University of New Mexico Orthopaedics Research Journal

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Volume 1

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Letter from the Chair

We are halfway through what is turning out to be a very busy year at the University of New Mexico (UNM) and in the Department of Orthopaedic Surgery. The UNM Orthopaedic faculty continues to grow alongside a wonderful residency program. I am continually impressed by the great camaraderie of our residents, faculty, and fellowship recipients. UNM and Albuquerque have always been great places to work and live, but our department strives to make this place of care and learning fun, as well. I am proud to say we work as a team and truly care about each other.

I would like to thank Dean Smith and all of our loyal alumni for their great efforts and support through the Sandia Orthopaedic Alumni Society over the past year. The Eric Thomas Memorial Golf Tournament, a fundraiser for SOAS and the Leukemia & Lymphoma Society, was a fantastic success. I hope you'll make plans to join us again in September for the Second Annual Eric Thomas Memorial Tournament. We had a wonderful gathering of current residents, faculty, and graduates in San Francisco at the AAOS reception in February. Be sure to get in touch with Ryan Wood at rwood03@salud.unm.edu to find out about more exciting alumni activities.

We welcome many new faces to the department. Ross Arena is the new section chair of Physical Therapy (PT) and has great vision and energy for the PT section. I would like to thank the former section chair, Sue Queen, for all her hard work. I would also like to thank Ron Andrews for his interim section chair work that paid off so nicely in the hiring of Ross. Pediatric Orthopaedics has continued to grow under the leadership of Dale Hoeksta. Antony Kallur, long-time faculty member Elizabeth Szalay, and recently hired Selina Silva (UNM Ortho Class of 2010) have set us on a great path for the care of children here in New Mexico. Trauma has seen changes. Our long-time and revered professor of the Socratic technique, Tom DeCoster, stepped down from a full-time faculty position, transitioning to a part-time retiree who still is actively involved in making our residents really question what they know and especially what they do. Thank you, Tom. Our adult reconstruction program continues to grow with the addition of Jerry Becker (UNM Ortho Class of 1997) working with Chris Hanosh (UNM Ortho Class of 2001), Rick Gehlert, Dan Wascher, and many others.

It is with great sadness that we see Bob Quinn leave, but we wish him the best at his new position of Professor and Chair in the Department of Orthopaedic Surgery at University of Texas in San Antonio. It is with high regard and respect that I congratulate him on his selection. I am excited about this new opportunity for Bob as well as for the Orthopaedics Department in Texas. We all know he is going to do great things in San Antonio, and the program there is very fortunate to have him as their new leader. At the same time, I am pleased that Dr. Gehron Treme has accepted the position of Program Director here as Bob moves on to San Antonio. Gehron graduated from UNM Orthopaedics in 2006, did his sports medicine fellowship at University of Virginia, and returned to Albuquerque after two years in private practice in Louisiana. Gehron will make an excellent director, having worked in both private practice and now in academics, and I believe he will do phenomenal things in the Orthopaedic Residency Program here at UNM.

The future is very exciting for our residency program. We wish our senior residents well as they end this phase of their careers and begin new ones. Bryon Hobby will do a trauma fellowship at UC Davis, Jan Gilmore a sports fellowship at the University of Virginia, Johnson Patman has a sports fellowship at the University of Utah, David Rust will do a sports fellowship in Minneapolis, and Dan Stewart will start a hand fellowship at the University of Colorado.

Research continues to make great progress. Drs. DeCoster and Mercer have redoubled their efforts, and we now have a full time research coordinator—Kimberly Fields. Christina Salas, our research assistant, is back at UNM after doing a yearlong internship at Mayo Clinic. There are half a dozen biomechanics studies in process now. Residents and faculty meet monthly to go over current studies and research topics, and the number of projects and papers continues to increase. Names that must be mentioned with continued successes in publications and projects include Elizabeth Szalay and Deana Mercer, as well as residents Nate Morrell and Dustin Richter. Congratulations to everyone involved in our growing research initiative!

As we continue through 2012, we look West, both near and far. Nearby, along University Boulevard, the UNM Orthopaedic Center is on track for construction in 2013. It will be a 2 story facility with a 15,000 square foot ground floor clinic space and a second story that will be home to outpatient physical therapy and the Orthopaedic Academic offices. The location will be adjacent to the Outpatient Surgery and Imaging Services center, just north of that facility. Looking farther west, we are pleased to see the opportunities in Rio Rancho. Sandoval Regional Medical Center is in its final stages of construction and is set to open and care for patients this summer. We are currently recruiting 3 full time faculty members to work at the Rio Rancho UNM Hospital. Many orthopaedic faculty will work out there, part-time, as well. The hospital has 60 beds, a level III emergency room, and a fully integrated medical center with an attached 50,000 square foot medical office building. This center is unique. It is designed as an open medical staff model, an academic community hospital where private practitioners will practice alongside the UNM faculty. More than 50 faculty members are being hired to staff the medical center in Rio Rancho at Unser and Paseo del Volcan. Google it!

This is an exciting time for UNM Orthopaedics. I agree with Dean Smith's observation that "through your support, we are making a difference." I want to join Dean in inviting graduates, current residents, and faculty members to participate in our future. Please contact us for ways in which you can participate with the growth and success of UNM Orthopaedics.

Sincerest regards,

Robert C. Schenck Jr. MD
Professor and Chair
UNM Orthopaedics

Letter from Vice Chancellor for Research

Congratulations to the Department of Orthopaedics and Rehabilitation on the publication of the first issue of *University of New Mexico Orthopaedics Research Journal*. This is another notable accomplishment for the faculty, fellows, residents, staff, and students whose work is highlighted in it.

Each year the UNM Health Sciences Center continues to make extraordinary progress in expanding its research efforts to improve the health and quality of life for New Mexicans. Despite recent fiscal challenges at the university, state, and national levels, researchers at our institution were awarded a record amount of grant funds totaling $147,000,000 in FY 2011. This success demonstrates the commitment of faculty and staff to building the research enterprise and cultivating an environment of innovation and scientific excellence.

The Department of Orthopaedics and Rehabilitation is an outstanding example of how, as an institution, we are succeeding in our mission: to provide an opportunity for our students to obtain an outstanding education; to advance research in areas of health that address the needs of our communities; and to ensure that all populations in our state are provided with the highest quality of health care. As a comprehensive musculoskeletal program, the Department provides an education to future health professionals in all areas of orthopaedics, including hand microsurgery, knee replacement surgery, musculoskeletal oncology, trauma, pediatric orthopaedics, and sports medicine. Residents and fellows are given training in the latest innovations in the field and encouraged to pursue research through a curriculum in both basic science and clinical research. The Department is renowned for its advances in microsurgical techniques and its hand surgery program, which was the first academic division of hand surgery in the nation. Faculty in the program inspire students through novel research methods, such as Dr. DeCoster's collaboration with engineers in the study of traumatic knee dislocations, and Dr. Mercer's study of operative techniques to increase joint stability in the thumb.

The Orthopaedics and Rehabilitation program at UNM is also unique in its commitment to patient care and meeting the needs of people across the state. For example, its Pediatric Outreach Clinics provide care to children with musculoskeletal health issues in communities that otherwise do not have access to orthopaedic specialists. Doctors, residents, and researchers go to these communities to visit patients, screen for pathologies, help people decide on treatment plans, and educate others on the latest knowledge in the field. The department is also closely connected to the UNM Hospital's Trauma Center, the only Level-1 trauma center in the state, and handles nearly one-fourth of the surgeries performed at UNMH.

