of the right knee demonstrated a discoid lateral meniscus (Fig. 2).

The patient had an arthrotomy because of persistent pain, catching, and giving way. A discoid lateral meniscus was found. There was an anterior vertical rent (arrow) approximately 1 cm. in length in the midportion of the anterior horn of the discoid meniscus (Fig. 1-inset). The remainder of the knee joint was unremarkable except for the definite cupping of the tibial plateau. There were no osteophytes, and the articular cartilage appeared normal. The post-operative course was unremarkable.

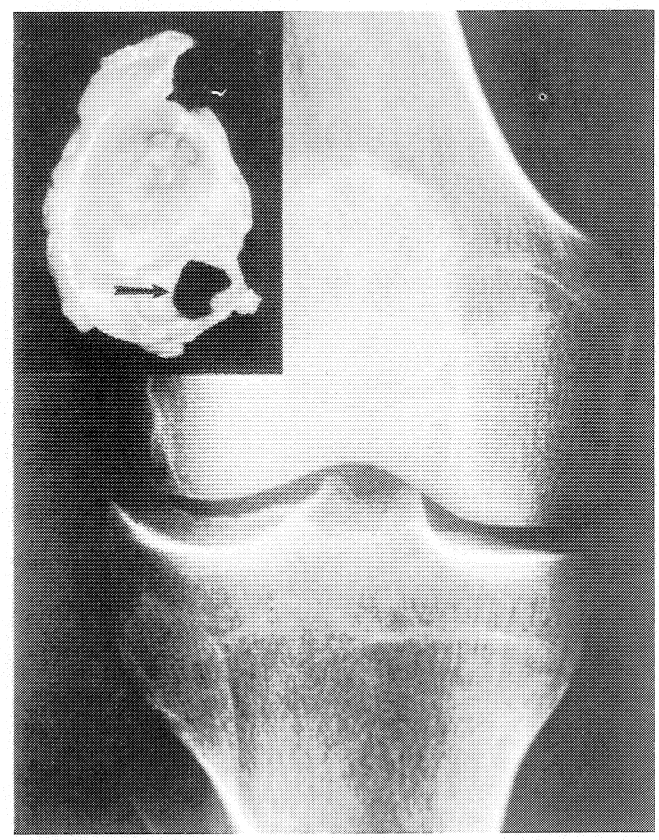

Figure 1.

Discussion

On plain films there are several radiographic signs of a discoid meniscus. Finder[1] noted that a widening of the lateral joint space may be associated with an enlarged discoid cartilage. Jeannopoulos[2] also noted widening of the lateral joint space when compared to the unaffected knee in several patients with discoid lateral meniscii. Another radiographic finding which he noted was occasional mild hypoplasia of the lateral femoral condyle. Previously, cupping of the lateral tibial plateau on standard AP view roentgenogram of

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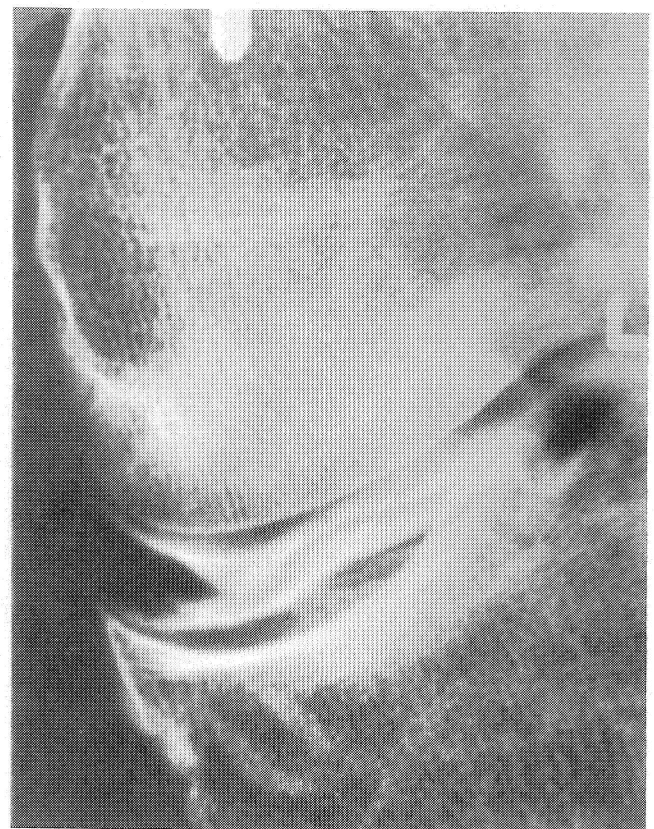

Figure 2.

the knee has not been noted in patients with discoid lateral meniscii. This radiographic finding may provide an additional clue to the diagnosis of discoid lateral meniscii.

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CROSS-COUNTRY SKI INJURIES: A PROSPECTIVE STUDY

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Introduction

Because of its wide range of appeal, cross-country skiing has become a popular recreational activity. People of all ages have taken to the trails not only for its beneficial effects on fitness, but also to enjoy the beautiful scenery. To many, cross-country skiing is a risk-free alternative to its Alpine counterpart, whereby one can enjoy the vigors of the outdoors without having to worry about injury. Unfortunately, this is a widely held misconception.

Cross-country skiing is not as benign a sport as generally believed. Westlin reported 290 cross-country skiing related injuries over three seasons.[1] Eriksson and Danielsson observed 140 and 381 cross-country skiing injuries in 1974 and 1976 respectively, and estimated the injury rate to be about 0.2/1000 skiers.[2,3] Cote discussed the frequent occurrence of injuries in cross-country skiing and stressed the importance of physical conditioning and proper technique in their prevention.[4] Lyons and Porter described eleven cross-country skiing injuries requiring hospitalization.[5] Most occurred while descending an incline, and nine of eleven involved the lower extremities. Gamble estimated the incidence of injury in track skiing and back country touring to be 0.1 and 0.5 per 1000 skier days respectively.[6] None of these figures, however, are based on accurate knowledge of the population at risk. Thus, we decided to conduct a controlled, prospective study of cross-country skiing injuries in northern Vermont.

Method

Our investigation involved four ski touring centers in northern Vermont. The study population was composed of all persons who obtained passes to ski from January 1 through April, 1980. The skiers were made aware of the study through strategically placed signs in the lodge and on the trails. They were encouraged to report all injuries, regardless of severity, to the ski patrol members or personnel in the lodge.

Each injured skier was administered a questionnaire designed to gain information concerning physical characteristics, skiing habits, ability and experience, the cause and the mechanisms of the accident, and skiing conditions at the time of the injury. Whenever possible, trained personnel were present to answer questions and help with completion of the form. We contacted injured skiers within three weeks of their accident to gain more information about the nature and treatment of their injury. When necessary, this information was obtained from the treating physician.

A control population was selected for questioning on a random basis from uninjured skiers in the lodge. Control skiers were evaluated in exactly the same fashion as injured skiers except questions relating to an injury were omitted.

Results

Diminished snowfall and comparatively warm temperatures provided an atypical ski season for study. The four touring centers involved normally provide approximately 75,000 skier days, but for the 1979-80 season only 14,500 occurred. We evaluated 21 injured skiers during the study, resulting in an injury rate of 1.5/1000 skier days. Twenty-six control skiers were also evaluated.

Slightly more than half of the injured skiers (11) were female, while only 38% of controls were women. Forty-three percent of the injured subjects (9) were 30 years old or more, compared to 23% of the controls. Physical parameters, i.e. height and weight, were similar in both groups.

An attempt was made to correlate injury with self-assessed skiing ability, number of lessons, and previous cross-country and downhill skiing experience. Slightly more than half of the controls (54%) and the injured (57%) subjects considered themselves intermediate cross-country skiers. One-fourth of the injured skiers and a third of the controls rated themselves as beginners. Seventy percent of control subjects had downhill skiing experience, compared to only 29% of injured skiers.

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Ninety-two percent of controls owned their skis and boots, while 8% used rentals. Twenty-nine percent of injured skiers used rentals or borrowed ski equipment. Touring skis were much more common than racing skis (only one injured subject used the latter). All control skiers and 71% of injured skiers wore below-the-ankle style boots. However, 29% of injured skiers wore above-the-ankle boots. All six of these subjects sustained lower extremity injuries.

Particular attention was directed toward toe and heel plate design. All controls and injured skiers wore pin bindings (Fig. 1). All but one control used a standard heel plate (Fig. 2). The single exception used the newer ridged heel plate and boot heel groove arrangement (Fig. 3). Only 70% (15) of injured skiers wore the standard heel, while 30% (6) used the ridge and groove design. All but one of these injuries involved the lower extremity. In neither group was a deeper peg and locator type of heel plate utilized (Fig. 4).

Snow and atmospheric conditions did not vary significantly between controls and injured skiers.

Twenty-one skiers sustained a total of twenty-four injuries as described in Table I. These can be divided into three main groups:

1. Upper extremity – six (25%)
2. Lower extremity – fifteen (62%)
3. Face, head, trunk – three (12%)

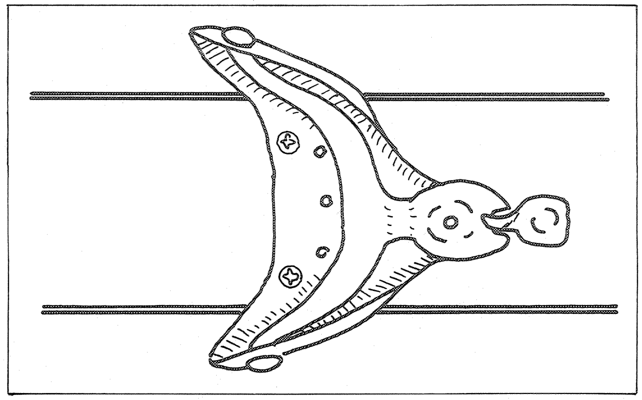

Figure 1. Diagram of pin binding for cross-country skiing.

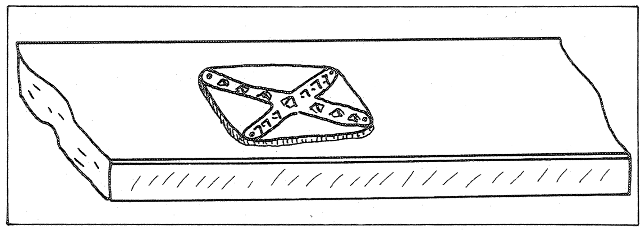

Figure 2. Standard heel plate here depicted with small studs protruding upward from its surface. Several other techniques for increasing the friction of this square or rectangular, slightly elevated heel plate are available.

Table I: Injuries

Subject	Age	Cause of Accident	Cause of Injury	Diagnosis
M	25	hit bare spot	fell and struck rock	*disrupted patellar tendon
F	41	caught tip	twisted knee	mild knee sprain
M	35	lost edge control	struck object	contused hip
F	25	caught tip	fell and struck ground	contused knee
M	26	caught tip	struck ground	contused patella
M	21	lost edge control	struck object	contused knee
M	60	hit bare spot	fell and struck ground	*hip fracture
F	52	broke through crust	twisted knee, struck ground	mild knee and thumb sprains
F	37	caught tip	twisted knee	*3°medial collateral and anterior cruciate sprains
F	26	caught tip	twisted leg	°fractured fibula and tibia (boot-top)
M	30	deliberate fall	struck rock	*extensive subdermal hematoma of hip
M	14	caught edge	impact with object	contused hip, contused tibia
F	29	struck rock	twisted in pole strap, struck ground	finger sprain, patellar contusion
M	27	caught tip	struck ground	+lacerated knee
F	27	lost edge control	struck ground	shoulder contusion
M	48	lost edge control	impact with pole	thumb sprain
F	49	slipped while standing	fell and struck ground	°Colles fracture
F	35	lost edge control	fell and struck ground	supraspinatus tendonitis
M	20	deliberate fall	struck object	contused coccyx/fractured sacrum
F	35	slipped while standing	struck object	concussion, facial laceration
M	23	lost edge control	struck ground	ear laceration

* – requires surgery
+ – required sutures
° treated with casts

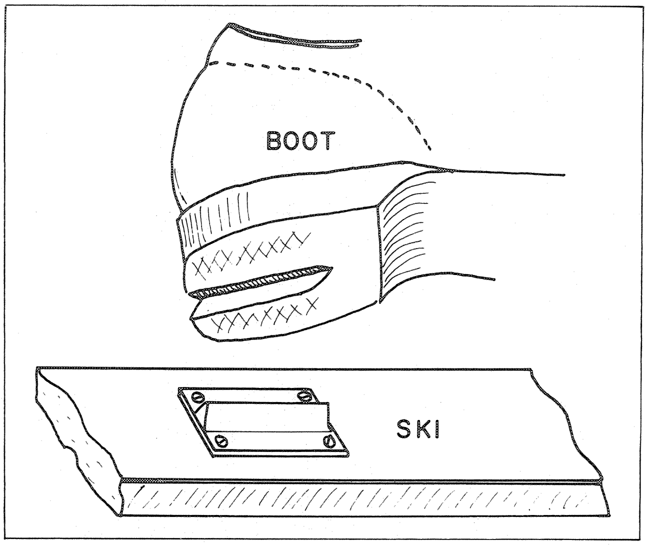

Figure 3. Ridged heel plate with grooved boot heel. The boot is especially designed to fit exactly the ridged heel plate.

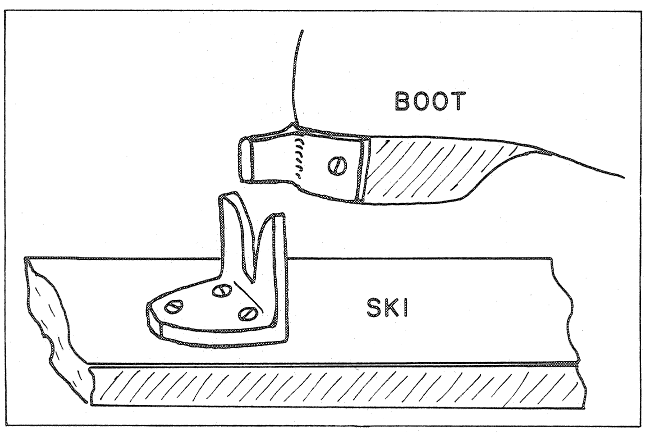

Figure 4. Peg and locator type of heel plate.

A listing of lower extremity injuries by site and type is presented in Table II.

Table II: Lower Extremity Injuries

Hip Contusion	3
Hip Fracture	1
Knee Contusion	4
Partial Ligament Rupture – Knee	2
Total Ligament Rupture – Knee	1
Patellar Tendon Rupture	1
Laceration Requiring Sutures	1
Leg Contusion	1
Tibia & Fibula Fracture	1
Ankle Fracture	0
Ankle Sprain	0
TOTAL	15

Thirteen skiers (62%) blamed loss of edge control or catching a tip as the cause of their accident. Skiing on exposed ground was responsible for three mishaps. Nineteen accidents (90%) occurred on downhill terrain, including all of those resulting in lower extremity injuries. All but two skiers were on a prepared trail at the time of their accident.

Most injured skiers (76%) admitted to being slightly or moderately fatigued at the time of their accident. However, four (19%) skiers had left the lodge less than thirty minutes prior to their mishap.

Discussion

The epidemiology of Alpine skiing has been studied extensively over the past decade. Estimates of injury rate generally range from three to six injuries per thousand skier days.[7,8,9,10,11,12] Types of injuries produced in downhill skiing accidents have been described by many authors. Most of these involve the lower extremities and tend to be more serious than those involving the upper body. The relationship of equipment, snow conditions, skiing ability, and terrain to Alpine skiing injuries has also been examined in well controlled studies.[10,11,13] To our knowledge, this is the first controlled, prospective study of injury in cross-country skiing. Despite an abbreviated season, the four ski touring centers involved recorded 1.5 injuries/1000 skier days, which is considerably higher than previously suspected.

Females appeared to be more frequently injured than males, though this may reflect a greater tendency of females to report their injury.[13,14]

Beginner and intermediate skiers formed the majority of the touring center population (over 80%). This is not surprising since ski touring has only recently become a popular activity among people who previously had little or no experience. Supposedly, most people enjoy cross-country because it is a gentle-motion, pleasurable activity. Ten to twenty percent might be classified as active skiers, while the remainder are ski walkers.[15]

A background in Alpine skiing appears to decrease risk of injury. Three-fourths of all controls claimed previous downhill experience, while only one-fourth of the injured skiers reported such a background. Certain skills such as edge control, turning, stopping and balancing perhaps carry over to cross-country techniques, providing the skier with more confidence and control, especially on downhill terrain.

In Alpine skiing, equipment function and design can greatly influence the frequency and pattern of injury.[10,11,13,16] Improperly functioning bindings and incompatibility of equipment with skiing ability is a definite factor in downhill accidents.[10,11,13,14] This may be true to a lesser extent in cross-country skiing. Today's cross-country equipment market abounds with an assortment of skis, boots and bindings. Most control and injured skiers used touring rather than racing skis, which seems to correlate well with their reported skiing ability. Although all control subjects wore below-the-ankle level ski boots, more than a fourth of those with injuries used above-ankle boots. Although all above-ankle boot injuries involved the lower extremity, variation of the mechanism of injury made it difficult to implicate high boots in any specific injury pattern.

We believe that some of the newer heel plate designs may significantly alter boot-ski interface mechanics and thus potentially increase injury risk. Due to a growing interest in skiing downhill terrain, there has been an increased demand for better edge control and turning ability. This has led to the development of a variety of heel plates designed to interlock with the boot heel and provide a more rigid system for control. When one weights the ski boot heel, motion from side to side becomes restricted. The degree of limitation is dependent upon the type of device used, with deeper grooves tending to be more confining.

In this study, more than one fourth of injured skiers wore heel plates of the ridge and groove design, compared to 4% of the controls. Two of the three knee sprains, and the only boot top fracture, occurred while wearing this interlocking type of heel plate. All claimed to have caught a ski tip and twisted their leg while skiing on downhill terrain. Implicating interlocking heel plates in injury is difficult based on such small numbers, but the trend is ominous. Inability of the skier to free the heel from the binding in a weighted, twisting fall may result in transmission of damaging torque from the ski to the lower extremity. This is unlikely to occur with the standard heel plate. Thus rotational type injuries may become more prevalent as the use of interlocking heel bindings gains in popularity.