It is an honor to write on behalf of the Department of Orthopaedics and Rehabilitation. Plans are currently underway to build a new comprehensive center that will house all of its clinical and research facilities under one roof. We can look forward to exciting developments in its training and research programs.

Sincerely,

Richard Larson MD, PhD
Vice Chancellor for Research

Letter from the Co-Editors

Greetings!

We welcome you to the first edition of the *University of New Mexico Orthopaedic Research Journal,* featuring research and educational efforts of UNM Department of Orthopaedics faculty, alumni, fellows, residents, and students.

We thank all the contributors to this production, as well as Mary Jacintha, Department Administrator and Kimberly Fields, Research Coordinator, whose encouragement and "gentle reminders" were instrumental in bringing it to fruition.

Please explore further these recent departmental publications:

- **Arena R**, Williams M, Forman D, et al; on behalf of the AHA exercise, cardiac rehabilitation and prevention committee of the council on clinical cardiology, council on epidemiology and prevention, and council on nutrition, physical activity and metabolism. Increasing referral and participation rates to outpatient cardiac rehabilitation: the valuable role of healthcare professionals in the inpatient and home health settings: a scientific advisory from the American Heart Association. *Circulation.* 2012;125:1321-1329.
- Guazzi M, Vicenzi M , **Arena R**. PDE5-inhibition with Sildenafil reverses exercise oscillatory breathing in chronic heart failure: a long-term cardiopulmonary exercise testing placebo-controlled study. *Eur J Heart Fail.* 2012;14:82-90.
- **Arena R**, Guazzi M, Myers J, et al. The Emerging Role of Cardiopulmonary Exercise Testing in the Assessment of Suspected or Confirmed Pulmonary Arterial Hypertension and Secondary Pulmonary Hypertension. *Expert Reviews in Pulmonary Medicine.* 2011;5:281-293.
- **Benson E**, Faber K, Athwal G. Glenoid fixation in total shoulder arthroplasty: what type of glenoid component should we use? In: Bhandari M. ed. *Evidence-Based Orthopedics*. Oxford: Wiley-Blackwell; 2012:284-293.
- **Cheema T**, Salas C, Morrell N, Lansing L, Taha MM, **Mercer D**. Opening wedge trapezial osteotomy as possible treatment for early trapeziometacarpal osteoarthritis: a biomechanical investigation of radial subluxation, contact area and contact pressure. *J Hand Surg [A].* 2012;37(4):699-705.
- Poole JL, Nakamoto T, McNulty T, Montoya J, Weill, D, **Dieruf K**, Skipper B. Dexterity, visual perception and activities of daily living in persons with multiple sclerosis. *Occup Ther Health Care*. April 2011;24(2):159-170.
- **Gurney A**, **Wascher D, Schenck R,** Tennison A, Jaramillo B. Absorption of hydrocortisone acetate in human connective tissue using phonophoresis. *Sports Health: A Multidisciplinary Approach*. July/August 2011;3(4):346-351.
- **McGrew C.** Avascular necrosis of the proximal femoral epiphysis (Legg-Calve-Perthes disease); Mononucleosis. In: Bracker M. ed. *The 5 Minute Sports Medicine Consult 2nd ed.* Philadelphia, PA: Lippincott Williams & Wilkins; 2011:42-43;394.
- **McGrew C,** Navarro, R. Freiberg's disease. In Bracker M. ed. *The 5 Minute Sports Medicine Consult 2nd ed*. Philadelphia, PA: Lippincott Williams & Wilkins; 2011:268-269.
- Salas C, **Mercer D, DeCoster T,** Taha M. Experimental and probabilistic analysis of distal femoral periprosthetic fracture: a comparison of locking plate and intramedullary nail fixation. Part A: experimental investigation. *Computer Methods in Biomechanics and Biomedical Engineering.* 2011;14(2):157-164.
- Salas, C, **Mercer D, DeCoster T,** Taha M. Experimental and probabilistic analysis of distal femoral periprosthetic fracture: a comparison of locking plate and intramedullary nail fixation. Part B: probabilistic investigation. *Computer Methods in Biomechanics and Biomedical Engineering.*2011;14(2):175-182.
- Lovald S, **Mercer D,** Hanson J, et al. Complications and hardware removal after open reduction and internal fixation of humeral fractures. *J Trauma.* May 2011;70(5):1273-1278.
- **Mercer D,** Saltzman M, Neradilek M, et al. A reproducible and practical method for documenting the position

of the humeral head center relative to the scapula on standardized plain radiographs. *J Shoulder Elbow Surg.* 2011;20(3):363-371.

- **Mercer D,** Gilmer B, Saltzman M, et al. A quantitative method for determining medial migration of the humeral head after shoulder arthroplasty: preliminary results in assessing glenoid wear at a minimum of two years after hemiarthroplasty with concentric glenoid reaming. *J Shoulder Elbow Surg.* 2011;20(2):301-307.
- Lovald S, **Mercer D,** Hanson J, et al. Hardware removal after fracture fixation procedures in the femur. *J Trauma.* January 2012;71(3):282-287.
- Morrell NT, **Mercer DM, Moneim MS**. Trends in the orthopaedic job market and the importance of fellowship subspeciality training. *Orthopedics*. April 2012;35(4):e555-560.
- Richards A, Afifi A, **Moneim M.** Four-corner fusion and schaphoid excision using headless compression screws for SLAC and SNAC wrist deformities. *Tech Hand Up Extrem Surg.* June 2011;15(2):99-103.
- Poole J, Walenta M, Alonzo V, Coe A, **Moneim M.** A pilot study comparing of two therapy regimens following carpometacarpal joint arthroplasty. *Phys Occup Ther Geriatr.* December 2011;29(4):327-336.
- **Szalay E,** Tryon E, Pleacher M, Whisler S. Pediatric vitamin D deficiency in a southwestern luminous climate. *J Pediatr Orthop.* June 2011;31(4):469-473.
- **Szalay E,** Cheema A. Children with spina bifida are at risk for low bone density. *Clin Orthop Rel Res*. 2011;469(5):1253-1257.
- Dominguesz-Bartmess SN, Tandberg D, Cheema AM, **Szalay EA**. Efficacy of alendronate in treatment of low bone density in pediatric and young adult population. *J Bone Joint Surg*. Forthcoming May 2012.
- Passarelli R, Veazey B, **Wascher D, Veitch A, Schenck R.** Management of the multiple ligament-injured knee. In: Miller M, Wiesel S. eds. *Operative Techniques in Sports Medicine Surgery.* Philadelphia, PA: Lippincott Williams & Wilkins; 2011:386-400.

We invite you to peruse these offerings, and hope that they inspire thought and discussion, as well as future research ideas and contributions.