All epidemiologic surveys have their drawbacks and this study is no exception. The 1979-80 season had one of the mildest winters on record, which reduced the usual number of skier days by approximately 75%. Ground cover was poor and many of the trails normally blanketed with two to three feet of snow had rocks and stumps exposed. This may have resulted in an atypically high rate of injury and may explain the relatively high incidence of contusions. Ski area operators, however, did not believe that the season was atypical from an injury standpoint.

Summary

A controlled, prospective study of the incidence of injury in cross-country skiing was carried out at various ski touring centers in northern Vermont. The rate of injury was determined to be 1.5/1000 skier days. Most injuries occurred in beginner or intermediate skiers on downhill terrain. Lower extremity injuries were the most common. Boot and heel plate design may be implicated in injury, though results at this time are inconclusive. These findings are presented as a preliminary study of cross-country skiing injuries. Plans are currently underway to continue this study through the ensuing ski season.

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RECURRENT LEGG-CALVE-PERTHES DISEASE

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Recurrence of Legg-Perthes disease after complete healing of a previously affected femoral head is a rare entity, with only four cases previously described.[3,5,6,7] This case provides another example of the characteristic age at onset and clinical course of recurrent Legg-Perthes disease.

Case Report

C. W., a six year old white male, first saw an orthopaedic surgeon because he had a painless mass in his left thigh. With the exception of the mass, his physical examination, including hip motion, was normal. Radiographic examination revealed a sessile osteochondroma, and as an additional finding, irregularity of the ipsilateral proximal femoral epiphysis (Fig. 1). An excisional biopsy of the mass established the diagnosis of osteochondroma. Because he had no hip symptoms he received no treatment for his hip at that time.

Figure 1.

Later he began to complain of pain in both hips. Examination revealed mild limitation of internal rotation and abduction of his hips. Radiographic examination (Fig. 2) revealed irregular densities of the proximal femoral epiphysis bilaterally, suggesting avascular necrosis with collapse of the anterior segments, but without "at risk" signs. He was diagnosed as having Legg-Perthes disease and was treated with a two week period of bed rest, followed by limitation from

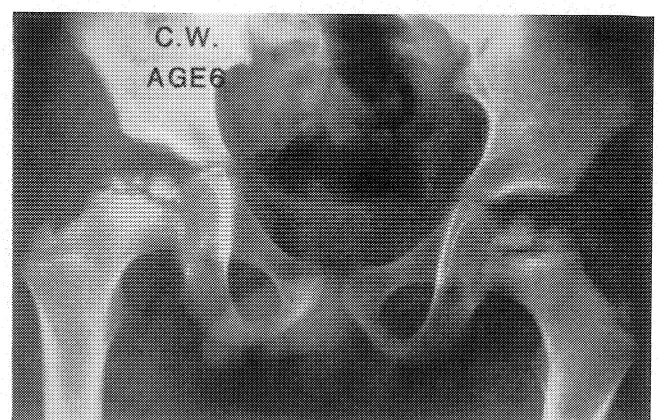

Figure 2.

strenuous activity for several months. His clinical course was benign and radiographs taken three years later revealed complete healing (Fig. 3).

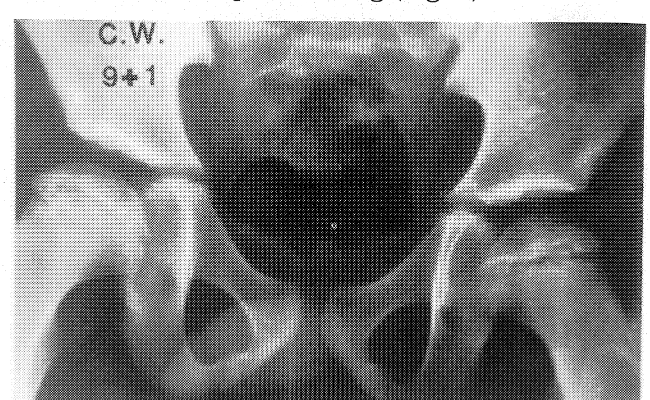

Figure 3.

At age ten the child developed a limp and complained of left hip pain. Radiographs revealed a subchondral fracture and increased density in the left

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femoral head (Figs. 4a and b), and he was referred to the Texas Scottish Rite Hospital. Physical examination revealed a left Trendelenburg gait and decreased

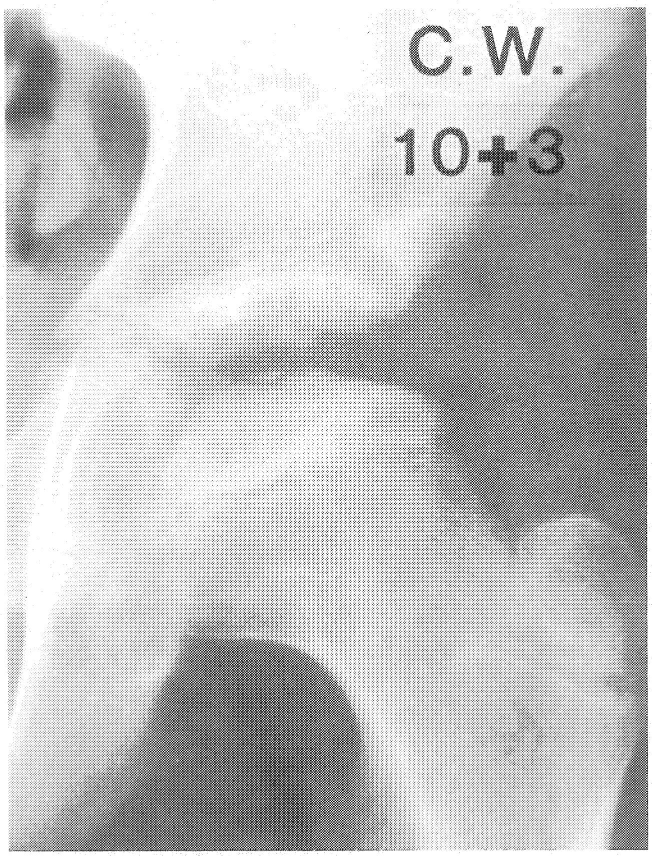

Figure 4a.

abduction and internal rotation of the left hip. Subsequent radiographs taken at the age of ten years and nine months (Fig. 5) revealed further collapse with significant head involvement and lateral subluxation. Radiographs of other epiphyses, as well as his spine, were normal. Bone age films revealed a bone age two standard deviations less than his chronological age. Laboratory exam revealed normal calcium, phosphorus, blood urea nitrogen, creatinine, alkaline phosphatase and normal thyroid function.

Because of the significant femoral head involvement with lateral subluxation and inability to comply with brace treatment, we elected to surgically contain the femoral head by proximal femoral varus osteotomy (Fig. 6). He did well postoperatively and two years after surgery has a pain-free hip with a nearly full range of motion. He continues to have a mild Trendelenberg gait secondary to proximal femoral physeal arrest (as a consequence of the Legg-Perthes disease). with resulting relative greater trochanteric overgrowth (Fig. 7).

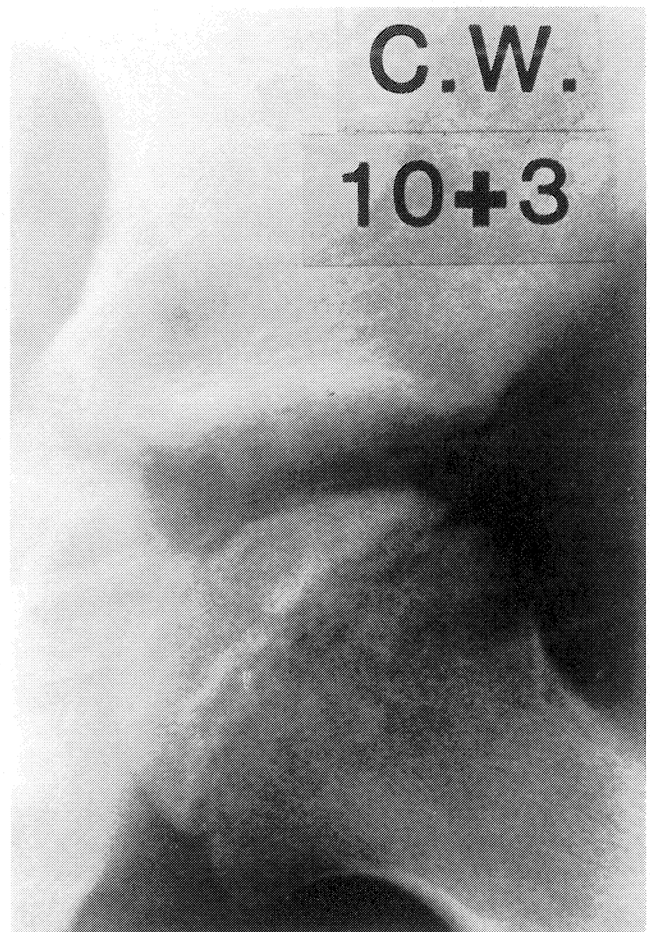

Figure 4b.

Discussion

Recurrent Legg-Perthes disease is rare. This case is only the fifth reported. In these five cases, the age at onset of the initial episode ranged from two to six years, with an average of 3.9 years. The length of time until recurrence ranged from three to five years, with an average of 4.5 years. All five patients were male. Two patients had unilateral disease, while three were affected bilaterally.

Judging from previous reports,[3,6,7] all cases had Catterall 2 or 3 involvement at the initial episode. With the repeat episode, all but one had complete head involvement (Catterall 4), and three of five had "at risk" signs, including lateral subluxation, lateral calcification, as well as Gage's sign. Evaluation of this small group of patients suggests that the second episode of avascular necrosis is more severe and usually affects the entire head. Thus, the prognosis is worse. In addition, the child is older at the second episode, and older age is also widely accepted as being associated with a worse prognosis.[4]

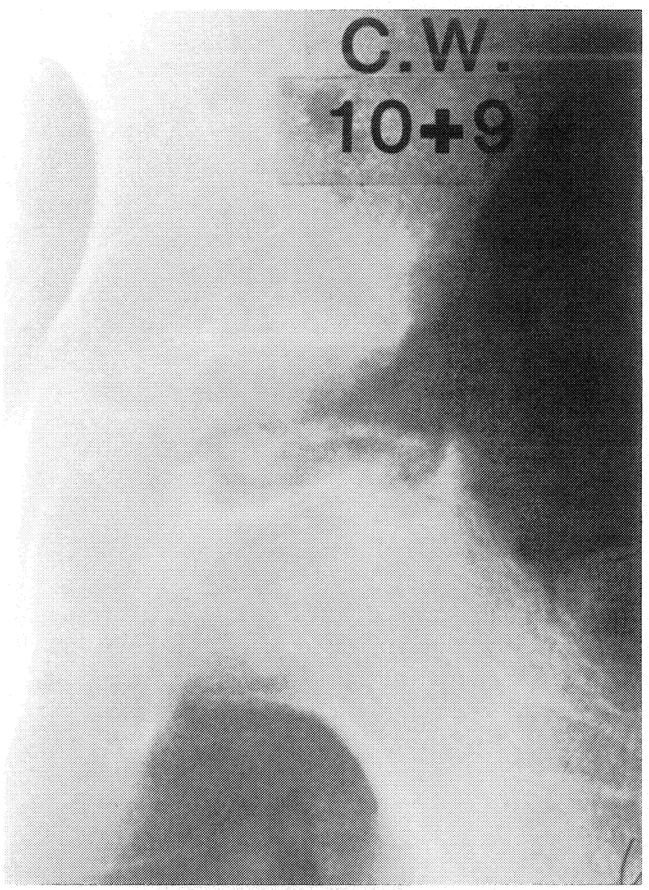

Figure 5.

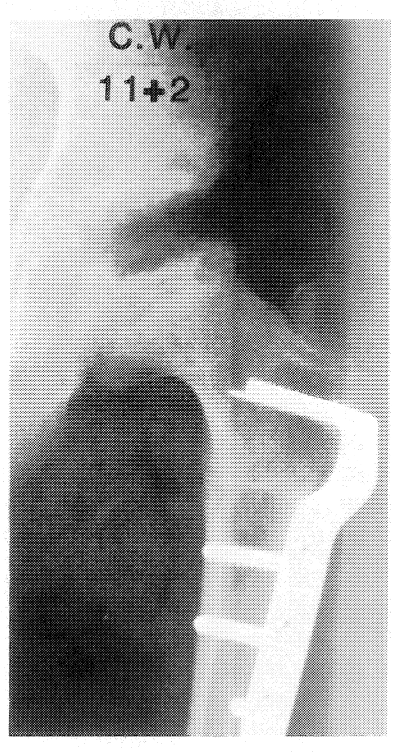

Figure 6.

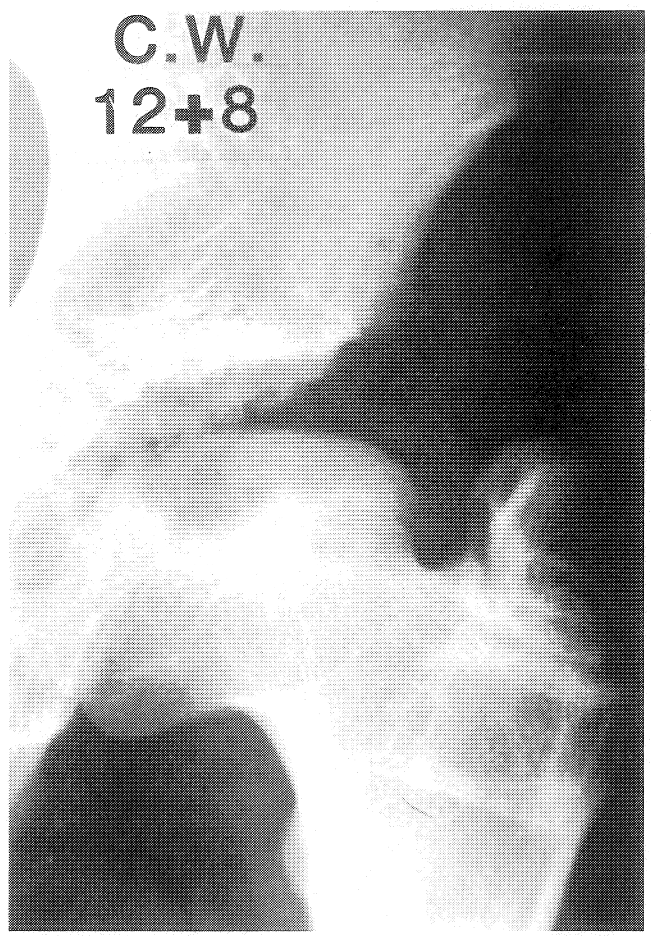

Figure 7.

Any case of bilateral Legg-Perthes disease should raise the suspicion of epiphyseal dysplasia.[1] Our patient had a thorough radiographic and laboratory workup which revealed no generalized disorder. This negative survey, coupled with the fact that the initial lesions healed, suggests that this case represents recurrent avascular necrosis (Legg-Perthes disease) rather than an epiphyseal dysplasia.

One concept of the etiology of Legg-Perthes disease is that of repeated episodes of infarction.[8] Patients with recurrent Legg-Perthes, therefore, may have repeated vascular insults over a several year period. What predisposes this very small group of patients to recurrence, and what protects the majority of patients from recurrence, is unanswered.

We selected surgical containment for this patient because of progressive subluxation and head collapse and the patient's refusal of brace containment. He developed one of the known complications following containment by proximal femoral osteotomy, that is, greater trochanter overgrowth. The overgrowth was not caused by the surgical procedure but, instead, was due to physeal closure which occurs in a significant number of older children with Legg-Perthes disease. However, addition of the varus osteotomy to the already compromised biological situation (physeal closure secondary to severe disease) resulted in an even farther proximally positioned greater trochanter with resulting limp. Evidence of premature growth plate closure in Legg-Perthes disease may be an indication for containment by some method other than proximal femoral varus osteotomy.[2]

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ZICKEL NAIL INSERTION: AN ALTERNATE TECHNIQUE

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The Zickel intramedullary appliance has proven to be a valuable fixation device for pathologic[1,5] and traumatic subtrochanteric fractures[3] as well as for impending pathologic fractures. Although our experience with the Zickel device has been gratifying, insertion of the applicance may be technically difficult even in experienced hands.[4] In the original description of the operative technique the patient is placed in lateral or semisupine position with a roll beneath the flank and the limb is draped free.[2,4] By modifying patient position, roentgenographic technique, and surgical equipment we found the device less difficult to insert for prophylactic fixation in patients with impending pathologic fracture. Subsequently, we found the same patient position and technique useful for the internal fixation of displaced fractures, both pathologic and nonpathologic.

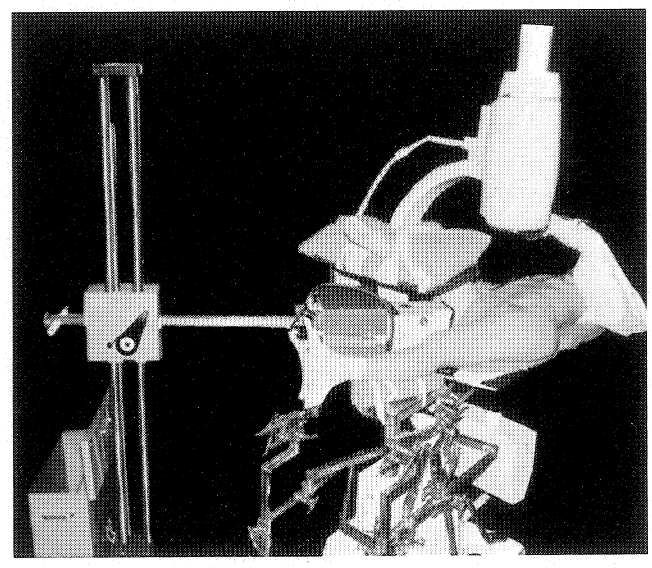

Figure 1.