Sincerely,

Elizabeth Szalay MD
Co-Editor

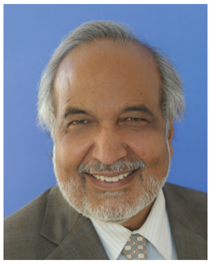
Daniel Wascher MD
Co-Editor

Department of Orthopaedic Surgery Faculty

Jeremy Becker MD-Assistant Professor
Medical Degree: Albany Medical College
Residency: University of New Mexico
Fellowship: University of New Mexico
Clinical Expertise: Hip Arthroscopy, Total Joint Arthroplasty

Attlee Benally DPM-Assistant Professor
Medical Degree: California College of Podiatric Medicine
Post Medical School: Jerry Pettis Memorial VA Hospital, Saint Joseph's Hospital
Clinical Expertise: Podiatry

Eric Benson MD-Assistant Professor
Medical Degree: Georgetown University
Residency: University of New Mexico
Fellowship: Shoulder, Elbow and Hand Fellowship, Hand and Upper Limb Centre, University of Western Ontario
Clinical Expertise: Shoulder and Elbow Arthroscopy, Reconstruction and Trauma



Tahseen Cheema MD-Professor
Medical Degree: Nishtar Medical College, Multan, Pakistan
Residency: College of Medicines and Dentistry, New Jersey
Fellowship: Hand and Microsurgery, Rush Presbyterian-St. Lukes Medical Center,
Clinical Expertise: Hand and Microsurgery

Thomas DeCoster MD-Professor; Chief, Division of Orthopaedic Trauma, Assistant Team Physician, UNM Lobos; Orthopaedic Trauma Fellowship Program Director
Medical Degree: University of Missouri, Columbia
Residency: University of Vermont
Fellowship: Trauma/Sports Medicine, University of Iowa
Clinical Expertise: Musculoskeletal Trauma, Sports Medicine, Fractures

Paul Echols MD-Professor; Chief, Division of General Orthopaedic Surgery
Medical Degree: University of Texas, Galveston
Residency: University of New Mexico
Clinical Expertise: General Orthopaedic Surgery

Rick Gehlert MD-Associate Professor
Medical Degree: University of Maryland School of Medicine
Residency: Ohio State University
Fellowship: Orthopaedic Trauma, University of Pittsburgh Medical Center
Clinical Expertise: Orthopaedic Trauma

Christopher Hanosh MD-Assistant Professor
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Residency: University of New Mexico
Fellowship: Reconstruction, Arizona Institute for Bone and Joint Disorders
Clinical Expertise: Upper Extremities and Joints

Dale Hoekstra MD-Assistant Professor
Medical Degree: Wayne State University
Residency: William Beaumont Hospital
Fellowship: Pediatric Orthopaedic, Hospital for Sick Children
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Antony Kallur MD-Assistant Professor
Medical Degree: University of Calicut
Residency: Mahatma Gandi University
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Clinical Expertise: Hand and Upper Extremity

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Residency: University of Texas Health Science Center, Houston
Fellowship: Hand Surgery, University of New Mexico
Clinical Expertise: Hand Surgery

Department of Orthopaedic Surgery Faculty

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Medical Degree: University of California, Los Angeles
Residency: University of New Mexico
Fellowship: Foot/Ankle with Dr. Roger Mann of San Leandro, California
Clinical Expertise: Injuries and Reconstructive Surgery of the Foot and Ankle

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Medical Degree: Cairo University
Residency: Duke University
Fellowship: Hand Surgery, Hospital for Special Surgery, Cornell University
Clinical Expertise: Hand Surgery

Andrew Paterson MD-Assistant Professor
Medical Degree: University of Louisville
Residency: University of New Mexico
Fellowship: Orthopaedic Spine Surgery, Panorama Orthopaedics
Clinical Expertise: Spine

Robert Schenck, Jr. MD-Professor and Chairman
Medical Degree: Johns Hopkins University
Residency: Johns Hopkins Hospital
Fellowship: Foot and Ankle Surgery, Boise, ID; Sports Medicine, Cincinnati Sports Medicine and Orthopaedic Center
Clinical Expertise: Sports Medicine

Frederick Sherman MD-Professor Emeritus
Medical Degree: Yale University School of Medicine
Residency: San Francisco Orthopaedics Residency Training Program
Fellowship: Pediatric Orthopaedics, Shriners Hospital, Los Angeles, CA; Pediatric Orthopaedics, Children's Hospital Medical Center, Boston, MA
Clinical Expertise: Pediatric Orthopaedics

Selina Silva MD-Assistant Professor
Medical Degree: University of Colorado School of Medicine
Residency: University of New Mexico
Fellowships: Pediatric Orthopaedic Surgery, University of Michigan
Clinical Expertise: Hip Dysplasia, Scoliosis, Limb Deformities

Elizabeth Szalay MD-Professor
Medical Degree: University of New Mexico
Residency: University of Texas Health Science Center at San Antonio
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Residency: University of New Mexico
Fellowship: Sports Medicine, University of California Los Angeles
Clinical Expertise: Sports Medicine

Daniel Wascher MD-Professor, Chief, Division of Sports Medicine; Assistant Team Physician, UNM Lobos; Orthopaedic Sports Medicine Fellowship Program Director
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Medical Degree: Albert Einstein College of Medicine, Bronx, NY
Residency: Montefiore Medical Center, Bronx, NY
Practice: Intermountain Health Care, Provo, UT

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Medical Degree: University of Michigan Medical School
Residency: Michigan State University, Kalamazoo Center Medical Studies, Kalamazoo, MI
Practice: Orthopaedic Associates, PA, Farmington, NM

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Medical Degree: Vanderbilt University Medical School, Nashville, TN
Residency: Lenox Hill Hospital, New York, NY
Practice: Oklahoma University, Norman, OK

Leroy Rise MD-Trauma
Medical School: University of Florida College of Medicine, Gainesville, FL
Residency: The Ohio State University, Columbus, OH
Practice: Christus St. Vincent, Santa Fe, **NM**

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Residency: Texas Tech University Health Sciences Center, Lubbock, TX
Practice: OrthoArkansas, Little Rock, AR

Department of Orthopaedic Surgery Chiefs

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Medical School: University of New Mexico School of Medicine
Fellowship: Sports Medicine (University of Virginia; Charlottesville, VA)

David Rust MD
Medical School: Creighton University School of Medicine
Fellowship: Sports Medicine (Fairview Southdale Hospital; Eden Prairie, MN)

Bryon Hobby MD
Medical School: University of Washington School of Medicine
Fellowship: Trauma (University of California, Davis Medical Center; Sacramento, CA)

Daniel Stewart MD
Medical School: University of Texas at Houston Medical School
Fellowship: Hand Surgery (University of Colorado; Denver, CO)

L. Johnson Patman MD
Medical School: University of Texas at Houston Medical School
Fellowship: Sports Medicine (University of Utah; Salt Lake City, UT)

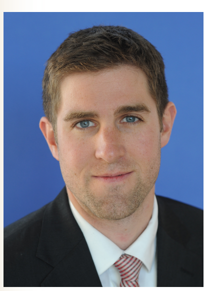
Department of Orthopaedic Surgery Residents

PGY 1

Luke Bulthuis MD
Duke University School of Medicine

Judd Fitzgerald MD
Medical College of Wisconsin

Mischa Hopson MD
University of New Mexico School of Medicine



Reilly Kuehn MD
University of Wisconsin Medical School

Heather Menzer MD
University of New Mexico School of Medicine

PGY 2

Scott Evans MD
Medical College of Wisconsin

Sean Kuehn MD
University of Wisconsin Medical School

Dustin Richter MD
University of New Mexico School of Medicine

Greg Strohmeyer MD
Northwestern University Medical School

Heather Woodin MD
University of Arizona College of Medicine
Health Sciences Center