Positioning and Technique

Prophylactic Internal Fixation:

Following completion of anesthesia the patient is carefully transferred to a fracture table. The affected limb is adducted approximately 20 to 30 degrees, or more in the obese patient, and placed in foot plate traction on the fracture table. If the fracture table will allow limb adduction to 20 to 30 degrees the foot plate of the same leg is used. Some fracture tables do not allow adduction of the limbs; here the foot plate of the opposite limb is used (Fig. 1). The other limb is gently rested and tied on a pillow padded Mayo stand in 90 degrees of hip and knee flexion. The x-ray machines for standard anteroposterior and true lateral roentgenograms of the hip are placed as shown (Fig. 1) or a C-arm fluoroscopy unit may be used for anteroposterior and lateral roentgenographic control. After sterile preparation and draping, a lateral skin incision is made. After incising the iliotibial band longitudinally, a portion of the insertion of the gluteus medius at the greater trochanter is incised and retracted exposing a 2 by 2 centimeter area at the apex of the greater trochanter. A drill hole is placed in the apex of the trochanter and enlarged with a bone rongeur or curette. A guide wire is then directed from the trochanter into the medullary canal of the femur. After confirming position of the guide wire roentgenographically, we use a flexible intramedullary reamer to enlarge the medullary canal. Reamings from the canal should be obtained for confirmation of pathologic diagnosis. We ream the medullary canal .5 millimeters larger than the intramedullary rod size to be used and generally find that the smaller rods (11 to 13 millimeters) are adequate. The trochanteric region must be reamed to at least 17 millimeters before the intramedullary rod is inserted. Generally the rod is inserted to the tip of the greater trochanter. Proper rotation is judged by palpation of the anterior femoral neck and alignment of the femoral neck guidewire with this angle. The lateral roentgenogram will help to confirm correct placement of the femoral neck guide wire. The remainder of the operation is completed according to the original descriptions of Zickel.[1,4] Wound closure is facilitated by abducting the limb from its adducted position to relax the iliotibial band.

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Insertion for Subtrochanteric Fracture:

In patients with subtrochanteric fractures the same technique may be used. We recommend that the proximal fragment be reamed from the trochanteric apex distalward, rather than in a retrograde fashion. This centers the device in the trochanteric area and helps prevent fracture of the trochanter. The only cases in which it is difficult to achieve stable internal fixation with the Zickel device are in patients with spiral subtrochanteric fractures with large (greater than 15 millimeters) medullary canals. In these instances rotatory stability is achieved with the additional use of cortical screws or circlage wire.

Discussion

With the increasing awareness of physicians regarding the potential for pathologic fractures, the prophylactic fixation of impending pathologic fractures is becoming more commonplace. The Zickel intramedullary device is useful in treating patients with subtrochonteric lesions and fractures, but the device may be difficult to insert.[4] We believe the technique described facilitates the ease and precision of insertion. The adducted position and a flexible reamer allow easier reaming of the femur because the greater trochanter is prominent. It is important to begin the reaming at the superior aspect of the trochanter because the shape of the intramedullary rod requires this positioning and fracture of the trochanter occurs less often. The Zickel device provides excellent stability in cases of prophylactic internal fixation and generally the 11 millimeter or 13 millimeter rod is of sufficient size. One advantage of using a fracture table is that the x-ray technique allows accurate intramedullary rod and triflanged nail placement. Internal fixation for subtrochanteric fractures by this method will allow traction to be employed during the operative procedure. Before attempting to use this technique on displaced fractures, the surgeon should have experience with the Zickel nail in impending fractures.

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CLASSIFICATION, TERMINOLOGY AND MEASUREMENTS IN SPONDYLOLISTHESIS+

Leon L. Wiltse, M.D.*

Classification

Spondylolisthesis is a slipping of all or part of one vertebra forward on the other. The term is derived from the Greek "spondylo" meaning vertebra and "olisthesis" meaning to slip or slide down an incline.

When the two words are combined as in spondylolisthesis, as is customary when combining words in the Greek, the last vowel of the first word is dropped. So the word becomes spondylolisthesis.

The following classification[12] of spondylolisthesis has been derived from previous classifications published by the author, by Newman, and also by MacNab.[6,7,8]

I. Dysplastic (congenital)
II. Isthmic
  A. Lytic–fatigue fracture of the pars.
  B. Elongated but intact pars.
  C. Acute fracture of pars (not to be confused with "traumatic" [see IV]).
III. Degenerative
IV. Post Traumatic
V. Pathologic

Discussion of the types

Dysplastic: (Fig. 1)

There is congenital dysplasia of the upper sacrum or the neural arch of L5. Because of this dysplasia, there is insufficient strength to withstand the forward thrust of the superincumbent body weight, and the last free lumbar vertebra gradually slips forward. The pars interarticularis may remain unchanged. If it remains unchanged and the ring is intact, the slip cannot exceed more than about 35 percent before there will be pressure on the cauda equina. There is a strong hereditary element in this type.[14]

Isthmic

The basic lesion is in the pars interarticularis. Secondary changes (e.g., alteration in the shape of the body of L5) may occur but are not fundamental to its etiology.

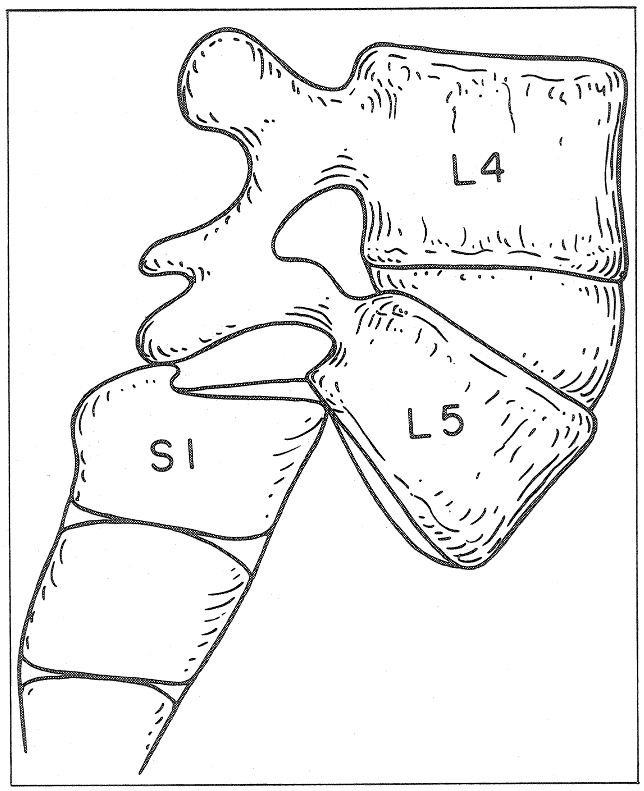

Figure 1. Drawing of congenital or dysplastic spondylolisthesis. Note superior articular processes of S1 are underdeveloped.

Subtype A, Lytic (Fig. 2)

This is due to separation of the pars resulting from a fatigue fracture.[11] It is the common type below age 50. Statistically, it is seldom seen in patients below age 5, but it does occur even in infancy. At the end of the first year of school, the incidence is 4.4 percent. By the age of 18, the incidence increases to 6 percent.[1] Boys have the condition about twice as frequently as girls. Flexion, extension and twisting motions are all probably important in producing the stress fractures, but extension is most important.[4,14]

Subtype B, Elongation of the pars without separation (Fig. 3)

This is fundamentally the same disease as Subtype A. Repeated micro-fractures in the pars allow it to heal in an elongated position as the body of L5 slides forward. The author knows of five families in which the pro-

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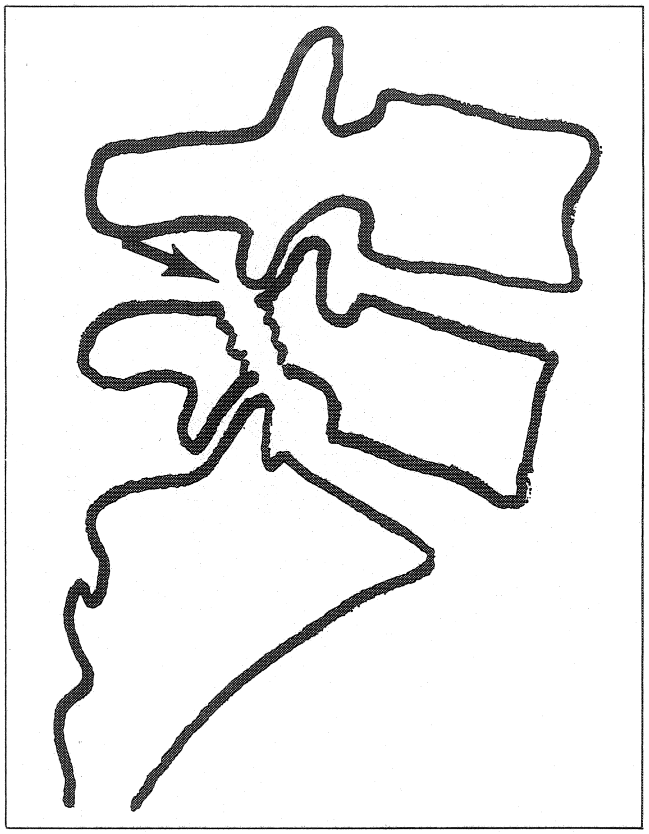

Figure 2. Lateral drawing of isthmic spondylolisthesis, Type II-a.

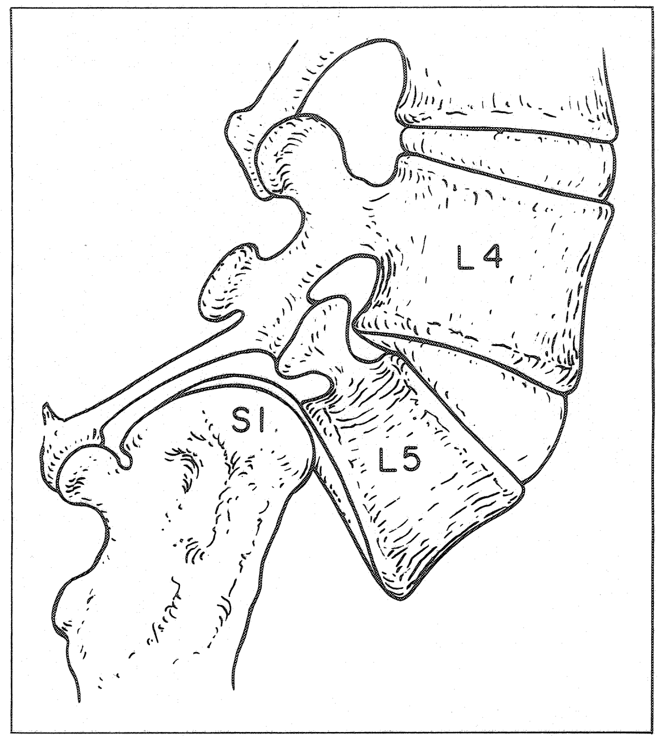

Figure 3. Lateral drawing of elongated but intact pars, Type II-b.

bands had an elongated but intact pars while several other members of their immediate families had typical spondylolysis or spondylolisthesis with the classic pars defect seen in Subtype A.

Subtype C, Acute pars fractures

These are an acute fracture of the pars secondary to severe trauma and are extremely rare.

Degenerative (Fig. 4a and b)

This lesion is due to longstanding intersegmental instability. Remodeling of the articular processes at the level of involvement results. Farfan[3] believes that in addition to degeneration of the disc there are multiple small stress compression fractures of the inferior articular processes of the olisthetic vertebra. As the slip progresses, the articular processes change directions and become more horizontal. One side nearly always rotates more than the other. This is an integral characteristic of this disease. Farfan believes that the typical hour-glass deformity seen on the myelogram is due to rotation of the upper vertebra with displacement of the pedicle.

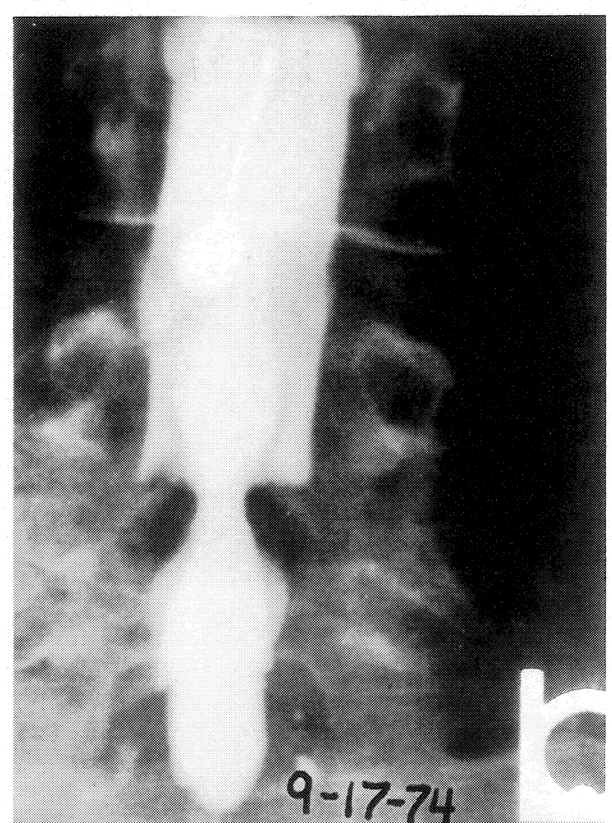

Figure 4a. AP myelogram of a typical case of degenerative spondylo.

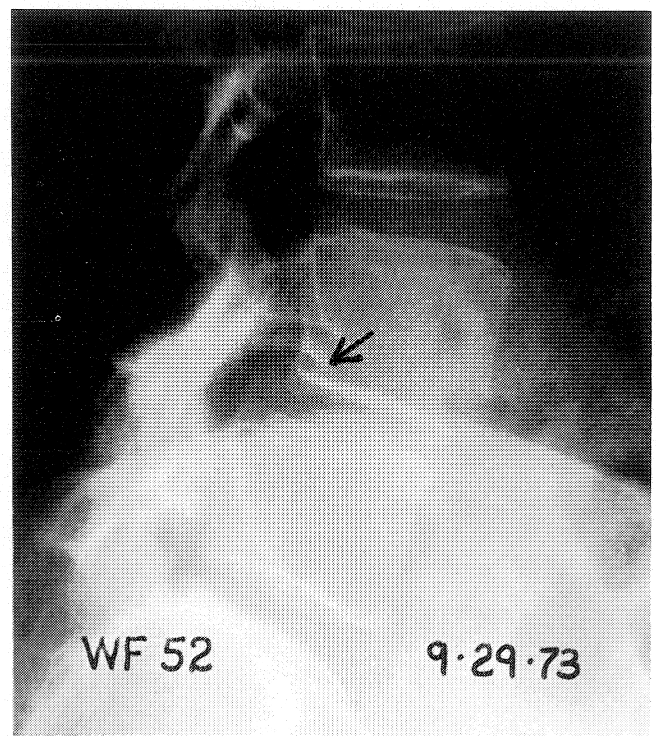

Figure 4b. Lateral myelogram of a case of degenerative spondylolisthesis.

In patients with clinical symptoms, degenerative spondylolisthesis occurs six times more frequently in females than in males;[9] six to nine times more frequently at the L4 interspace than at adjoining levels; and four times more frequently when the 5th lumbar vertebra is sacralized. When the lesion is at L4, the L5 vertebra is more stable and in less lordosis than average. The author has not seen this lesion in any patient under age 40.

Post Traumatic (Fig. 5)

This lesion is secondary to a severe injury which fractures some part of the supporting bone other than the pars. This allows forward slip of the vertebra above on the one below. Unlike the acute isthmic fracture, an isolated pars fracture is not present. The slip occurs gradually. It is not an acute fracture dislocation.

I see about one case a year of this type.

Pathologic

Because of local or general bone disease, the bony hook mechanism (consisting of the pedicle, the pars, the superior and inferior articular processes) fails to support the forward thrust of the superincumbent body weight and forward slip of a vertebra on the one below occurs.

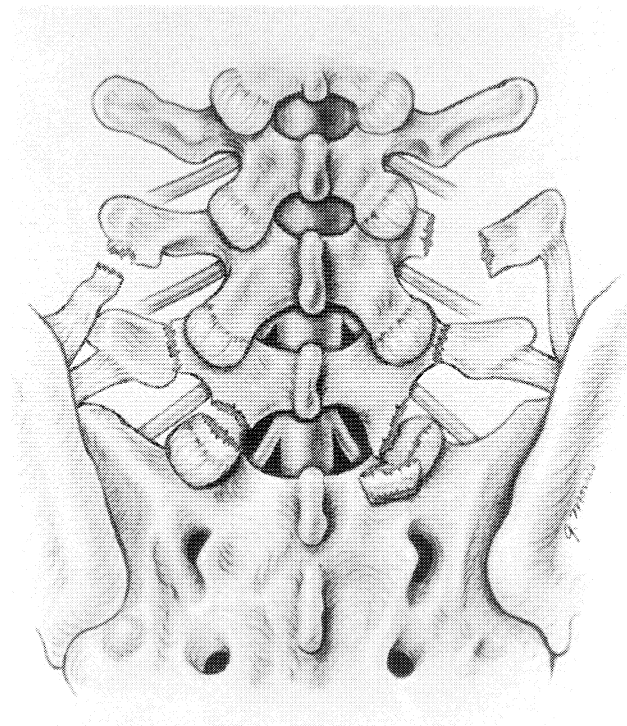

Figure 5. Drawing of an actual case of traumatic spondylolisthesis.

Terminology and Measurements

Dr. Robert Winter and Dr. David Bradford collaborated with me in formulating this terminology.[2,13]

A. *Displacement* (anterior translation, slip, olisthesis)

The forward displacement of one vertebra in relation to the next one below is best measured as a percentage. The anterior–posterior diameter (depth) of the body of S1 is used as the baseline. The widest point of the body of S1 is chosen. A line is drawn at right angles to a previously drawn line on the back of S1 (Fig. 6).

B. *Sacral Inclination* (sacral tilt, sacral vertically)

Sacral inclination refers to the relationship of the sacrum in the sagittal plane to its horizontal or vertical reference line. Normally the sacrum is inclined forward. That is, the upper sacrum is more anterior, the lower sacrum more posterior.

To determine sacral inclination a lateral roentgenogram is taken with the patient standing erect with the knees straight. A vertical line is drawn perpendicular to the floor and the relationship of the sacrum to this line is established.

The problem is the definition of the sacrum which tends to be a curved bone. The best reference area appears to

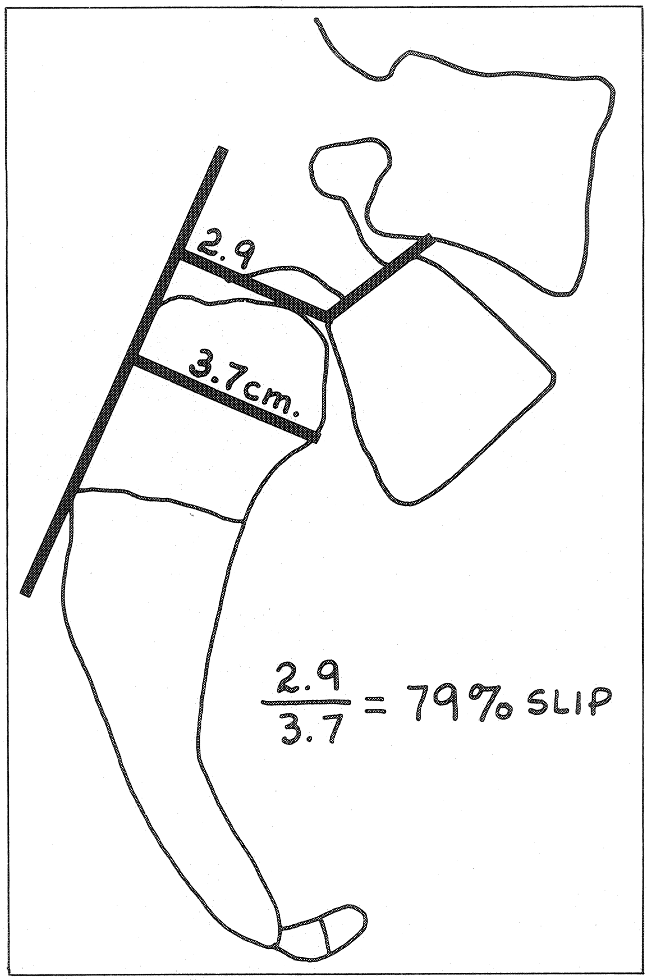

Figure 6. Anterior displacement. The quantity of anterior displacement is expressed as a percentage. The percentage of anterior displacement (slip) is obtained by dividing the amount of displacement (determined by the relationship of the posterior cortex of L5 to the posterior cortex of S1) by the maximal anteroposterior diameter of S1 and multiplying by 100. There can be no higher quantity of slip than 100%.

be the posterior aspect of S1 which is usually a straight line and can be used as a reproducible line of reference. This same line is used also for other measurements. Occasionally, this line cannot be drawn accurately. Then, a dot can be made at the center of the top of S1 and another dot in the center of the top of S2 and a line drawn between the two dots can serve as a reference line.

As the sacrum tends to become more vertical with increasing olisthesis, the angle of inclination will become smaller (Fig. 7).

C. *Sagittal Rotation* (slip, sagittal roll, lumbosacral kyphosis) (Fig. 8)

Sagittal rotation refers to the angular relationship between L5 and S1 in an L5, S1 olisthesis. The line along the posterior aspect of S1 is one again used as a line of reference for the sacrum. A line drawn along the anterior aspect of L5 almost always parallels the posterior aspect of L5 and is perpendicular to the line along the upper end plate of L5. This line will intersect the S1 line, giving an angular relationship to S1.

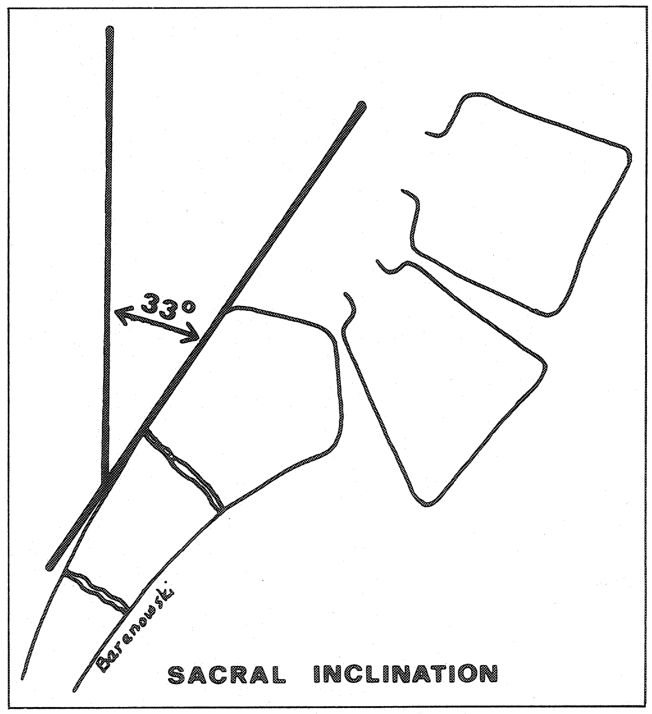

Figure 7. Sacral inclination. Sacral inclination is determined by drawing a line along the posterior cortex of S1 and measuring the angle created by this line intersecting the true vertical line.

The greater the degree of sagittal rotation, the higher the angle. Occasionally this angle is less than zero and should be recorded as a minus figure.

D. *Lumbar Lordosis* (Swayback) (Fig. 9)

Lumbar lordosis is the quantity of anterior curvature of the lumbar spine in the sagittal plane. In patients without spondylolisthesis it is traditional to measure the angle between the upper end plate of L1 and the upper end plate of S1. However, in spondylolisthesis there tends to be an abnormal kyphotic relationship between L5 and S1. The lumbar lordosis is a secondary or compensatory malalignment rather than a part of the primary deformity. Therefore, it is appropriate to measure lumbar lordosis from the top of L1 to the top of L5 and not L1 to S1.

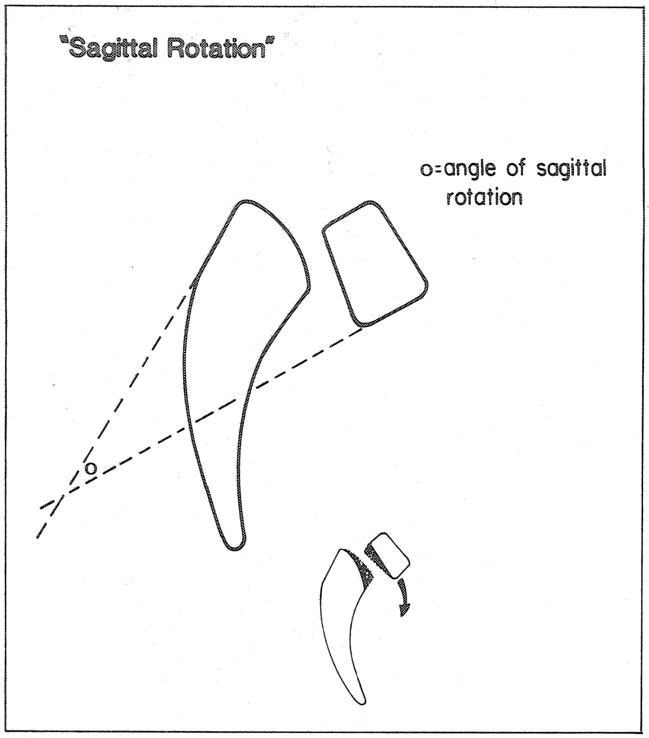

Figure 8. Sagittal rotation. Sagittal rotation is the term used to express the angular relationship between L5 and S1. It has previously been called "sagittal roll," "slip angle," or "lumbosacral kyphosis." The angular value (angle O) is determined by extending a line from along the posterior cortex of L5 until it intersects the reference line drawn along the posterior cortex of S1. In the normal individual, this angle is usually zero. The greater the degree of sagittal rotation, the higher the angular value.

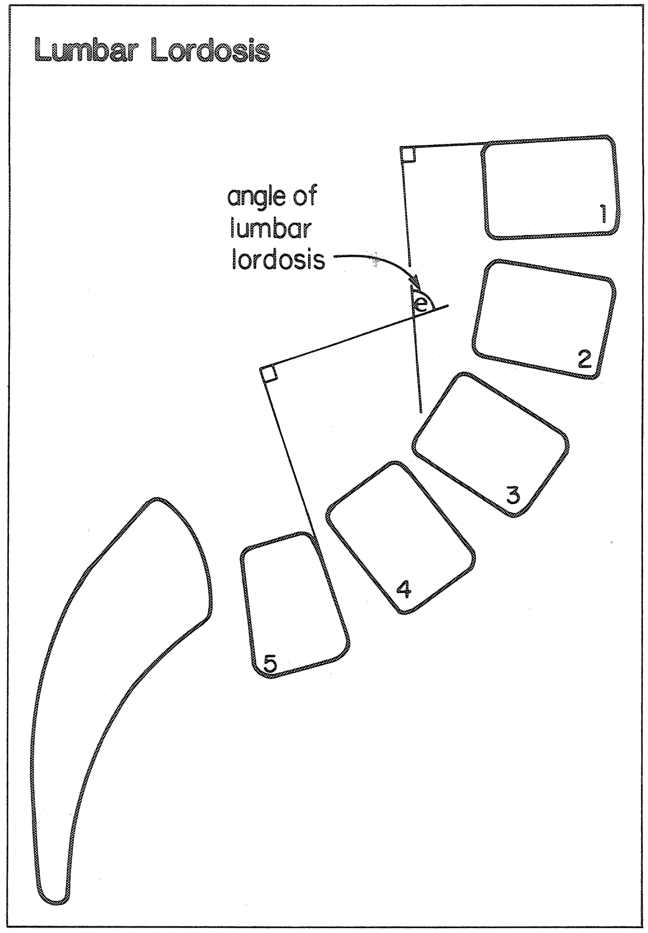

Figure 9. Lumbar lordosis. In patients with spondylolisthesis, the quantity of lumbar lordosis is defined as angle e, the angle created by perpendicular lines from the superior end plates of L1 and L5. With significant degrees of sagittal rotation, there may be lordosis extending well up into the thoracic spine in which case "total spinal lordosis" can be distinguished from lumbar lordosis.

E. *Wedging of the olisthetic vertebra (lumbar index)* (Fig. 10)

A less frequently used measurement, the wedging of the olisthetic vertebra is most appropriately expressed as a percent wedging, obtained by dividing the anterior vertebral height into the shortened posterior vertebral height and multiplying by 100. Percentage of wedging seems a more universally understandable concept than an "index" or "ratio."

F. *Sacral lumbosacral angle* (angle of the cephalic vertebral end plate of S1 with the horizontal, lumbosacral angle; lumbar lordosis[5]).

The angle of the cephalic border of the body of S1 often differs from the angle of inclination of the sacrum (Fig. 11).

Ferguson, Von Lachum and others[10] use the term "lumbosacral angle" for this. However, this seems incorrect since this is actually the angle of the cephalic border of the first sacral centrum with the horizontal and not the angle of S1 with the lumbar vertebra. One should calculate this angle from an x-ray with the patient in the standing position.

As noted in the line drawing (which is taken from a patient), the angle of the cephalic border of S1 may be quite different from the angle of inclination.[4] Farfan calls this the sacral lumbosacral angle. The final name of this is yet to be settled upon.

One might wonder why this is important. It is important because there may be a relationship between this angle and symptoms. Nachemson has reported that, according to the Swedish statistics, the incidence of symptoms increases if this angle is greater than 70 degrees. This has frequently been called lumbar lordosis but this too is obviously an incorrect term for this measurement.

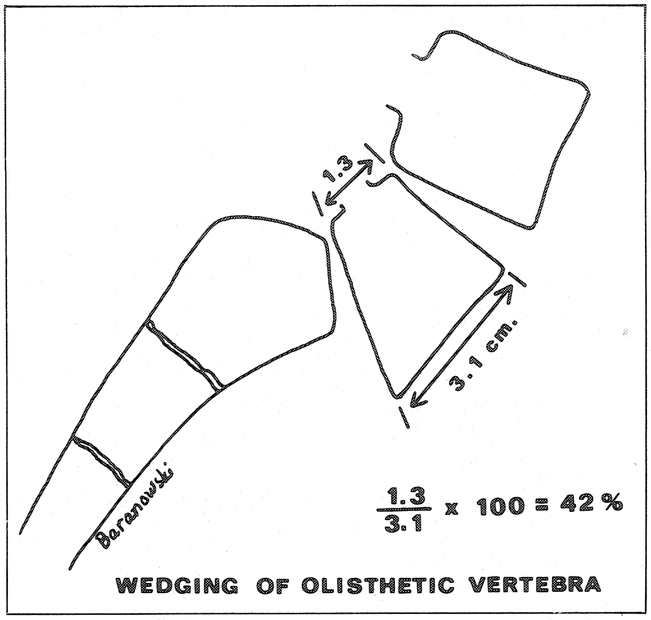

Figure 10. Wedging of the olisthetic vertebra. Wedging of the olisthetic vertebra (usually L5) is expressed as a percentage, determined by dividing the posterior height of L5 by the anterior height of L5 and multiplying by 100.

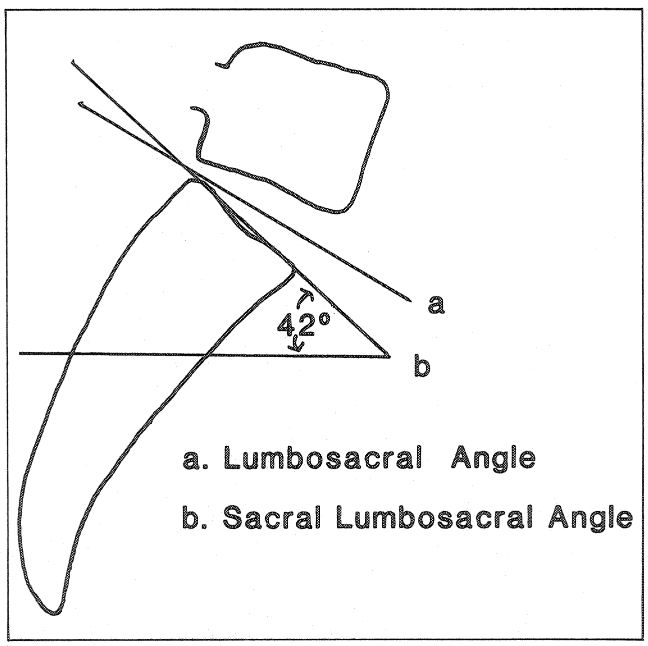

Figure 11. The lumbosacral angle should be a line bisecting the disc of L5. However, the line we are interested in is a line drawn across the cephallic border of the centrum of S1. Farfan calls this the "sacral lumbosacral angle."

Summary

The use of standardized nomenclature can greatly facilitate international communication and improve the quality of scientific presentations in the field of spondylolisthesis.

A system of terminology and measurement is being developed by a cooperative effort between members of the International Society for the Study of the Lumbar Spine and Scoliosis Research Society. Ultimately this will be published and I hope will stand unchallenged at least for a few years.

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SURGICAL TREATMENT FOR LUMBAR DISC PROLAPSE
238 Cases

Yu-Pu Lu, M.D.* +

Disc prolapse is one of the most common crippling back disorders. Trauma from acute injury or chronic abuse of the back is generally recognized as being associated with disc degeneration. Subsequent protrusion of disc material into the spinal canal with consequent backache, sciatica, occasional impairment of bladder and bowel function, and paraplegia may occur. Fortunately almost all patients can be relieved or markedly improved if appropriate measures are taken by non-operative or operative treatment.

During the last 24 years, 649 cases of lumbar disc prolapse have been cared for by our department. Of these, 411 were treated by a non-operative method devised here in 1959. Patients were placed in a traction bed with a pillow beneath the chest and one beneath the pelvis. While traction forces of 30kg were maintained on the thoracic and pelvic belts, gentle percussions with a rubber sponge covered pad were applied to the back at the level of the prolapse with a frequency about 100/min, for 20 minutes. Rapid and early good results were obtained in 81% of the cases. Myelography with myodil has proven this to be a method of reduction of the prolapse.

As to operative treatment, voluminous articles have been published since 1934. Nevertheless, opinions remain divergent about methods of diagnosis, localization of the lesion, indications for operation, operative technique, spinal fusion and post-operative treatment. We have endeavored to obtain better results with simpler and safer methods by eliminating all unnecessary or harmful diagnostic and operative procedures in the surgical management of discs.

Diagnosis and localization were established almost exclusively by clinical evaluation of the history, physical signs and plain x-ray films. In surgical treatment, we have been using local anesthesia; minimal unilateral, but adequate, exposure of the affected disc; no initial spinal fusion unless specially indicated; and early ambulation. There were no misdiagnoses or negative explorations.

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The results of 238 operations are excellent in 131 cases (55%), good in 87 cases (36.6%), fair in 12 cases (5%), improved in 3 cases (1.3%) and failure in 5 cases (2.1%).

Material

Sex and age: Among 238 cases, 185 (77.7%) were male and 53 (22.3%) female. The youngest was 17 years and oldest 60. Commonest occurrence was between 21-45 years of age, 188 (78%).