Department of Orthopaedic Surgery Residents

PGY 3

Jenna Godfrey MD
University of Colorado School of Medicine

J. Taylor Jobe MD
Texas Tech University Health Sciences Center School of Medicine

Seth McCord MD
Boston University School of Medicine

Nathan Morrell MD
Stanford University School of Medicine

Charlotte Orr MD
University of Kentucky College of Medicine

PGY 4

Owen Ala MD
Cornell University Medical College

Lex Allen MD
University of Utah School of Medicine

Dustin Briggs MD
University of Iowa College of Medicine

Aaron Dickens MD
University of Nevada School of Medicine

Daniel Hoopes MD
University of California, Irvine College of Medicine

Physical Therapy Faculty

Ron Andrews PT, PhD-Associate Professor
Degree: Masters, University of Wisconsin Madison; PhD, University of New Mexico
Teaching Expertise: Kinesiology, orthopaedic evaluation and treatment

Ross Arena PT, PhD, FAHA-Professor and Director, Physical Therapy Program
Degree: Masters, Medical College of Virginia/Virginia Commonwealth University-Richmond; PhD, Medical College of Virginia/Virginia Commonwealth University-Richmond
Teaching Expertise: Cardiopulmonary physical therapy, exercise science

Fred Carey PT, PhD-Assistant Professor
Degree: PhD, University of Michigan
Teaching Expertise: Neuroanatomy, acute care and cardiopulmonary, gross anatomy

James "Bone" Dexter PT, MA-Lecturer II
Degree: Masters, University of New Mexico
Teaching Expertise: Orthopaedics, geriatrics, prosthetics/orthotics

Kathy Dieruf PT, PhD, NCS-Assistant Professor
Degree: Masters, University of New Mexico; PhD, University of New Mexico
Teaching Expertise: Adult neuro evaluation and treatment, psychosocial issues, women's health, ethics, ethical decision making; quality of life

Burke Gurney PT, PhD-Associate Professor
Degree: Masters, St. Johns College; PhD, University of New Mexico
Teaching Expertise: Physical agents, exercise physiology, orthopaedic evaluation and treatment

Beth Moody Jones PT, DPT, MS, OCS-Assistant Professor
Degree: DPT, AT Still University, Masters, Old Dominion University; PhD AT Still University
Teaching Expertise: Gross anatomy, evidence based physical therapy, advanced spinal manipulation

Beth Provost PT, PhD, CHt-Associate Professor
Degree: Masters, University of North Carolina at Chapel Hill; PhD, University of New Mexico
Teaching Expertise: Pediatric evaluation and treatment; health, wellness, and fitness; mind body

Sue Queen PT, PhD-Associate Professor
Degree: PhD, University of New Mexico
Teaching Expertise: Neurology, pharmacology, pathology

Peg Wanta PT, DPT-Academic Coordinator of Clinical Education
Degree: DPT, AT Still University
Teaching Expertise: Orthopaedics, health promotion and wellness, women's health

Research Awards

CTH Winter Conference Research Award

Bryon Hobby MD
Prevention of Postoperative Osteopeniea Using IV Pamidronate: A Pilot Study

Daniel Stewart MD
Comparison of Physeal Ablation and 8-plate Techniques for Epiphysiodesis About the Knee

Resident Research Award

Daniel Hoopes MD

Nathan Morrell MD

Research Assistant

Christina Salas MS, Mechanical Engineering
PhD candidate in Biomedical Engineering

Research Articles

Physeal Resection in Polydactyly Reconstruction of the Fifth Metatarsal

Connor Tryon BS[1] and Elizabeth Szalay MD[2]

1. UNM School of Medicine 2. UNM Department of Orthopaedics & Rehabilitation

Abstract

Foot polydactyly is a common foot deformity that is usually corrected surgically early in life to facilitate shoewear. When the polydactyly involves a widened metatarsal head with a single metatarsal epiphysis that articulates with 2 toes, surgical correction involves removal of part of the ring apophysis of the metatarsal. Traumatic injury to the ring apophysis, such as a Salter VI lawn mower injury to the foot, frequently results in angular deformity and/or metatarsal shortening. The purpose of this study was to evaluate whether careful surgical resection of the ring apophysis causes growth deformity.

Radiographs and operative reports were reviewed in children with postaxial polydactyly. Those who had a widened metatarsal head that were surgically corrected with partial physeal resection including the ring apophysis were further examined. The fifth and second metatarsal lengths were measured in triplicate and their ratios were compared using a Wilcoxon rank sum test.

There were 131 children with postaxial polydactyly identified, of whom 7 (5 bilateral) had preoperative and postoperative radiographs suitable for measurement. The median age at surgery was 13 months with mean follow up time of 17.25 months. Of the 12 toes surgically corrected, only 1 showed a significant difference in metatarsal length ratios compared preoperative to postoperatively. There was no significant difference in metatarsal length ratios after surgical correction overall.

No statistically significant length deformity was demonstrated following surgical removal of the ring apophysis. While this study is small, out of the 54 cases that were reviewed, only 2 had complications requiring reoperation. The remainder had no recorded complaints of pain or angular deformity. Despite the absence of documented follow up, it is likely that patients would have returned had they had experienced pain, deformity of the foot, or difficulty in shoewear.

Introduction

Foot polydactyly is a common deformity, found in approximately 1.7 of every 1000 live births, with a degree of variance among different ethnicities.[1] Among the black population, foot polydactyly is found in up to 13.9 of 1000 live births.[1, 2] Polydactyly is commonly associated with many syndromes, but it is thought to be an autosomal dominant trait with variable penetrance when it is an isolated manifestation.[1-4] It is bilateral in 40% to 50% of cases; however, the anatomical configuration is not necessarily identical on both feet.

Foot polydactyly comprises a continuum of extra toes and/or metatarsals, which may be located in several positions. Temptamy and McKusic classified polydactyly as being preaxial, central ray, or postaxial.[1,2, 4] Preaxial refers to the duplication of the hallux; central refers to duplications of the second, third, or fourth toes; and postaxial refers to a duplication of the most lateral digit. Post axial polydactyly is most common, and was the focus of this study.[1-5]

Duplication or deformity of the metatarsal can accompany any of the forms of polydactyly. A classification based on anatomic configuration of the metatarsal was described by Venn and Watson.[2] This classification describes 6 types of polydactyly: (1) normal metatarsal with distal digit duplication, (2) block metatarsal, (3) Y-shaped metatarsal, (4) T-shaped metatarsal, (5) normal metatarsal shaft with a wide head (usually articulates with the extra digit), and (6) complete ray duplication.

The consequences of having foot polydactyly are variable and case dependent. Minor complications are shoe discomfort or difficulty fitting shoes. Other problems include discomfort or pain upon walking, exertional intolerance, and cosmetic and psychological concerns. Typically these problems are improved with surgery.[1,2,6-8]

Surgery is generally performed around 1 year of age: the anesthetic risk is reasonable, the foot is a reasonable size, and the child not yet learned to walk. There is, however, no consensus regarding surgical technique.[5-7] The most controversial issue is whether to remove the digit that is least developed or to remove the digit that restores the foot to the most normal contour, if these are not the same digit.