Table I

Level of Prolapse

Level	No. Case	Per cent
L3, 4	3	1.3
L4, 5	111	46.6
L5, S1	70	29.4
L4, 5 & L5, S1	54	22.7
Total	238	100.0

Table II (Fig. 1)

Types of Prolapse

Type	No. Case	Per cent
Lateral	171	71.8
Bilateral	9	3.8
*Central	28	11.8
**Extrusion of fragments	30	12.6
Total	238	100.0

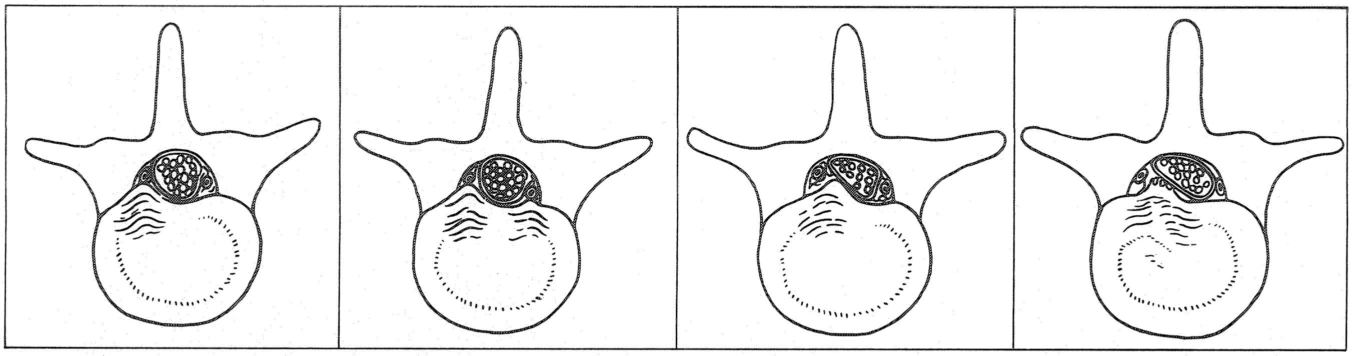
*In the central type, the more medially located unilateral protrusion caused impairment of spinal nerve and cauda equina.

**The type with extrusion of fragments in the lumbar canal clinically simulated the central type except with more extensive and often bilateral neural involvement. Two paraplegics were in this group.

Diagnosis

Diagnosis has been established almost entirely by clinical evaluation (see below). Plain x-ray films of lumbo-sacral spines were taken and read carefully. Myelographies were not advised for the usual cases. Of 23 myelographies all but two were performed before

Figure 1. Types of disc prolapse:



a. lateral **b. bilateral** **c. central** **d. extrusion of fragments**

admission to our department. The contrast media used were myodil in 16, lipiodol in one, oxygen in four and conray in two. Most patients complained of much distress from these procedures. Myelography with conray should possibly not be used as one of 5 operative failures was because of resulting arachnoiditis. In reviewing these cases, I feel that diagnosis and localization could have been made without myelography.

Lumbar puncture, Queckenstadt test and examination of CSF were usually omitted from our routine because they are uncomfortable and do not aid in diagnosis.

Table III

Cardinal symptoms and signs in 238 cases of lumbar disc prolapse

SYMPTOMS AND SIGNS			CASE		PER CENT
1.	Low backache with radiating leg pain		232		97.5
2.	Increased abdominal pressure aggravating symptoms (e.g. coughing, sneezing, etc.)		226		95.0
3.	Sensation diminished	limited	105	202	84.9
		extensive	97		
4.	Tenderness lateral to the interspinous space with radiating pain to leg*		194		81.5
5.	Limitation of forward bending		193		81.1
6.	Limited straight leg raising**		185		77.7
7.	Muscle strength diminished	limited	156	185	77.7
		extensive	29		
8.	Aggravation of symptoms bending to . . .	affected side	98		
		contralateral side	64	184	77.3
		both sides	22		
9.	Limping		172		72.3
10.	Ankle reflex	diminished	118	168	70.6
		absent	53		
11.	History of trauma		168		70.6
12.	Limitation of hyperextension		156		65.5
13.	Scoliosis of varying degrees		138		58.0
14.	Preference of lying position				
	. . . .	lying on one side with leg flexed	122	136	57.1
	. . . .	supine with legs flexed	14		
15.	Bladder or bowel incontinence (always accompanied with diminished or absent sensation of the perineum of one or both sides)		58		24.4

*Sometimes vigorous pressure or percussion may be necessary to elicit sign. Local tenderness without radiating pain not included in these statistics.

**Contralateral SLR was not recorded in all cases but was present in 62 patients.

Surgical Treatment

Indications for operation

Operations are usually required for patients with repeated episodes of incapacitating sciatica and with failure of non-operative treatment with inability to do normal work, especially by young persons. Also the central type with fragment extrusion resulting in dysfunction of the cauda equina necessitates early surgical intervention. For the mild cases in the aged or in women doing light work considerable surgical judgment is necessary.

Prevention of infection

Strict aseptic technique is essential in the prevention of infection. Infection of an intervertebral disc is indeed a catastrophy. Good preoperative preparation of the skin both in the ward and operating room, strict sterilization of all instruments and maintenance of sterile environment in the operating room are necessary. Gentle handling of tissues, complete hemostasis and saline irrigation of the wound before opening the disc and before closure of the wound are helpful.

Localization of lesion

Accurate localization is of vital importance in disc surgery. Many failures are due to negative exploration or operation at the wrong level because of incorrect localization.

We identify the interspace with maximal tenderness and whose palpation causes radiating pain to the leg and mark it with gentian violet. A metallic label is then placed over this mark and an AP x-ray marks the level (Fig. 2). Before incision, a horizontal scratch mark made with the back of the scalpel indicates the level to be explored. Skin clips or a straight mosquito clamp is fixed to the towel covering the wound in line with, but lateral to the scratch mark so that the localized level will not be altered by stretching or twisting of skin edges with retraction.

Extensive neural deficit with impaired bladder and bowel function reflects the presence of a large more or less medially located prolapse or a massive fragment extrusion (Fig. 3). Severe disability with marked scoliosis but localized sensory of motor impairment of leg indicates a large but laterally placed prolapse. Aggravation of symptoms on lateral bending to the symptomatic side indicates the prolapse to be anterolateral to the lumbar nerve. It is then easier to mobilize and retract the nerve medially to expose the prolapse. The opposite is true when the prolapse lies medial to the nerve. As

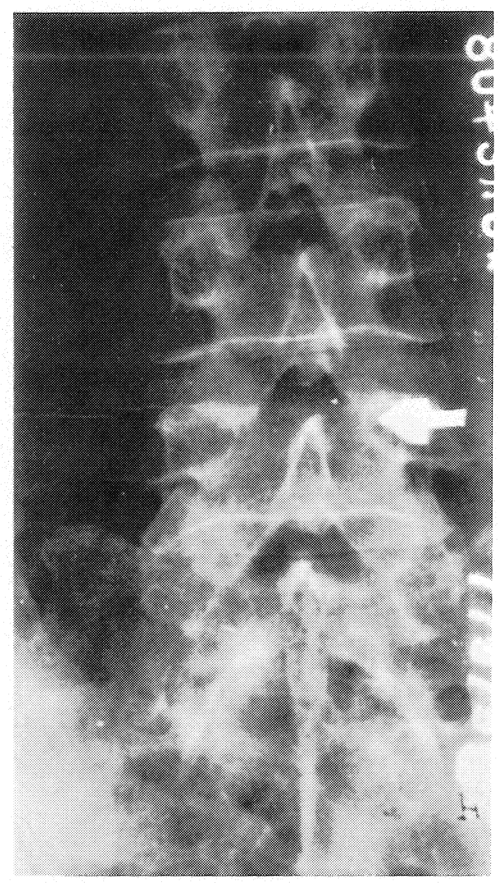


Figure 2. Localization of left lateral prolapse of L4, 5 by placing a metallic label.

soon as the site of prolapse is reached during laminectomy or removal of ligamentum flavum the patient experiences exquisite radiating pain, since the inflammed nerve is very sensitive to touch or pressure. Gentle exploration with a nerve probe verifies the presence of a prolapse at that level.

Operative technique

The patient is placed in a prone position with rolls of sheets or rubber sponge beneath the sides of the body and ankles.

Satisfactory local anesthesia for three hours may be obtained with a mixture of 10cc. of 2% lidocaine, 10cc. 0.3% decaine and 80cc. 0.5% novocaine.

A midline incision about 8-10 cm. is made centered on the scratch mark showing the level of the prolapse. The incision is deepened close to the spinous processes (usually L4,L5,S1) on the affected side. Care is taken to keep the interspinous ligament intact. The sacrospinalis is separated cleanly from the spinous processes and lamina with an osteotome. Generally two interlaminar spaces (L4,L5 & L5,S1) are exposed using a Taylor

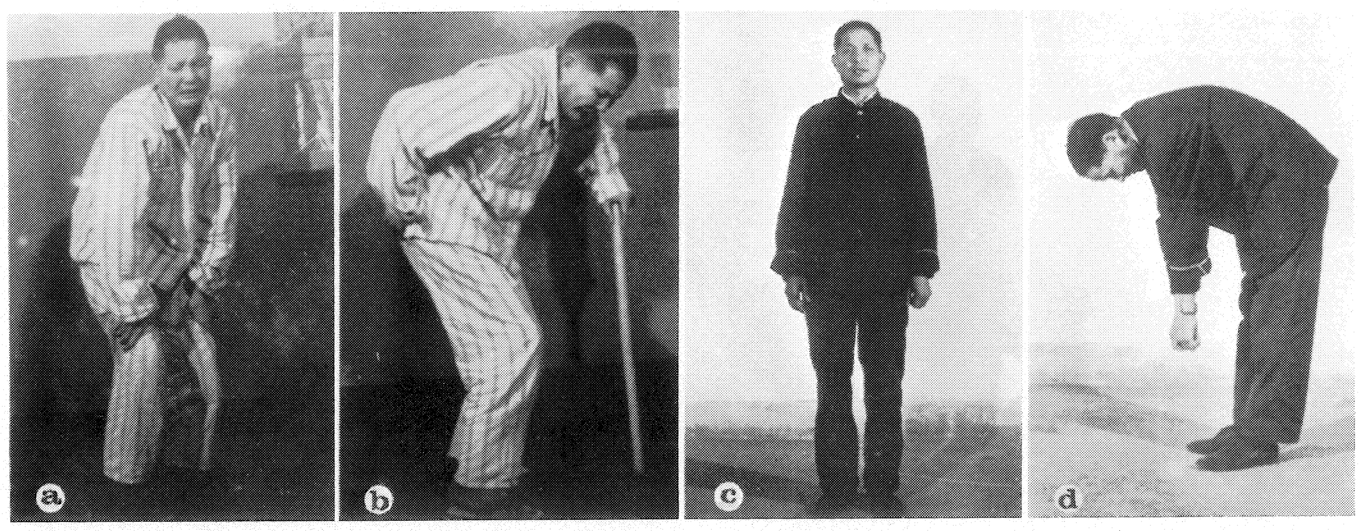


Figure 3. Case 202224, age 47 with backache six years, agonizing sciatica, bladder dysfunction for over a month, extensive sensory and motor deficit on the left, diminished sensation of the left perineum, and difficulty standing and walking. He was relieved immediately after removal of a big prolapse of left central type and enjoyed normal activity in three months. a,b, before operation, c,d, three months after operation.

spinal retractor. Fenestration or hemilaminectomy and occasionally total laminectomy of the involved space is performed. Unilateral exposures were performed in 229 cases (96.2%) and total laminectomies in 9 (3.8%) in our series. No significant difference in results was noted between fenestration and hemilaminectomy on unilateral exposure. It is usually easy to expose the space between L5-S1 since the interlaminar space is wide. When the L4-5 interspace is very small or the lamina overlapping, one should not hesitate to start from L5,S1 for a hemilaminectomy of L5 to remove an L4-5 prolapse. It would be unwise to use a chisel for opening a window on the lamina. Attention should be paid to avoid nipping the dura or its content with the rongeur. Rongeur bites should be close to the bone or ligament in clear view. Release it if in doubt. Inject the sensitive nerve with local anesthetic as soon as possible to ease the patient's pain.

Removal of lesion

Separate the dura and nerve gently. We usually start from the areas above and below the lesion. At this time we can usually verify the location of the prolapse in relation to the spinal nerve and dura as predicted preoperatively. Try to avoid the engorged veins. Cotton pledgets and suction are necessary to keep the view clear. The affected nerve is usually swollen and often adherent to the underlying disc or extruded fragment. If possible, try to expose the prolapse by gently retracting the spinal nerve and dura medially. When a large prolapse lies between the dura and nerve, one should not attempt to retract the nerve and should proceed to open the disc and remove its content before mobilizing the nerve.

A circular incision is made around the summit of the lesion with a pointed knife by moving up and down one centimeter deep. Usually the disc material comes out readily and pituitary rongeurs of varying sizes are used to grasp the ruptured fragments in the intervertebral space. Remove the loose fragments of the degenerated nucleus pulposus and ruptured annulus fibrosus completely to prevent recurrence. One should not go too far in order to avoid large vessels anterior to the disc. Extreme caution should be taken in the removal of extruded fragments which are usually firmly adherent to the dura and nerve. Any separation or cutting should be done under clear view to avoid injury to the nerve and cauda equina.

Annoying bleeding may occur during operation. Good lighting and suction are always necessary. Constant suction is often necessary to keep the view clear. As soon as surgery is finished, however, bleeding usually stops or slows. Gentle pressure with cotton pledgets and waiting should stop the remaining bleeding. Complete hemostasis is required before closure. Blood transfusion should be ready although it is used only occasionally.

Postoperative care

Postoperative reactions were usually slight because of minimized operative trauma and use of local anesthesia. During the last 10 years early ambulation has been instituted with the patient up on the 3rd postoperative day. No jacket or belt is used. Bladder and bowel function as well as general health recovered quickly.

Rest and gentle walking are advised for 3 months. Patients may start light work in the first year and then resume normal activities except heavy lifting and competitive sports.

Results

238 disc operations were performed from 1956 to 1980. Longest follow-up is 22 years.

Table IV

Results of operations

Grade	Case	Percent
Excellent	131	55
Good	87	36.6
Fair	12	5
Improved	3	1.3
Poor	5	2.1

Seven (2.9%) repeat operations were performed for recurrence of symptoms with excellent results in 2, good in 1, fair in 1 and improved in 2. Two patients were reoperated for symptoms at a different level with satisfactory results. The other five were reoperated for recurrent symptoms in the previously operated space and were explored with difficulty. Two of these had a history of violence, and extruded fragments were found at the 10th and 18th postoperative years.

In five cases of spondylolisthesis associated with disc prolapse, excision of the prolapsed disc through hemilaminectomy of L5 and spinal fusion of L4,L5, S1 by means of combined method of Albee and Hibbs with autograft taken from the ilium was done. Postoperatively they were confined to a plaster bed for three months. All were relieved of backache and sciatica and resumed normal life.

Two cases of spinal stenosis complicated by disc prolapse were operated upon by hemilaminectomy of L5 and partial laminectomy of L4 and S1. Removal of the prolapsed disc gave satisfactory results.

There were 30 cases with extruded fragments and profound disability. Two were partially paraplegic, five unable to get out of bed, 23 walked with an extreme limp and 17 had bladder and bowel dysfunction. Good results were obtained in 26 cases, three fair, and one failure due to injury of the cauda equina.

Scoliosis with limping appeared in 138 (58%) of 238 cases because of spasm of the sacrospinalis involuntarily protecting the affected nerve. It predominated on the side toward which lateral bending would aggravate radiating pain. Once the prolapse was removed, scoliosis disappeared (Fig. 4).

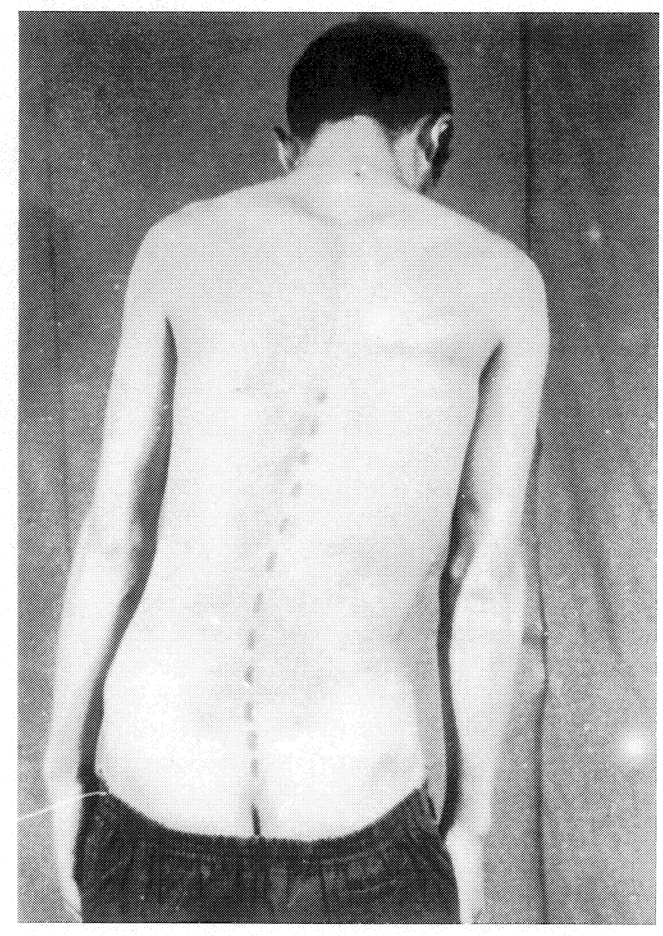


Figure 4. Case 200427, age 28, backache and sciatica five years; impaired sensation and motor power of the left leg, back muscle spasm and scoliosis for three months; lateral bending to the left aggravating radiating pain. A large prolapsed disc lateral to left 5th lumbar nerve was removed. Sciatica and scoliosis disappeared shortly after operation. a. scoliosis before operation, b. after operation, a few days after removal of stitches.

Of five cases with poor results, three were due to disc space infection although sciatica had been relieved, one sustained partial injury of the cauda equina due to technical error, and the other was due to arachnoiditis from severe reaction to myelography with conray.

Postoperative infection occurred in three patients (1.3%). All had infection in the intervertebral space and the symptoms were controlled by external fixation with a double spica cast and antibiotics. All suffered long, painful courses.