In instances of a duplicated or widened metatarsal, the metatarsal must be narrowed. This typically involves removing part of the width of the physis, which also removes the ring apophysis on the lateral side of the metatarsal.

Traumatic avulsion of the ring apophysis has been demonstrated to cause growth disturbances,[7] as seen in a Salter-Harris fracture type VI injury to the metatarsal.[9] Bone grows across the physis, closing that side of the physis,[9] which can lead to significant angular and length deformities.

The risk of a similar growth disturbance is unknown when patients have a surgical resection of the physis and ring apophysis rather than a traumatic one. This study sought to examine whether surgical ablation of the ring apophysis of a metatarsal, when done as part of polydactyly reconstruction, resulted in growth deformity or inhibition.

Materials and Methods

A retrospective chart review from 2000 to 2010 was conducted, searching for children who had surgical reconstruction of foot polydactyly, toe excision, or toe amputation. Medical records and radiographs were reviewed for these patients to determine the type of polydactyly. Patients who exhibited a widened metatarsal head, in addition to the extra toe, were included.

The charts and radiographs were evaluated either electronically using the program ISite PACS[10] or using the hard copies of the radiographs. Patients who did not have radiographs done at least 6 months postoperatively were excluded. For those with both preoperative and postoperative radiographs, the lengths of the second and fifth metatarsals of the affected foot were measured in triplicate using the program ISite PACS.[10] The triplicate measurements of the metatarsals were averaged, and the ratio of fifth to second metatarsals was calculated from the averages. Preoperative and postoperative ratios were compared for change in metatarsal length ratios. The Wilcoxon rank sum test was used to evaluate statistical significance. A p-value of 0.05 was considered to be significant, and two tailed tests were used throughout. Standard summary statistics were calculated for demographic and other variables.

Results

Records and radiographs with surgical codes corresponding to polydactyly or toe amputation were reviewed, totaling 131 patients with 189 toes. Sixty-nine of the patients were males and 62 were females. None of these patients had more than 6 toes per foot. There were 58 bilateral cases (35 male and 23 female). Of the total 189 toes, 62 toes in 47 children required surgical excision of a portion of the metatarsal head, including part of the physis and the ring apophysis: 54 of these 62 were the fifth metatarsal and the remainder involved the first metatarsal. All 54 cases of postaxial polydactyly had at least 1 follow up with cast removal, but only 20 of these 54 cases had follow up that included x-rays; 12 of these 20 had documented exams and radiographs 6 months or more following the index surgery, likely adequate time

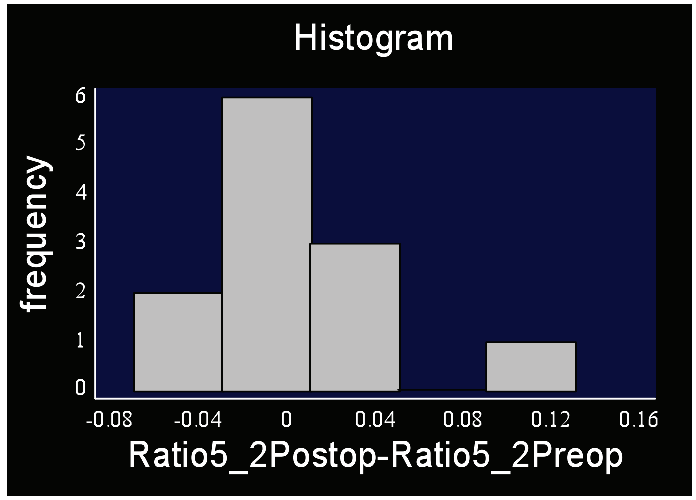


Figure 1. The preoperative ratios were subtracted from the postoperative ratios and the differences were plotted above by frequency.

to see growth changes. Of the 54 cases (42 patients), 31 patients with 42 toes were asked to return as needed following a clinic visit that ranged from 3 weeks to 4 years postoperatively. There were 11 patients with 12 toes who were given a return clinic appointment but did not keep the appointment. All patients who were lost to follow up had at least 1 postoperative evaluation by the surgeon.

In total, 7 patients with 12 toes were included in the final analysis. There were 3 male and 4 female: 5 of the cases exhibited bilateral polydactyly. Average age at surgery was 22.5 months, with median age of 13 months and a range of 5 to 76 months. Mean post-operative follow up interval was 17.25 months (6 months to 48 months). The mean length ratios of the fifth to second metatarsal were 0.85 preoperatively and 0.85 postoperatively. The length ratio of the second metatarsal compared to the fifth was the same postoperatively as it had been preoperatively. The ratio differences are depicted in Figure 1. This was not significantly different from 0 (p=0.4561) when using the signed rank test. None of these 12 patients required further surgeries, and there were no complications noted in the medical record.

One patient included in the study exhibited an increase in second to fifth metatarsal ratio post-operatively: the fifth metatarsal was longer in proportion to the second metatarsal 5 months after the operation. The initial ratio was calculated to be 0.79 preoperatively and was found to be 0.90 postoperatively. In further follow up visits, the patient has not had complaints regarding pain or shoe wear.

Discussion

The Salter Harris type VI fracture, involving traumatic damage to or avulsion of the ring apophysis,[11] has been shown to cause angular and length deformities in growing children.[9] Bone growth spans the physis in the injured area, causing the closure of the physis on the injured side. Growth of the remaining physis can produce the growth inhibition or angular deformity. In the foot, these fractures are often associated with lawn mower or other crushing injury.[12]

A similar, albeit less traumatic, event occurs during the surgical reconstruction of foot polydactyly when the supernumerary digit shares a widened metatarsal head with the normal digit such that the 2 toes share a common metatarsal head. In order to narrow the residual metatarsal to correspond to the residual toe, part of the metatarsal head including part of the physis and the ring apophysis, is resected along with the extra toe. Although this surgical correction is strikingly similar to the Salter-Harris type VI fracture, in this small group of patients with polydactyly correction, excision of part of the physis and ring apophysis did not cause appreciable growth inhibition or angular deformity.

The primary limitation of this retrospective study is the small number of children who had follow up radiographs for inclusion at 6 months or more postoperatively. Accordingly, definitive conclusions about the incidence of growth deformity involved with surgical removal of the ring apophysis in polydactyly cannot be made.

Polydactyly reconstruction is a frequent surgical procedure in young children, and the fact that patients rarely present with growth-related issues support speculation that this procedure rarely results in symptomatic growth complications. None of the 12 patients included in analysis had cosmetic complaints or shoewear difficulty.

There were a total of 42 patients with 54 toes (including the ones whose data was included in this study) who underwent the same procedure. Thirty-one patients with 42 toes continued to be followed until they were told that they no longer required follow up. That 24 of these patients did not have radiographs at the follow up visit suggests that no complaint was expressed and the treating physician evidenced no need for radiographs.

Pediatric orthopaedic care in this state is limited to one facility, making it likely that significant postoperative complications, even after years of growth, would be referred back to this center rather than being treated at an outside facility. The lack of follow up complaints, coupled with the favorable outcome of the children in this small group, suggests that surgical correction of polydactyly with a widened metatarsal head is unlikely to cause the growth deformity sometimes seen in traumatic injury.

References

1. Haber LL, Adams HB, Thompson GH, et al. Unique case of polydactyly and a new classification system. *J Pediatr Orthop*. 2007;27:326-328.