Comment

Diagnosis of disc prolapse can be reliably made on careful evaluatin of symptoms, signs and plain x-rays,

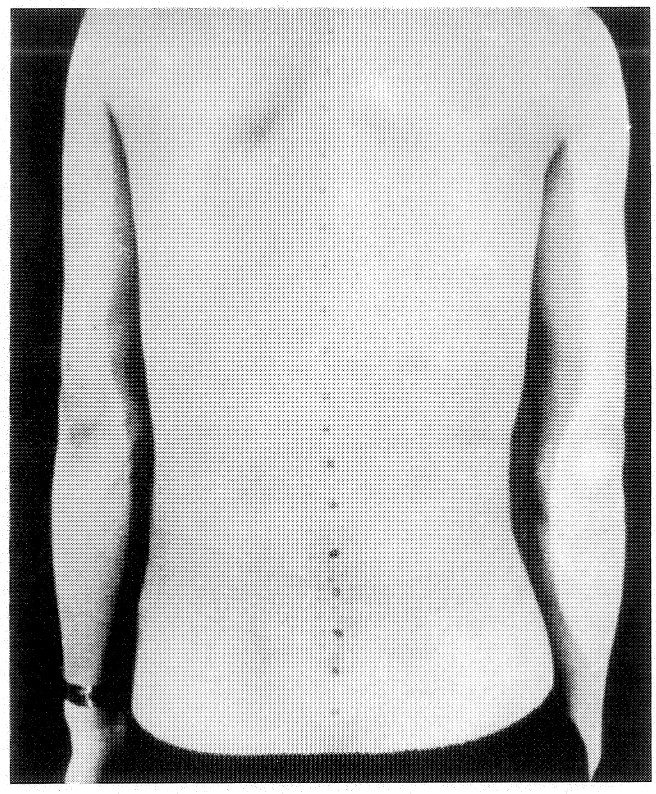


Figure 4b.

rather than by potentially harmful myelography or discography.

There are few orthopaedic problems that can be treated by operation with such quick and dramatic results as disc prolapse, if properly done. Operative procedures accomplished with minimal trauma to musculoskeletal structures and slight postoperative reactions enables early ambulation and recovery. However, there are pitfalls for this operation. Neural injury, disc space infection, hemorrhage, and recurrence of symptoms are among the worst.

It can not be overemphasized that disc surgery should be done by experienced surgeons.

Operation relieves the symptoms of sciatica and backache by eliminating the irritation of the sensitive nerve and disc. Though the operated disc is not restored to normal, the dense fibrosis which gradually takes place, is compatible with normal function.

Concomitant spinal fusion is unjustified since a majority of cases do well without it. One can always arthrodese the spine at a later time when indicated. We indicated only two cases of spinal instability for arthrodesis.

We also found routine exploration of two discs unjustified. The incidence of two lesions in one patient was high in our series, i.e., 54 (22.1 per cent) of 238 operated cases, probably because equivocal discs were removed and counted. However, since abandoning this routine we found only one patient with two lesions in the last 55 operated cases.

Unnecessary surgery not only adds more morbidity and risk but also confines the patient to bed unduly, e.g., with spinal fusion for at least three months.

We have employed no marked difference in operative technique for disc prolapse of lateral, bilateral and central types. Unilateral exposures were usually employed. In cases with extruded fragments in the lumbar canal resulting in severe distress and neural deficit, wider exposures were often required as the fragments were found to be adherent to the dura and spinal nerve.

We are not quite satisfied with the present results and much needs to be done to improve them.

CLOSED REDUCTION OF FRACTURE DISLOCATIONS OF THE THORACIC-LUMBAR SPINE

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The primary goal of the initial treatment of the spine injured patient is the immediate reduction of spine malalignment which eliminates compression of the spinal cord and its nerve roots. Considerable enthusiasm exists for early surgical restoration utilizing spinal instrumentation in fracture/dislocations of the thoracic and lumbar spine. The necessity for early operative alignment is debatable. However, stabilization of the spine by instrumentation reduces prolonged bed care and hospitalization.[2,5,7,12,14]

Realignment of the thoracic and lumbar spine has been achieved by nonoperative methods. Restoration of vertebral body alignment using postural reduction began in the 1920's for fracture/dislocations of the thoracic and lumbar spine. Slings, frames and hammocks were used to hyperextend the prone patient.[4,20] Watson-Jones in 1934 reported spine reductions by placing the patient with a thoracic or lumbar spine injury prone between two tables.[22] Manipulation then achieved reduction. After reduction he placed the patients in an extension body plaster or "plaster bed." Absent sensation below the level of injury with consequent danger of skin pressure ulceration beneath the cast now contraindicates the use of the "plaster bed." Also, Stanger reports a high rate of recurrent dislocation with this treatment.

Frankel[8] and Guttman,[9,10] long advocates of "postural reduction" of the thoracic-lumbar fractures, placed patients at prolonged bedrest in a hyperextended position for up to 11 to 13 weeks. Meticulous nursing care prevented skin pressure ulceration. Also, a specially designed bed provided side-to-side turning.

Recently, rapid anatomical reduction of fracture/dislocations of the thoracolumbar spine was reported utilizing halo-femoral traction.[23] The use of Harrington instrumentation and fusion, followed by a total contact orthoplast jacket then allowed early post-operative mobilization.

The safety of performing a manipulative reduction on a displaced fracture has been questioned.[10,11,18] To date no reports of neurologic deterioration attributed to manipulation have been recorded.[5,15,16]

Rib fractures with intra-abdominal or intra-thoracic injuries preclude immediate spine reduction by closed manipulation. Also, closed reduction of fracture/dislocations of the thoracic spine with incomplete neurologic injury or intact neurologic function should be eliminated due to the danger of extending or creating a neurologic injury in this portion of the spine, which has the narrowest canal diameter.

In the absence of the above contraindications, and without a deteriorating neurologic status, the following method of treatment of fracture/dislocations evolved. We attempt immediate closed manipulation on each patient with vertebral body displacement of at least fifty per cent of vertebral body width. We then maintain the patient in a hyperextended position on a turning frame and achieve early mobilization by spinal instrumentation and fusion.

Materials and Methods

Between July 1972 and December 1978, 349 patients with acute thoracic and lumbar fractures were admitted to the Midwest Regional Spinal Injury Care System at Northwestern. One hundred and nine were unstable and required instrumentation and fusion. Twenty-two of the 109 patients with unstable spines exhibited gross vertebral body displacement of at least 50% of the vertebral body width. This group with marked vertebral body displacement underwent closed manipulation initially, in order to achieve immediate reduction of spine malalignment. Spine stabilization by instrumenta-

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tion and bone grafting was performed at two to three weeks following injury.

The fracture/dislocation levels were as follows: nine were thoracic, seven thoracolumbar, six were lumbar.

The fractures were classified similarly to the fracture/dislocation injuries described by Flesch and Rogers.[7,19] There were three flexion-rotation comminuted vertebral body fractures. There were fifteen wedge compression fractures of the vertebral body and one vertebral body "burst" fracture. All these injuries had fractures of the posterior elements. Three spines demonstrated minimal wedge compression fractures of the vertebral body with facet dislocation, which were not described by Flesch and Rogers.

All fractures of the vertebral body in this series involved forward subluxation of the superior vertebral body upon the inferior vertebral body.

The neurologic assessment of the twenty-two patients was recorded on admission and post-manipulation. Each fracture was classified according to the method described by Frankel.[8] These results are diagramatically represented on a grid similar to Frankel's (Fig. 1).

Fracture Dislocation
Thoracic—Lumbar Dislocations

1972 - 1978

Post Manipulation

	A	B	C	D	E
A	8				
B		5	1		
C				3	
D					2
E					3

FRANKEL[14] Neurological Classification

A. Complete absence motor and sensory function.
B. Sensory Intact, Absent Motor.
C. Sensory Intact, No Useful Motor.
D. Sensory Intact, Useful Motor.
E. Normal Neurological.

Figure 1.

Closed Reduction Technique

Upon admission a rapid, careful, history and physical examination, including a thorough neurologic assessment, and radiographic evaluation are performed on each patient.

If a closed reduction is indicated, an intravenous line is inserted. The patient is given nothing orally. If steroids have not previously been administered, Dexamethasone 20 mgs. followed by 20% Mannitol in 500 cc. are administered intravenously. Intravenous Valium 10 mgs. in conjunction with morphine or Demerol in a dose appropriate for the patient's size is given. This combination produces sufficient relaxation to perform the closed reduction. If head injury is suspected, narcotics are contraindicated.

In addition to an orthopaedist and neurosurgeon, a physician from the respiratory care service who is skilled in intubation, participates in the initial assessment and treatment. Ventilatory support following the administration of the Valium-morphine mixture may be necessary.

Within ten to fifteen minutes after administering the Valium-morphine combination, the patient is placed on a Stryker® wedge turning frame and turned prone. With one assistant placed at each ankle to provide longitudinal traction in a caudal direction, a third assistant provides traction in a cephalad direction by a transverse sheet placed beneath the upper chest directed dorsally through the axillae and over the posterior aspect of the shoulders. The patient's arms are maintained at the side (Fig. 2). After localization of the spine defect by palpation, a physician experienced in the closed reduction maneuver applied perpendicularly directed pressure over the most prominent spinous process. This promi-

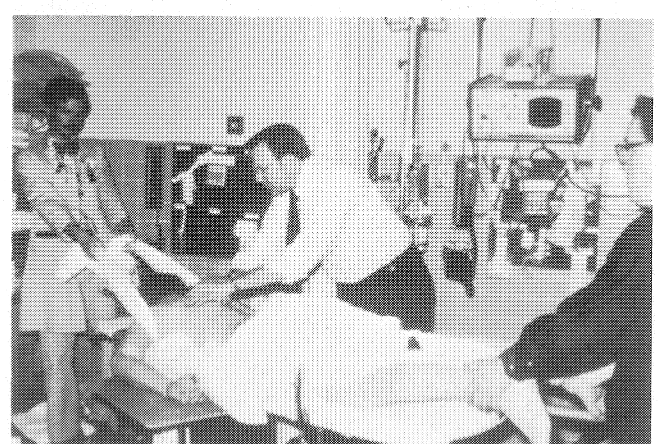

Figure 2. Closed reduction maneuver. Note traction both proximally and distally, while vertical pressure is applied over the prominent proximal spinous process of the distal segment.

nence coincides with the gibbus produced by the most proximal vertebral spinous process of the distal spine segment. Pressure is applied for one or two periods of up to four minutes.

The patient reports to the physician any feelings of altered sensation during the procedure.

Reduction is detectable by palpation. A "cross-table" lateral radiograph is obtained to document reduction (Fig. 3, 4). If the reduction fails, the maneuver is repeated. A third attempt at reduction should not be performed.

Whether or not spinal alignment has been improved by manipulation, the patient is maintained in hyperextension until operative stabilization is performed. This is accomplished during the turning cycle by placing two pillows at the level of the dislocation when the patient is supine, and by placing two pillows each beneath the chest and lower pelvis when the patient is prone.

All twenty-two patients underwent operative stabilization and fusion between one and three weeks following injury. Fifteen (68%) were stabilized by Weiss Springs, 6 (27%) by Harrington Rods and one (5%) by a combination of Harrington Rod and Weiss Spring because of a unilateral facet and contralateral vertebral body-pedicle fracture.

All patients were immobilized post-operatively. A Taylor-Knight orthosis was utilized for upper thoracic spine injuries, while a Jewett hyperextension orthosis or body cast was used for lower thoracic, thoracolumbar, and upper lumbar injuries. One patient with a traumatic dislocation of L5-S1 was placed in a one leg pantaloon spica. The minimum period of immobilization was three months.

Results

Follow-up of this group of twenty-two patients ranged from two months to sixty-one months. Fourteen (64%) had an average follow-up of greater than two years. Two patients (9%) had follow-up of greater than one year. Six patients (27%) had a follow-up of less than one year.

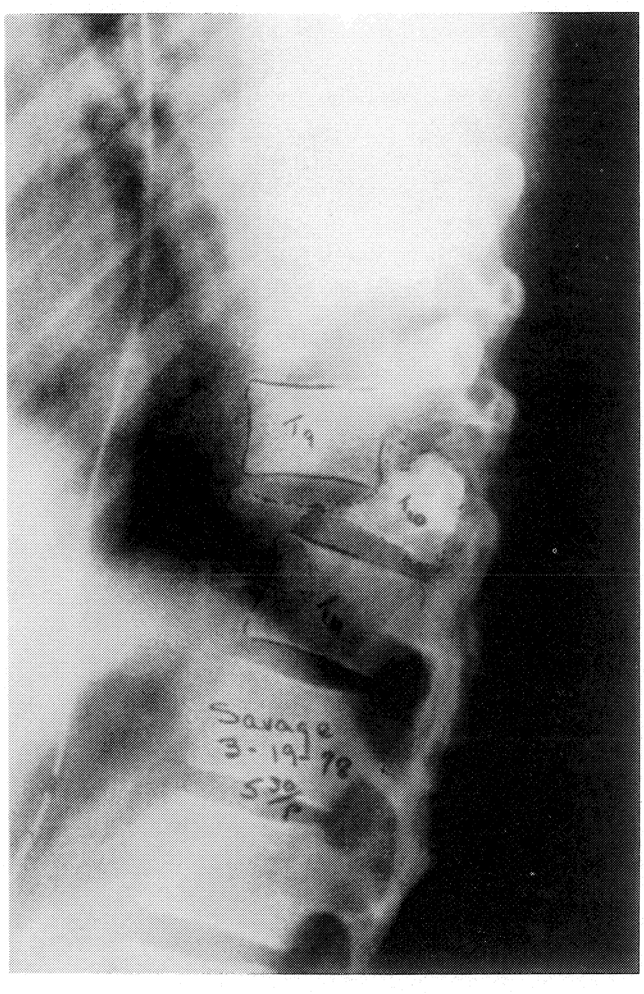

Figure 3. Pre-reduction.

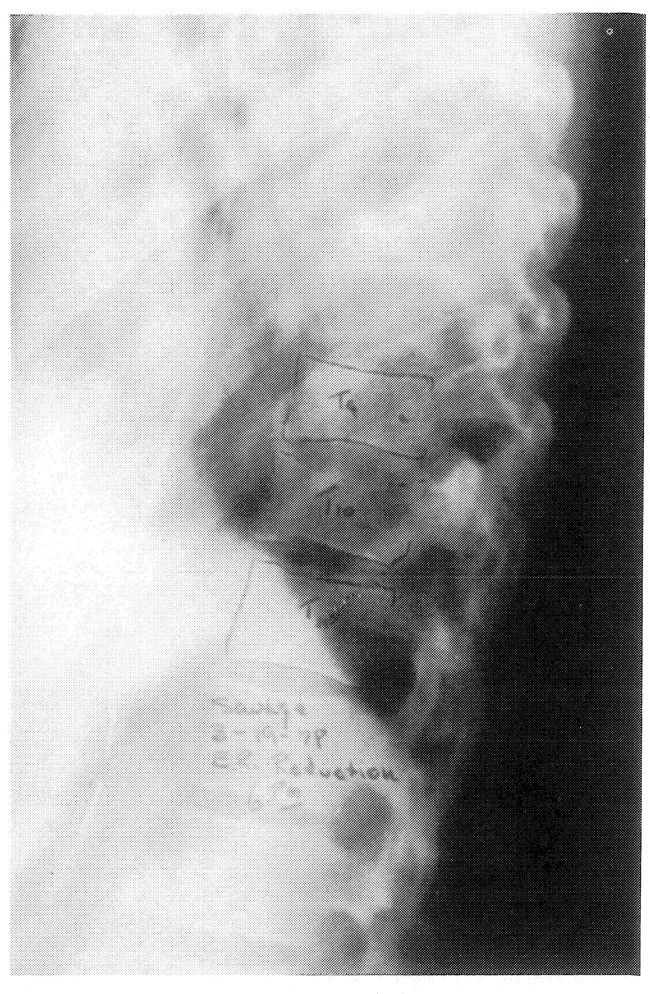

Figure 4. Post-reduction.

Nineteen (86%) were successfully reduced. Three (14%) failed to reduce. Causes for failure were thought to be bilateral locked facets, bone impingement from comminuted vertebral body fragments, and extensive instability from a complete dislocation (Fig. 5, 6, 7).

Of the group who had successful reductions, three had a recurrent dislocation of one or both facets within two or three weeks following reduction.

No failures of internal fixation or loss of vertebral alignment of greater than 5° occurred. No pseudoarthrosis of the fusion mass has been detected to date.

No patient experienced deterioration of neurologic status post-manipulation or post-stabilization. Neurologic improvement was noted in the incomplete group of patients as recorded in Figure 1. No patient with complete neurologic injury demonstrated any sensory or motor return. All patients entered an active rehabilitation program within two weeks of spine stabilization. The length of hospital stay averaged twenty-six days. One patient experienced an acute pulmonary embolus two weeks post-surgery and five weeks post-injury.

Discussion

Immediate operative intervention in acute spine injuries with vertebral column malalignment and associated neurologic injury has been advocated.[6,24] Other reports support delaying surgical stabilization of thoracic and lumbar dislocations up to two weeks.[1,7,11,12,13,14,15,16] Most authors agree that the paramount objective of immediate spine injury care is reduction of spine malalignment eliminating compression of the spinal cord and nerve roots.

That early surgical restoration and decompression is required is doubtful except in certain situations.[3] Certainly when treating a patient with a deteriorating neurologic status, every available diagnositc tool should be employed to assess the etiology. An immediate open reduction to effect a decompression is then considered. Also, when there is evidence of significant encroachment of the neural canal by bony fragments in a patient with an incomplete neurologic injury, surgical decompression is required despite realignment of vertebral body displacement.

When treating a patient with a stable neurologic status, operative stabilization can be delayed. However, some method of spinal realignment should be attempted early. Significant fracture/dislocations should not be allowed to remain for greater than two weeks. Beyond two weeks, even open reduction will often fail. Every effort should be made to achieve an early adequate realignment by closed means.

Healing of spinal fracture/dislocation by postural maintenance alone requires prolonged bedrest and may be associated with recurrent dislocation.[18] We failed to obtain reduction in three patients, and three patients (14%) experienced recurrent facet dislocations. Stanger reported a redislocation rate of 25%.[21] Postural maintenance of reduction also requires extremely meticulous nursing care to prevent skin pressure ulceration.

In the absence of contraindications, immediate spinal realignment of fracture/dislocations of the thoracic and

Figure 5. Bilateral locked facets.

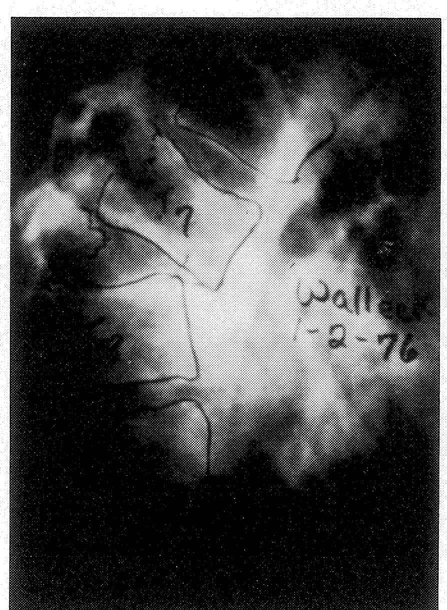

Figure 6. Comminuted vertebral body fragments preventing reduction.

Figure 7. Complete dislocation.

lumbar spine can be safely achieved by closed manipulation followed by postural maintenance in a hyper-extended position. We advocate delayed operative stabilization to prevent recurrence of facet dislocation and to provide early mobilization. Delaying operative stabilization one to two weeks after successful closed reduction allows the overall status of the patient to improve or at least stabilize.

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TERMINAL TRANSVERSE CONGENITAL FOREARM DEFICIENCY

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Joseph A. Buckwalter, M.D.**
William F. Blair, M.D.**

Introduction

Although many investigators have studied congenital anomalies of the upper extremity, few have focused their attention on complete congenital limb defects. These patients share certain problems with those having traumatic amputations or surgical amputations for neoplastic or infectious disease. However, the patient with a congenital limb defect has additional problems and different needs. Proper attention to the identification of these differences becomes vital in providing the best possible care.

Purpose

This study attempts to: (1) describe characteristics of patients with terminal transverse congenital deficiency of the forearm, (2) describe prosthetic care for these patients, and (3) describe the attitudes of patients and parents toward prosthetic treatment.

Review of Literature

Birch-Jensen[3] examined records of over four million patients to determine the incidence of the below elbow amputation. In his classic study (Fig. 1) he identified a

OCCURENCE OF CONGENITAL BELOW ELBOW AMPUTATIONS

		Shurr (1980)		Birch-Jensen (1949)		Aitken & Frantz (1955)		Aitken & O'Rahilly (1961)	
Number of Patients		48		161		49		331	
Male	(%)	19	(40)	69	(43)	22	(45)	156	(47)
Female	(%)	29	(60)	92	(57)	27	(55)	175	(53)
Left	(%)	35	(69)	108	(67)	37	(76)	212	(64)
Right	(%)	16	(31)	53	(33)	12	(24)	119	(36)

Figure 1.—No legend

total of 161 patients as congenital below elbow amputees. Sixty-nine were male, 92 female, 108 occurred on the left and 53 occurred on the right. Aitken and Franz[1] reported a total of 49 patients; 22 males and 27 females, 37 involved the left and 12 the right. Aitken and O'Rahilly[2] reviewed 331 cases. Of these 156 were male, 175 female; 212 involved the left arm and 119 the right. Each of these studies shows a predominance of females, and a left to right ratio of nearly 2:1.

Methods

Two-thousand-five-hundred-twenty-seven patient records have been classified in the files of the University of Iowa Congenital Hand Project. We reviewed the records of all patients with congenital forearm amputations (Fig. 2) and established a standardized list of questions. We evaluated all available patients during an outpatient clinic visit and obtained information from both the patient and parent(s). Some patients in this series were lost to follow up and appear only in the incidence section of this report.

Figure 2.—The classic terminal transverse congenital deficiency of the forearm.

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Results

We identified 48 patients with below elbow amputations (Fig. 1). This series included 19 males and 29 females. Four patients had bilateral upper extremity amputations (one patient had a contralateral elbow disarticulation and three a bilateral below elbow amputation) making a total of 52 amputations. Of 51 below elbow amputations, 35 were on the left and 16 were on the right. These patients may be placed into two groups: Group 1–unilateral below elbow congenital amputees, and Group 2–patients with associated anomalies.

Infants seen in the University of Iowa Department of Orthopaedics in recent years have been treated in the following manner. They are fit with a plastic below elbow socket, suspension strap, and a passive hand as early as five months (Fig. 3). Physical therapists instruct the parents in how to evaluate proper fit, means

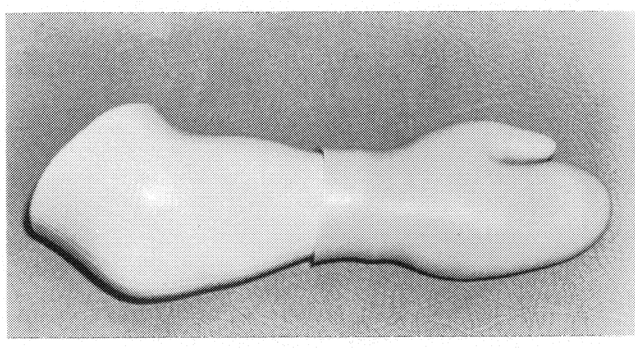

Figure 3.–Below elbow prosthesis with paddle.

of donning and doffing the prosthesis, how to assist the child in using the device, and what to expect functionally. Attention is given to prosthetic tolerance. Unilateral below elbow amputees should wear their prostheses all day from an early age on. We scheduled regular return visits to follow the child and to answer questions of concerned parents.

When the child outgrows the initial prosthesis, usually at age one and one-half to two years, we prescribe a new socket and introduce a split-hook Dorrance terminal device (Fig. 4). We carefully instruct the parents about the body motions needed to power the voluntary opening terminal device. Delaying the first split-hook prosthesis one year allows for the family to become accustomed to the child's amputation and to contemplate the future use of a prosthetic hook. In America we live with the negatives associated with the fictional pirate, "Captain Hook." Few families will accept a split-hook for their six-month-old child, even if it could be functional.

No patients have been fitted with myoelectrically controlled electric hands, although the Muenster design

Figure 4.–Below elbow prosthesis with split hook.

socket is the socket of choice in the adult below elbow wearer. For those adults who desire to lift heavy loads, such as farmers, more conventional sockets and harnesses are used.

A successful wearer may be defined as a person who wears the prosthesis most of the waking hours. Using this definition, many successful wearers were fitted prior to age one. Parents of successful wearers expressed satisfaction with the aggressive, early-fitting approach. Most volunteered to talk to other parents and relate how quickly their child used both limbs after the fitting of the below elbow prosthesis. Parents report that functional milestones, including dressing independence and tying one's shoes, are often delayed. Most parents comment about the improved function of their child with the use of the device. This is difficult to measure objectively, since no controls exist and since a comparison with a normal limb would be unrealistic. However, successful wearers are not necessarily successful users; and, as demonstrated by one farmer who wore his arm only for certain tasks, a successful user may not always be a successful wearer. Concerning the appearance of the prosthesis, parents often describe it as "cold," "clunky," "ugly," or "noisy," but most of these same families admit that their child looks "naked without it."

Most successful wearers and their families believe that the prosthetic device or hook is functionally satisfactory. Many, however, refer to the day in the future when a prosthetic hand will be as practical and useful as a hook. Many teenage children, who are frequently concerned about their appearance, report discontinuing the use of a prosthesis during the ages of 13 to 20, only to return to prosthetic use at a later age.

Discussion

An unsuccessful wearer seldom wears the prosthesis. The unsuccessful wearers are usually those who were fitted after the age of five. Drastic changes in wearing history appear to be rare. Charts reviewed from the 1940's commonly revealed references to late-childhood or even adolescent-age fitting as the recommendation of choice.

Children with both arm and leg deficiencies present a particularly challenging problem. In the past, lower limb fitting appeared to be based on the chronology of motor skill development, but the philosophy of fitting upper extremity amputations was not based on the child's motor development.

We have adopted the practice of early fitting because this results in successful wearers. In the children fit as adolescents, successful wearers were few. For example, one patient felt that her skills with just the elbow crease and normal hand were equal to her abilities with a prosthesis. Others feel that the prosthesis gives the appearance of a "handicapped person" and going without anything is more satisfying to their self-image.

Conclusions

The congenital below elbow terminal transverse amputation appears to be a distinct entity, usually well defined in its unilateral presentation. It occurs in our series more often in females (29 versus 19) and more often on the left (35 versus 16). Early aggressive fitting of prostheses at about six months of age is well accepted by both parents and children. This approach yields a functional prosthetic user at a young age and leads to successful adult wearers.

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ULNAR TUNNEL SYNDROME

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Compression of the ulnar nerve at the level of the wrist produces ulnar tunnel syndrome. I find one case of this common syndrome for every ten cases of carpal tunnel syndrome. This report describes my experience with diagnosis and surgical treatment of 34 cases.

History

Symptoms of ulnar tunnel syndrome resemble carpal tunnel syndrome but localize to the ulnar aspect of the hand and wrist. Patients with ulnar tunnel syndrome complain of pain in the wrist and hand, numbness and tingling, and weakness. Usually pain is the most disturbing symptom.

Symptoms begin after use of the arm and hand and often wake the patient at night. The pain frequently radiates from the wrist into the ulnar aspect of the elbow and occasionally to the axilla. The differential diagnosis then includes compression of the ulnar nerve at the elbow. Determination of where the pain is most intense, where it starts, and the pattern of radiation will help in the differential diagnosis of these two conditions. Compression of the ulnar nerve at the wrist and elbow may co-exist as it did in four of 34 cases. Compression of the deep branch of the ulnar nerve was present in three of the cases. These patients all presented with atrophy of the small muscles of the hand and complained of weakness. There were no complaints of numbness or tingling since compression was distal to the sensory fibers.

Physical Examination

Patients sometimes pointed to the ulnar tunnel as the site of their most intense discomfort. Sensation, compared to the normal hand, was decreased in the little and ring fingers in 27% of cases. In the remainder the sensation was normal.

Tinel's test caused tingling in the ulnar nerve distribution in 44% of cases. Phalen's test was positive in 92% and was the most reliable finding. Atrophy of the ulnar-innervated intrinsic muscles occurred only if the deep branch of the ulnar nerve became compressed. Concomitant compression of the ulnar nerve at the elbow was diagnosed by eliciting tenderness and a strongly positive Tinel's sign over the ulnar groove at the elbow. I have the patient feel the little finger with his normal hand and if he feels numbness, an ulnar tunnel syndrome may be present.

Electromyography

EMG and nerve conduction studies helped little in the diagnosis. EMG and nerve conduction studies were done in fifteen of the thirty-four cases, and were positive in only four.

Anatomy

The ulnar tunnel begins at the proximal pole of the pisiform and ends just distal to the hook of the hamate (Fig. 1). The flexor retinaculum and the origin of the hypothenar muscles form the floor of the ulnar tunnel. Proximally the roof is the volar carpal ligament. Distally the roof consists of the palmaris brevis and fibers from the palmar fascia. These structures are in the same plane as the volar carpal ligament but are not shown in Fig. 1.

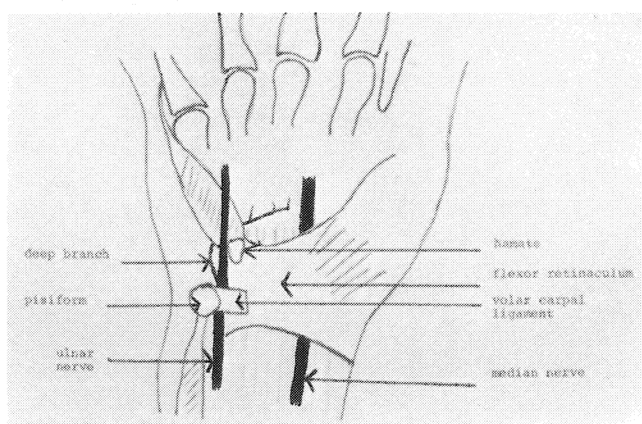

Figure 1. The ulnar tunnel starts at the proximal pole of the pisiform and ends distal to the hook of the hamate. It encompasses the deep branch of the ulnar nerve.

The most common site of compression of the deep branch of the ulnar nerve is just distal to the hook of the hamate where a ganglion or granulation tissue pushes the nerve against the origin of the two hypothenar muscles. The most common site of compression of the ulnar nerve at the wrist is the level of the pisiform where the floor consists of the flexor retinaculum and the roof of the volar carpal ligament.

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The deep branch of the ulnar nerve leaves the main trunk just distal to the pisiform where the nerve exits from beneath the volar carpal ligament and passes deep to the hypothenar muscles that attach to the hook of the hamate.

A cross section through the wrist at the level of the pisiform (Fig. 2), shows that the ulnar tunnel at this level is triangular and sits on top of the flexor retinaculum and carpal tunnel.

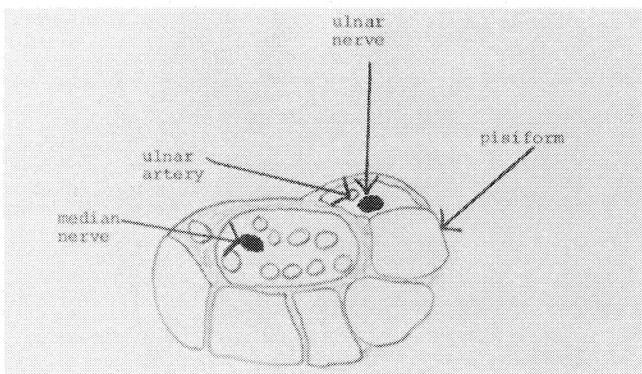

Figure 2. The cross section of the wrist at the level of the pisiform shows the ulnar tunnel. The roof is the volar carpal ligament and the floor is the flexor retinaculum. The ulnar tunnel is superficial to the carpal tunnel.

Surgical Procedure

The solid line in Fig. 3 shows the incision recommended for ulnar tunnel decompression. It is .75 cm ulnar to the thenar crease of the palm, and it stops abruptly at the wrist. Incisions that pass across the wrist often leave unsightly scars.

Deep to the skin and subcutaneous tissue the palmaris brevis is encountered with fibers from the palmar fascia. These are incised in line with the skin incision. Next the ulnar artery comes into view. The initial skin incision is insufficient to decompress the entire ulnar tunnel. Therefore the skin should be elevated proximally, and the volar carpal ligament and the forearm fascia should be incised 3/4 inches proximal to the volar carpal ligament. The ulnar artery is then elevated to reveal the ulnar nerve deep to it. The usual site of compression is at the level of the pisiform. An indentation in the nerve is found in longstanding cases. In the absence of muscle atrophy this is sufficient to cure the ulnar tunnel syndrome.

If muscle atrophy is present, the deep branch of the ulnar nerve must also be exposed. It is found by elevating the ulnar nerve in the ulnar tunnel and looking deep to it. This branch is followed around the hook of the hamate by incising the hypothenar muscles that originate from the hook. Compression of the deep branch of the ulnar nerve was found in three of the thirty-four cases. In two cases the compression was by a gangion and in one case by granulation tissue.

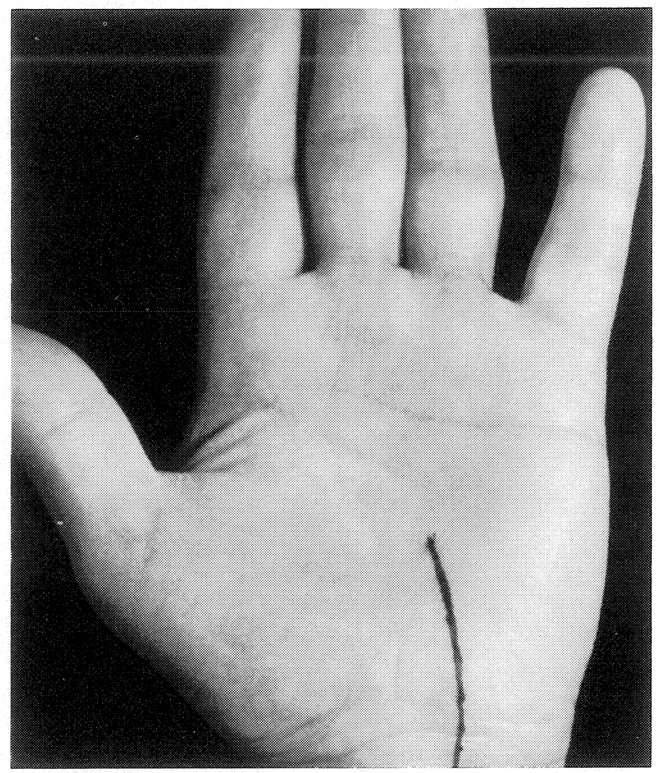

Figure 3. The solid line is the recommended incision for ulnar tunnel decompression. It stops abruptly at the level of the wrist. The incision may be extended as shown by the broken line in order to secure adequate exposure.

If there is concomitant compression of the median nerve in the carpal tunnel it can be decompressed through the same incision.

Discussion

Ulnar tunnel syndrome is of two distinct types. One is due to compression of sensory and motor fibers and the symptoms resemble carpal tunnel syndrome except they involve the ulnar aspect of the hand and wrist. The other type is due to compression of the deep branch of the ulnar nerve and presents as atrophy of the ulnar intervated muscles. The former type is ten times as common as the latter.

Ulnar tunnel syndrome will not be diagnosed unless it is specifically looked for. It can occur concomitantly with carpal tunnel syndrome (5 of these 34 cases). Patients' complaints of their entire hand becoming numb is not enough to diagnose ulnar tunnel syndrome. One must check sensation in the little finger. Look for an ulnar tunnel syndrome in patients who have persistent symptoms after carpal tunnel decompression.

EMG's frequently remain normal for several years after significant symptoms arise in ulnar tunnel syndrome. The diagnosis is much more reliably made by history and physical examination.

IDENTIFY THE PROBLEM

Richard A. Brand, M.D.*

Patient dissatisfaction is an element of every physician's medical practice. There are many causes of patient dissatisfaction. The concerned physician learns to identify those causes in order to decrease its frequency.

A common cause of patient dissatisfaction is the failure of the physician to identify the patient's problem, which may not be his or her chief complaint. If the problem is not identified, the patient is unlikely to be satisfied with the treatment rendered. Patient dissatisfaction may show in one of several ways. The patient may repeatedly return to the physician who orders more tests, recommends other treatment, or in frustration, refers the patient to another physician; or the patient may become frustrated or angry and seek another opinion. As long as the problem (as the patient perceives it) is unidentified and unaddressed, the process of looking for answers may continue. This results in significant unnecessary expenditure of the patient's time, energy, and money as well as society's medical resources.