2. Turra S, Gigante C, Bisinella G. Polydactyly of the foot. *J Pediatr Orthop B*. 2007;16:216-220.

3. Wheeless CR III. *Wheeless Textbook of Orthopedics*. Brooklandville, MD: Data Trace Internet Publishing; 2008. http://www.wheelessonline.com/ortho/polydactyly_of_foot. Accessed August 2009.

4. Beighton P. *Inherited Disorders of the Skeleton*. Philadelphia, PA: Churchill Livingstone; 1988.

5. Huang WS, Chen SL, Chen SG, et al. Polydactyly of the foot: manifestations and treatment. *J Med Science T*. 2000;20(9):519-530.

6. Chiang H, Huang SC. Polydactyly of the foot: manifestations and treatment. *J Formos Med Assoc.* March 1997;96(3):194-198.

7. Morley SE, Smith PS. Polydactyly of the feet in children: suggestions for surgical management. *BJPS*. 2001;54:34-38.

8. Smith JR, Kozin SH. Identifying and managing physeal injuries in the upper extremity. *JAAPA*. September 2009; 22(9):39-45.

9. de Pablos J, Herranz PG. *Fracturas Infantiles: Conceptos y Principios*. Seattle, WA: Global HELP Organization; 2005.

10. *ISite PACS* [computer software]. Andover, MA: Philips Healthcare. http://www.healthcare.philips.com/main/products/healthcare_informatics/products/enterprise_imaging_informatics/isite_pacs/isite_pacs.wpd. Accessed March 2010 – October 2011.

11. Rang M, ed. *The Growth Plate and Its Disorders*. Edinburgh, Scotland: Harcourt Brace/Churchill Livingstone;1968.

12. Ogden JA. *Skeletal Injury in the Child.* 3rd ed. New York, NY: Springer-Verlag New York, Inc.; 2000.

Comparison of the Accuracy of X-ray, 2D-CT, 3D-CT, and Physical Modeling in Classification of Fractures about the Elbow Needing Operative Treatment

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Abstract

The goal of this study is to compare the accuracy of using X-ray, 2D-CT, 3D-CT, and physical modeling in classification of fractures about the elbow as a means of evaluating their relative utility in preoperative workup and treatment planning of fractures.

Ten patients with fractures about the elbow that required operative fixation underwent preoperative X-ray, 2D-CT, 3D-CT, and physical modeling of their injury. Ten orthopaedic physicians classified each injury using each of those four modalities. The answers given by the 10 physicians were compared to an established correct classification for each case, and that data was used to compare the relative accuracy of each modality.

The average accuracy for the given modalities was 62% for X-ray, 76% for 2D-CT, 80% for 3D-CT, and 88% for physical modeling. ANOVA analysis across all modalities revealed findings are statistically significant; however, when compared side by side, only moving from X-ray to 2D-CT yielded significant results.

There was greater percentage correct classification achieved using the more advanced modalities, which therefore may theoretically result in more accurate preoperative planning. However, one must view this finding within the context and limits of this study, which is restricted by the relatively small sample size. Future study into methods of fracture characterization should be done to further evaluate findings such as these, with the goal of promoting better patient outcomes.

Introduction

Amongst all fractures in humans, those occurring about the elbow can be quite complex and challenging to treat.[1] Therefore, accurate preoperative radiological characterization of the fracture is important and facilitates the planning and execution of injury management. Prior studies into the value of such preoperative investigations have demonstrated improved injury characterization with three-dimensional (3D-CT) compared to two-dimensional computed tomography (2D-CT) images and radiographs.[1-8] In addition, over the last 20 years there has been significant investigation into the utility of three-dimensional (3D) physical models that are constructed from CT images of bony injuries. These physical models can actually be held in the hand of the physician and may facilitate superior evaluation of fracture characteristics in surgical planning.[7] However, these prior studies have been based upon retrospective data, and the accuracy of the images in particular relied strongly upon recollection and operative notes. Additionally, there have been no studies published that comparatively evaluate the utility of all four modalities (X-ray, 2D-CT, 3D-CT, and physical modeling) in fracture evaluation. Therefore, using fractures about the elbow as the chosen injury type, we will evaluate those modalities by comparing the accuracy of classification of those fractures by orthopaedic surgery physicians using each modality to evaluate a set of cases for which all evaluative methods were obtained. As a study like this has yet to be published, our hope is that through a manageable sample size here at University of New Mexico Hospital (UNMH) we can carry out a successful pilot prompting future larger studies.

Methods

In order to obtain a set of cases suitable for this study, we identified 10 adult (18 years of age or older) patients, regardless of sex, race, or ethnicity, as they presented to UNMH with a fracture about the elbow that required operative treatment and underwent both plain film and 2D-CT studies, per standard of care in this case, in the preoperative evaluation of their injury. All of these patients were consented for their involvement in this study and signed an informed consent agreement. We then contacted the UNMH Radiology Department and had the 2D-CT data for each of the 10 cases reconstructed into a 3D-CT representation. Additionally, the 2D-CT data was deidentified and sent via secure connection to Medical Modeling LLC of Golden, Colorado for manufacturing of physical models of the injuries via laser stereolithography. These models were then sent back to the Department of Orthopaedics and Rehabilitation at UNMH. The data modeling company then destroyed the data used to manufacture the model. Concurrently, the patient underwent surgery at UNMH. At this point, we had created a set of 10 cases for which all 4 imaging modalities were obtained.

To evaluate the utility of the 4 imaging modalities, a computer program was written by Evan Baldwin (EB) using Microsoft Access that allows a user to answer sequential questions about a given injury and proceed through the Orthopaedic Trauma Association (OTA) fracture classification scheme to arrive at a single fracture classification value. The program then transferred all of the selections and the final answer into a database. A total of 10 orthopaedic surgery physicians at UNMH, not directly involved in the original patient case, were then asked to use the computer program to classify the injuries in the 10 cases. These 10 physicians went through all 10 cases, classifying the injury using each of the 4 modalities, thus creating 10 points of data for each of the modalities that could be used to compare the accuracy of the imaging modality. To avoid any confusion using the OTA classification, each user was given a copy of the classification scheme, complete with illustrations, as published in the *Journal of Orthopaedic Trauma* (Vol. 21, Number 10 Supplement, Nov/Dec 2007). EB was present with all of the physicians involved to ensure the data was collected accurately.

In order to process the data, it was necessary to develop a gold standard for correct classification of the fracture about the elbow in each of the 10 cases against which the data for that case could be compared to develop the relative accuracy of a given modality. This was done by having an attending physician of upper extremity specialization classify the fracture using all 4 modalities to create a single answer and comparison to operative notes for the given case.

Results

The answers entered into the computer by the 10 physicians going through the cases were compared to the gold standard in order to determine the level of accuracy that was obtained using that modality. The results are presented in Table 1.

Overall, the average accuracy for the given modalities was 62% for X-ray, 76% for 2D-CT, 80% for 3D-CT, and 88% for physical modeling. Graphical representation of the progression of increasing correct classifications can be seen in Figure 1. ANOVA (analysis of variance) testing ($\alpha = 0.05$) across all the modalities revealed a p value of very much less than 0.05 (0.0003).

However, when comparisons from one level of evaluation to the next are made, the significance is notably different: X-ray/2D-CT p=0.026, 2D-CT/3D-CT p=0.433, and 3D-CT/modeling p=0.136.

Discussion

En masse, the relative percentage correct achieved using the more advanced modalities to classify the fractures was greater, and therefore, theoretically more likely to result in more accurate preoperative planning. However, one must view this finding within the context

Table 1.

Percent Correct Fracture Classification by Case and Modality

		Percent correct classification by evaluative modality			
Case Number	Correct OTA Classification	X-ray	2D-CT	3D-CT	Physical model
1	21-B1.1 (1)	70%	80%	90%	90%
2	13-B1.1 (1)	50%	70%	80%	80%
3	21-B2.1 (2)	70%	70%	80%	80%
4	21-B1.1 (4)	70%	80%	80%	100%
5	21-B1.3 (3)	50%	60%	80%	90%
6	21-C2.3	70%	80%	80%	80%
7	21-C1.2	40%	60%	90%	100%
8	21-C1.2	80%	90%	60%	60%
9	21-C2.1	50%	70%	70%	100%
10	21-B2.1 (2)	70%	100%	90%	100%

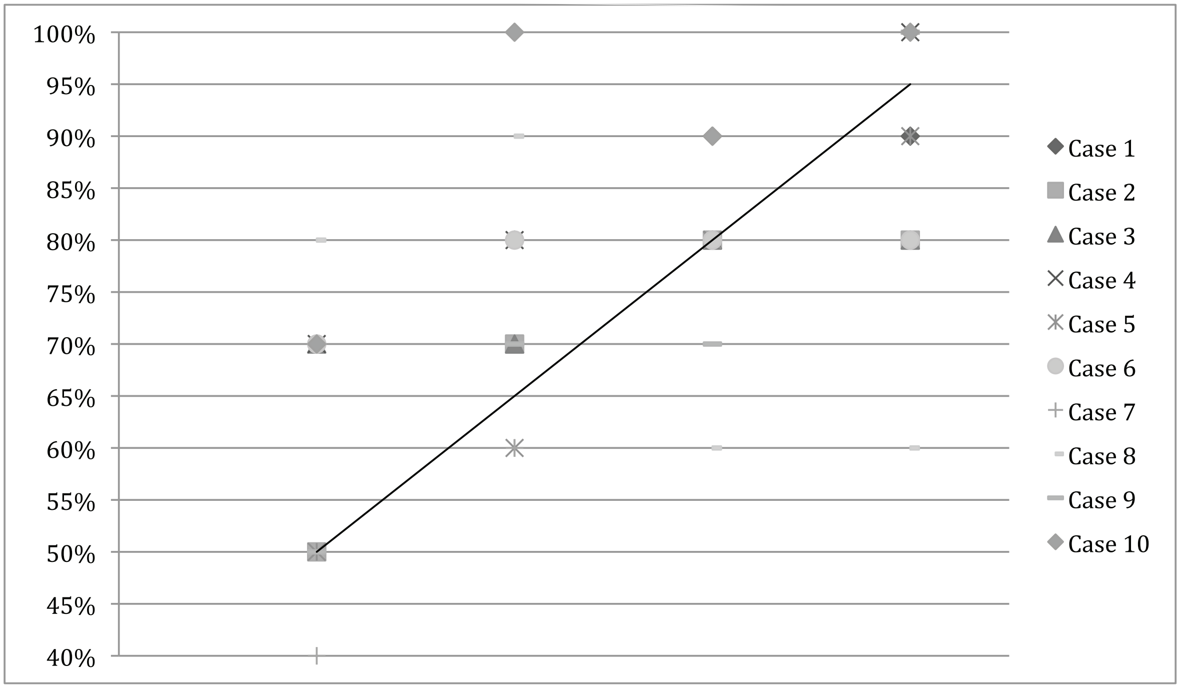

Figure 1: Percent correct fracture classification, proceeding from X-ray to 2D-CT to 3D-CT to Physical Modeling, with average trend line.

and limits of this study. First, we must acknowledge that the relative superiority is seen only using ANOVA across all of the modalities, and that when viewed in a post hoc manner, only moving from X-ray to 2D-CT produces a statistically significant finding. This is an important distinction because in cases of fracture about the elbow that require operative treatment, 2D-CT is already standard of care in most major medical centers with access to such imaging. This finding sheds light on debate regarding pursuit of more advanced imaging once standard of care is achieved – if a surgeon is not better able to classify a fracture, and therefore theoretically better carry out surgical planning, is it worthwhile to incur larger cost to the healthcare system to obtain information that does not significantly add value? While this may seem rhetorical, answering such a question should be done within not only the setting of today's healthcare infrastructure, but also that of the future, where the cost of pursuing more advanced imaging modalities might not add significant fiscal burden. In such an instance, expanding standard of care to include 3D-CT and/or physical modeling of bony injuries could be enacted as a means of ensuring every effort to promote patient well-being and safety is undertaken.

An interesting finding, although not easily addressed statistically, is the decreased correct percent classification in 2 of the cases that had a nondisplaced fracture fragment. Correct classification was more, or equally often, achieved with X-ray and 2D-CT as compared to 3D-CT and physical modeling in these instances. This conceivably occurred due to the inability of those 2 more advanced modalities to communicate fracture of bone without disruption of the natural contours, and the comparatively less discrete and sensitive manner in which the data is presented.

Furthermore, the findings of this study must be considered against its limitations. This study would be much more powerful if it not only had more patient cases, but also had many more physicians participating in the classification. This could be addressed in future studies where a multicenter approach might be better suited to attain large numbers. Every effort was made to eliminate all reasonable bias within the study, but it is possible that some may have occurred. We recognize that it is possible a participating physician could have unknowingly classified a fracture that he or she had previously been involved with, thus skewing the response. Although we attempted to control for physician inexperience with the OTA classification scheme by creating a user friendly computer program and providing supplemental visual materials, we did not control for experience with upper extremity trauma or naiveté with the system. Lastly, it is possible that the X-ray and CT data may not have been of identical fracture patterns, as the time interval between those imaging sessions and consequent patient movement could have disrupted the location of bones and fragments in a given case.

In sum, evaluation of our current methods of fracture assessment should be carried out on an ongoing basis, as should comparative study of our current standards of practice against new and emerging technologies and ideas. This study, while small in size, demonstrates that there is inequity in the information that practitioners receive from different imaging modalities when characterizing a bony injury. All methods-X-ray, 2D-CT, 3D-CT, and physical modeling-have advantages and drawbacks that should be further assessed in future study. Specifically, research is needed to investigate the generalizability of these findings to fractures outside of the elbow, relative costs to the healthcare system incurred when advanced modalities are employed, and whether or not better classifying a fracture alters treatment planning or patient outcomes.

References

1. Castagno AA, Shuman WP, Kilcoyne RF, Haynor DR, Morris ME, Matsen FA. Complex fractures of the proximal humerus: role of CT in treatment. *Radiology.* December 1987;165(3):759-762.

2. Siebenrock KA, Gerber C. The reproducibility of classification of fractures of the proximal end of the humerus. *J Bone Joint Surg Am*. December 1993;75(12):1751-1755.

3. Kuhlman JE, Fishman EK, Ney DR, Magid D. Complex shoulder trauma: three-dimensional CT imaging. *Orthopedics*. November 1988;11(11):1561-1563.