To identify any problem, a physician must be aware of it and consider its possible presence in the patient. Physicians should be aware that a patient's real problem (or motivation for seeking help) may not be readily verbalized. Denial, embarrassment, fear or other feelings may prevent the patient from expressing his or her real problem. Furthermore, the physician may make communication and identification of the problem more difficult by taking insufficient time, by not listening to (and hearing) the patient's concerns, or by failing to establish good rapport.

A number of these often unverbalized problems occur relatively frequently. Some of the more common are presented here as examples:

(1) *Concern about having some dread disease* (e.g., heart disease, cancer). Often a person has relatively minor symptoms which, for a variety of reasons, are interpreted by the individual as being caused by some fatal or crippling illness. Such concerns may be magnified if the doctor says, "I can't find anything wrong." Very little communication with the patient may convey the notion that the doctor is withholding bad news. The patient wants to be reassured that he or she does not have a serious illness. Ordinarily, a relatively simple evaluation allows the doctor to confidently relieve the patient's concerns if they have been identified.

(2) *Concern over medical problems unrelated to the chief complaint.* A patient may complain about one problem when unrelated symptoms motivated the visit. While the patient does not verbalize the problem of concern, he or she hopes the doctor discovers the problem. One identifies these concerns most often in patients who have obvious medical conditions but are afraid or embarrassed to discuss them. Patients with cancer or sexual disorders may present this way. A careful review of systems will usually allow the physician to identify the problem.

(3) *Concern over children or dependent elderly relatives.* Parents may take children (or children, elderly parents) to a physician with symptoms they would ignore in themselves. Physiologic intoeing in young children is one example. The intoeing does not interfere with the child's life and, in the absence of neuromuscular disease or relatively uncommon deformities, usually spontaneously corrects with growth. The real problem is parental concern. After the physician rules out the presence of more serious problems, a simple explanation ordinarily allays the concerns.

(4) *Unrealistic expectations of medical science.* A patient may "doctor shop" when each physician has adequately diagnosed and treated a condition for which there is no ready cure. Unless the nature of the condition and the results of treatment are explained in realistic and understandable terms, the patient may expect a "cure" or at least better results of treatment.

(5) *Generalized anxiety which has been somaticized.* In a technologically oriented society it is all too common to overinvestigate a minor medical complaint and overlook the patient's generalized anxiety. It is easier to treat the patient's symptoms than the anxiety. The longer the problem remains unidentified and the more diagnostic or therapeutic modalities are employed, the more fixed the somaticized complaint becomes. It is

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far better (medically and economically) to recognize the patient's complaint as a symptom of anxiety at the onset and direct treatment accordingly.

(6) *Loneliness.* This is relatively easy to identify. Most often the patient is elderly and returns repeatedly to the physician with minor complaints. The importance in identifying loneliness is in avoiding excessive diagnostic tests and in providing friendly reassurance.

(7) *Concern over economic or social problems.* Patients may request a visit when they have a problem collecting Workman's Compensation, Supplemental Security Income (SSI) or disability payments; when they are seeking medical support for a lawsuit; or when there are family problems. Usually, the patient knows of no resource other than the doctor to solve the problem. However, when asked the reason for the visit, the patient will mention a medical complaint. He or she may be too embarrassed to give the real reason. Tactful questioning can uncover the patient's real problem. In these cases, the physician should explain to the patient how he realistically can and cannot help the patient.

A physician may identify problems that are created (sometimes unknowingly) by previous physicians. These include:

(1) *The first physician did not spend enough time with or demonstrate enough compassion for the patient.* Even though the diagnosis was correct and the treatment appropriate, the patient may seek further help or opinions.

(2) *The referring physician is concerned about his diagnosis or treatment.* Both diagnosis and treatment may be correct, and the patient is satisfied, but we, as referring physicians, need reassurance.

(3) *The physician did not provide an explanation in terms understandable to the patient.* A patient may see another physician simply because of inadequate explanation. The condition may be relatively trivial to us, but if its nature is not explained in understandable terms, the patient may have gross misconceptions about his or her future (pain, ability to work, etc.). Patients may be embarrassed or afraid to ask questions of their primary physician (whom they know well) yet be able to ask the same questions of a new physician.

(4) *The patient desires another opinion.* We may have good rapport with the patient and have provided an understandable explanation to the patient, however, the patient has heard contrary opinions from relatives, friends, or other physicians. It is important to understand the patient's perception of his or her medical conditions and how he or she came about that perception.

(5) *The doctor did not want to treat the patient.* Referrals are occasionally made simply because we find the patient difficult, do not want to get involved in litigation or Workman's Compensation, or for other reasons.

Identification of the problem requires communication. A dialogue between the patient and doctor, and, in case of referred patients, also between the two doctors is required. An awareness that the real problem may not be strictly medical is necessary. The doctor should explore the patient's motivation for his or her visit. This must be done tactfully to avoid putting the patient on the defensive. The doctor should ensure that all of the patient's concerns are answered in terms which the patient understands. The patient should have no unanswered questions at the end of the visit. Identifying the patient's problems (and addressing those problems) results in a satisfied patient, saves time and energy for both the patient and the doctor, and conserves society's medical resources.

The author is indebted to one of his teachers, Dr. James Cary, for an awareness of the concept of "Identifying the Problem."

TEACHERS, TUTORIALS AND SCIENCE+

Reginald R. Cooper, M.D.*

Several areas in residency training absolutely demand our attention if we take this business of education seriously. Conversely, if we continue to ignore certain facets of graduate education, I predict that we will eventually receive a Flexnerian type of review of residencies. In fact, this may be highly indicated. Would we survive such an evaluation relatively unscathed, or would we at least be indicted for educational malpractice?

Logic indicates, and education theory and practice dictate, that establishing an educational program falls into three phases: (1) delineating goals and objectives, (2) then selecting appropriate techniques to allow the learner to reach these goals, and, finally (3) evaluating whether the learner accomplished what was planned. As a heavily biased observer with much vested interest, I suggest that we in Orthopaedics have advanced more rapidly in the last of these than in the former two. We have especially defaulted in establishing goals and objectives in a manner that is semi-objective and somewhat common to the majority of training programs. In a recent report by the Association of American Medical Colleges' Task Force on Graduate Medical Education, the authors state that the principal goals of graduate medical education are "to prepare proficient practitioners of medicine and to equip them for continued professional development."[1] I fail to find in that report a definition of proficient practitioners, nor do I find that list of equipment needed for continued professional development.

Records of prior discussions of orthopaedic educators are replete with sizzling debates about "how to teach it" without first having defined their objectives. Until we have more concrete goals and objectives, the educational techniques we select will be based upon our diversely perceived and less than lucidly articulated goals and objectives. Certainly, no educational program whose students will be responsible for life and limb can depend upon fortuitous circumstances to accomplish its goals. This almost overwhelming task should be initiated even if it is less than totally Magerian in form.

In 1966, a jointly sponsored seminar in Dallas chaired by Dr. Charles F. Gregory resulted in a document describing an adequate and acceptable residency training program in orthopaedic surgery.[2] A section in that meeting chaired by Dr. Paul Curtiss addressed techniques in teaching. Dr. James Miles talked about bedside teaching rounds conducted away from the bedside. Drs. Fahey, Lovell, Stamp, Wickstrom, Bonfiglio, and Coleman superbly delineated the strengths and weaknesses of the lecture, discussion groups, seminars, rounds, audiovisiual techniques, and reading lists. I will not review this litany, valuable though it may be. Instead, I want to consider a few approaches to training which span many content areas and techniques. You may charge me with being too theoretical. I hope to convince a few of you otherwise. I want to talk about *teachers, tutorials,* and *science.*

The clinical practice of orthopaedics demands two prerequisites: (1) a necessary base of cognitive, motor, and attitudinal skills, and (2) the utilization of these skills. While I will emphasize the second of these, I in no way want to minimize the importance of the acquisition of a data base. To paraphrase Dr. Henry Mankin, "a practitioner is more likely to successfully use a piece of information necessary to solve a clinical problem if he possesses that piece of information than if he doesn't."

The utilization of knowledge, skills, and attitudes represents the ultimate goal in residency training—that is, problem solving, clinical judgment, and synthesis based upon logical consideration of a pertinent and carefully established data base. This must be built around a variety of increasingly complex patients with disorders spanning the broad discipline of orthopaedics. However, merely putting the well informed resident into such a milieu, saturated with patients though it may be, does not guarantee appropriate learning without a final most important ingredient, namely, superbly qualified, enthusiastic, and devoted *teachers* to guide, monitor, and assure progress. We have, in my opinion, paid too little attention to this factor in the equation. Dr. Wallace Miller in an article in *Clinical Orthopaedics* in discussing teaching techniques correctly notes that "these techniques were not a panacea; they were teaching supplements, no more, no less, but they did not replace the teacher."[3] We devote countless hours to evaluating residents but little to developing and evaluating teachers. I realize that teaching is an art,

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perhaps even more than a science. It involves human emotions and values beyond exact mathematical quantitation. But, we can and must evaluate it. In talking about teachers, Dr. Miller states: "all of these individuals should have at least two things in common – competency in the field and a desire to pass on all that they know to another generation."[3] I agree. Subject matter, competency, and desire are essential *but not sufficient.* A critical third element is the ability to teach. Graduation from college, medical school and an orthopaedic training program does not guarantee expertise in teaching. Our competency in developing this art and science, practicing it, and evaluating its effectiveness deserves far more attention than it receives. The good teacher is characterized by his or her preparation. This involves much thought and study not only of the subject matter but of how best to help the resident establish and reach desired goals. The teacher should be familiar with principles by which adults learn and with the means of evaluating learning. Our training programs must include a variety of teachers who create an environment where the motivated resident receives constant stimulation, reinforcement, and an opportunity to maximally develop at his or her own pace. Teachers frequently do well on short term planning, but badly on long term planning. Each faculty in a graduate training program should not only know what they plan for a week or so but how this fits into the entire training program. Preparation includes constant scholarship to update content and methods and transfuse them with new vitality.

As noted by Dr. Gilbert Highet,[4] if we examine teaching historically in western civilization, we find that modern teaching emerged from two lines of teachers, the Greek philosophers and the Hebrew prophets. The first professional higher educators in the western world were the group of brilliant talkers and keen thinkers in Greece during the Fifth Century, B.C., the sophists. Because of their tendency to paint over gaps in their knowledge with glossy rhetoric, many fell into disrepute. By contrast, the first Greek tutor, Socrates, developed the method which, if skillfully applied, ranks as one of the best means to teach superb clinical practice to residents. Highet paints an interesting contrast between Socrates and those self-proclaimed authoritative sophists. "They toured the whole Greek world. Socrates stayed in Athens talking to his fellow citizens. They made carefully prepared continuous speeches; he only asked questions. They took rich fees for their teaching; he refused regular payment, living and dying poor. They were elegantly dressed, turned out like film stars on a personal appearance tour with secretaries and personal servants and elaborate advertising. Socrates wore the working man's clothes . . . . Lastly, the sophists said they knew everything and were ready to explain it. Socrates said he knew nothing and was trying to find out."[4] Of course, I do not mean to imply any parallels between this picture and the orthopaedic educators of today, but it is indeed an interesting portrait.

In the *tutorial* system, the teacher talks little but questions much. The constant "why" is paramount. The students talk. Socrates felt that teaching did not mean pouring new ideas into an empty brain but drawing out truths from the mind in which they lay concealed. What a teacher says outright sometimes goes unheard. Conversely, what the teacher stimulates the student to draw from his or her own mind often has far more potent influence. The questions must be skillfully posed. They are arranged so as to make the student aware of the critical elements needed to solve a clinical problem and to guide him or her toward a logical solution. The aim in this method is not to expose the student's ignorance and deflate his or her pretensions. The Socratic method demands of the student a long, hard search, refusing authoritative statements that lack data, controlled studies and follow up. The teacher must have a clear idea of possible solutions to problems. The questions must steer the pupil, sometimes slowly and perhaps with frequent failures and pauses, toward a logical conclusion. Combing the critical method and positive purpose represents the essence of the tutorial system.[4] This method is *education* in the sense of development of the individual's potential rather than *training* in the sense of uniformity of the end product. Perhaps the most difficult task for the instructor is to keep quiet at appropriate times in the tutorial. The teacher does, however, critique the resident's performance and put it in appropriate perspective. This system is difficult and expensive in terms of time and effort, but it is one of the most thorough and effective ways to teach. It can be used in the clinic, at the bedside, in conferences, in the laboratoy, and even in the operating room. This clearly represents the antithesis of the "cookbook" method. It is surely better for influencing the responses of the trainee in future practice when many clinical problems will not have ready answers in the book.

A useful teaching technique is to turn the tables and have the resident act as tutor. Allow him or her to use the tutorial method in teaching students and/or other residents. Monitor the precision of the resident's language to see how well he or she can formulate questions to guide another. We spend too much time on insisting that the resident come up with answers. It is just as important that they ask appropriate questions.

This extension of the tutorial interfaces with the final technique that I would like to discuss, namely, the use of the scientific method.

The *scientific method* should be taught in graduate training. I do not mean as it applies to laboratory research, but as it applies to clinical medicine, both on a day to day basis in clinical practice and in a clinical research project which, I believe, should be required of all residents. The relevance and relationship of science and the scientific method to orthopaedics seems at first overtly obvious. However, we do not find universal concurrence that science is ipso-facto preferable. There has been and still is much confusion about the relationship of basic science to clinical science. Unfortunately, basic science in many circles came to mean knowledge for knowledge's sake without any concern about utility as contrast to clinical science or applied science. Such a convention actually avoided a definition and instead defined the state of mind of the individual, thereby interjecting the elusive concept of motivation. A look at many past debates suggests that the appropriate meaning of science and its place in our discipline has been naively and superficially viewed. Realizing that my next thought may be at variance with certain current values, I nevertheless suggest that we might abolish some of the discord by abandoning the traditional view of basic science. Boundaries between disciplines have now faded. A common molecular level of comprehension and concepts unites many areas previously separated. I, therefore, suggest that the term basic science has evolved to a point where its validity in biomedicine must be questioned. The perpetuation of this tradition is illogical and indefensible and may actually be harmful to the advancement of a discipline. We must apply the scientific method regardless of the setting. If we in teaching and practicing orthopaedics do not include this, we stand far from the status of a scientific discipline. The scientific method is a state of mind, a way of thinking, an approach to problem solving. Several methods in fact share the basic tenets for rational thought as valid today as when they were outlined by Francis Bacon, the first modern philosopher of science in the late 1500's. I have time to comment on only part of this method. I will discuss only the initial step, namely, an awareness of the problem or, stated differently, can the resident ask the appropriate question? In clinical problem solving, establishment of the key question usually generates the successful solution. We base many of our management decisions on opinion and, therefore, remain immersed in dissension and doubt. Some of this undoubtedly results from our failure to teach and require a scientific approach during residency training. We have failed to apply Flexner's admonition that we should recognize no difference in intellectual attitude between investigator and practitioner. Unfortunately, a silent majority has little knowledge and no personal experience with the scientific method. If we do not follow the path required by the dictates of science, we elect to be an empirical trade school. A background in the use of the scientific method is necessary to evaluate the work of others and to avoid being led astray by the half truths of an uncritical enthusiast. An approach based upon science frees the physician from blind obedience to dictates of emotion, propaganda, group pressures, and authority. He or she will insist that the range of his or her curiosity can not accept limits imposed by external authority. He or she will prefer truth as measured by the yardstick of predictability and invest authority in the predictive content of statements rather than in people.[5] The resident also acquires the necessary survival skills to cope with contingencies that arise in the practice of orthopaedic surgery ten years hence. If, on the other hand, we fail to recognize the importance of science as a vital infrastructure to clinical medicine, we will find the mainstream of medicine being developed elsewhere. By developing this critical approach during training, residents will not be overwhelmed by the threat of educational obsolescence. The knowledge explosion is real and it has an interesting converse, namely, the ignorance explosion. As there becomes more and more to know, one person can know less and less of the total. Ginther[6] at the University of Chicago pointed out that as our ignorance increases, we should perhaps start courses in ignorology. Barzun[7] emphasized the futility of schooling for the practical life lest training be outmoded before it is complete. The simple transmitting of increased masses of technical data promises only trivial advantages. We must stop trying to have residents survey all conceivable problems and instead direct their attention to the mechanism of problem solving. Critical observational skills must be developed so, as noted by Dr. Harold Boyd, "the resident can learn to profit by the mistakes of others for he can not hope to live long enough to make all of them for himself."[8]

The use of the scientific method in carrying out a well designed clinical investigative project teaches the resident much about patients' charts, how to organize data, how to ask appropriate questions, how to establish a hypothesis, how to test it and how to draw appropriate conclusions. There is an ulterior motive in these projects. We need more quality clinical research in orthopaedics. We need better controlled data. Residents must learn the importance of follow up. Some of our published clinical studies rank as a perversion of academic standards.

In conclusion, let me ask you not to consider my remarks as an assault on training programs by an uncompassionate critic; nor do I pretend to have answered all of the questions I have raised; nor have we instituted all my suggestions in our training program at Iowa. I am well aware of the ever increasing interference from government, quasi-governmental, and public organizations, and of the increasing service demands. I realize that service demands and prime educational goals are frequently discoordinate. We must recognize this, admit it, and look for solutions which do not compromise patient care *or* resident education. The prime goal of residency training must remain the teaching of exemplary patient care which, to me, demands that we first give exemplary care. This also implies investigation by "basic and clinical" approaches to improve patient care.

Ideal orthopaedic resident education requires superb teachers skilled in the Socratic method of tutoring and able to instill a method of logical clinical problem solving.

How would you structure a training program? Would it closely resemble the program you now have? Would you have a didactic program at the beginning of the residency, more self instructional packages, and motor skills laboratories? Could we design a program to develop residents that resemble Francis Bacon who, in writing of himself, said "Gifted with a desire to seek, patience to doubt, fondness to meditate, slowness to assert, readiness to consider, carefulness to dispose and set in order and as a man that neither affects what is new nor admits what is old and that hates every kind of imposter."[9]

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