4. Kilcoyne RF, Shuman WP, Matsen FA III, Morris M, Rockwood CA. The Neer classification of displaced proximal humeral fractures: spectrum of findings on plain radiographs and CT scans. *Am J Roentgenol*. May 1990;154(5):1029-1033.

5. Smith RM. The classification of fractures. *J Bone Joint Surg Br.* July 2000;82(5):625-626.

6. Katz MA, Beredjiklian PK, Bozentka DJ, Steinberg DR. Computed tomography scanning of intra-articular distal radius fractures: does it influence treatment? *J Hand Surg [Am]*. May 2001;26(3):415-421.

7. Edelson G, Kelly I, Vigder F, Reis ND. A three-dimensional classification for fractures of the proximal humerus. *J Bone Joint Surg [Br]*. April 2004;86(3):413-425.

8. Borrelli J Jr, Goldfarb C, Catalano L, Evanoff BA. Assessment of articular fragment displacement in acetabular fractures: a comparison of computerized tomography and plain radiographs. *J Orthop Trauma*. August 2002;16(7):449,456; discussion 456-457.

9. Cole RJ, Bindra RR, Evanoff BA, Gilula LA, Yamaguchi K, Gelberman RH. Radiographic evaluation of osseous displacement following intra-articular fractures of the distal radius: reliability of plain radiography versus computed tomography. *J Hand Surg [Am]*. September 1997;22(5):792-800.

10. Marsh JL, Slongo TF, Agel J, et al. Orthopaedic Trauma Association Classification, Data and Outcomes Committee. Fracture and dislocation classification compendium-2007. *J Orthop Traum.* November/December 2007;21(10):S1-S6.

11. Andersen DJ, Blair WF, Steyers CM Jr, Adams BD, el-Khouri GY, Brandser EA. Classification of distal radius fractures: an analysis of interobserver reliability and intraobserver reproducibility. *J Hand Surg [Am].* July1996;21(4):574-582.

12. Bernstein J, Adler LM, Blank JE, Dalsey RM, Williams GR, Iannotti JP. Evaluation of the Neer system of classification of proximal humeral fractures with computerized tomographic scans and plain radiographs. *J Bone Joint Surg Am.* September 1996;78(9):1371-1375.

13. Horn BD, Rettig ME. Interobserver reliability in the Gustilo and Anderson classification of open fractures. *J Orthop Trauma*.1993;7(4):357-360.

Preoperative Predictors of Early Failure Following Hip Arthroscopy

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Abstract

The purpose of this study was to identify cases of early failure following hip arthroscopy and compare to cases in which no additional surgery was required during a 2 year postoperative period. The 2 cohorts were evaluated to identify potential preoperative predictors of early failure following hip arthroscopy. Early failure was defined as conversion to total hip arthroplasty (THA) within 2 years of arthroscopic surgery.

Study variables included gender, age, preoperative diagnosis, minimum joint space, lateral center edge angle (LCEA), the presence or absence of subchondral acetabular cysts, and the size of cysts (<1cm or ≥1cm).

The differences between the 2 cohorts in gender, age, and preoperative diagnosis were not statistically significant. Mean minimum joint space, LCEA, and presence of acetabular subchondral cysts were statistically different between the successful and failure cohorts. The difference in size of the cysts between cohorts was not statistically significant. Following multivariate analysis, the presence of acetabular subchondral cyst remained the only independent pre-operative predictor of failure following hip arthroscopy.

The presence of a subchondral acetabular cyst on MRI is associated with a high rate of THA following hip arthroscopy. While other predictors of early failure following hip arthroscopy may exist, we feel our study results should prove useful in counseling patients regarding appropriate treatment options for hip pain.

Introduction

Hip arthroscopy is a rapidly growing field with clear indications for treating multiple disorders, including femoroacetabular impingement (FAI), labral pathology associated with hip dysplasia, abductor tendon and trochanteric bursal pathology, and coxa saltans. Numerous studies document successful outcomes following arthroscopic treatment of these conditions, particularly FAI.[1] However, few studies have focused on predictors of early failure following hip arthroscopy.

A recent series of 20 patients showed that Outerbridge grade III chondromalacia noted during hip arthroscopy for FAI was a strong predictor of subsequent need for total hip arthroplasty at an average of 1.4 years following the index procedure.[2] Unfortunately, preoperative radiographs and Tonnis grading proved to be poor predictors of early failure in this study. A larger series of 111 cases of hip arthroscopy for labral debridement identified Outerbridge grades III or IV and advancing age as independent predictors of eventual hip replacement.[3] While intra-operative findings are strong prognosticators of success or failure following surgery, they are not useful in the preoperative counseling of patients regarding the risk of hip replacement following hip arthroscopy.

Other studies have identified preoperative predictors of severe intra-articular pathology at the time of surgery. A series of 355 hips were retrospectively reviewed to identify preoperative predictors of grade 3 or 4 Outerbridge changes at the time of surgery.[4] Multivariate regression analysis showed that male sex, alpha angle >50°, increasing age, and Tonnis grade 1 or 2 on plain radiographs were independent predictors of severe intra-articular pathology. The conversion rate to total hip arthroplasty in this very large cohort was not evaluated. In 2009, a small series evaluated the relationship between a novel radiographic finding, delamination cysts, and surgical findings during hip arthroscopy.[5] The presence of a subchondral acetabular cyst on preoperative radiographs was associated with acetabular cartilage delamination in 15/16 hips undergoing arthroscopy for labral debridement. This series did not report on the effect of the radiographic finding of a delamination cyst or cartilage delamination on the success or failure of hip arthroscopy.

The purpose of this study was to identify cases of early failure following hip arthroscopy and compare to cases in which no additional surgery was required during a 2 year postoperative period. The 2 cohorts were evaluated to identify potential preoperative predictors of early failure following hip arthroscopy. We hypothesized that the presence of an acetabular cyst on preoperative MRI was a predictor of early failure.

Methods

Between May 2006 and October 2009, a single-surgeon consecutive case series of 263 hip arthroscopies was retrospectively reviewed. All cases of hip arthroscopy for the treatment of debilitating hip pain secondary to FAI, labral tear, or labral tear associated with hip dysplasia, were evaluated for inclusion in the study. The diagnosis of FAI was based on clinical exam (typical pain pattern, anterior or posterior impingement sign, restricted range of motion, alpha angle >50°, or LCEA greater than 40° on plain radiographs and MRI. Labral tear was diagnosed based on clinical exam (mechanical symptoms and pain with provocative maneuvers) and MRI finding of labral injury. The diagnosis of hip dysplasia was based on a LCEA of <20°.

Inclusion criteria consisted of a complete medical record, including preoperative MRI scan and plain radiographs. Two cohorts of subjects were evaluated: early failures of hip arthroscopy, defined as conversion to total hip arthroplasty within 2 years of the index procedure, and successful cases of hip arthroscopy. Successful hip arthroscopy was defined as patients who have not had any additional operative intervention during the initial 2 year postoperative period. Exclusion criteria included any patient whose preoperative radiographs and/or MRI were not available for review.

Preoperative studies included 2 view plain radiographs (centered anteroposterior (AP) pelvis and modified Dunn view) and hip MRI (non-contrast or MRI arthrogram). A single sports medicine fellowship-trained orthopaedic surgeon experienced in hip arthroscopy performed all arthroscopic procedures. A standard 2-or 3-portal supine method was utilized. All cases of FAI underwent decompression of the impinging lesions and repair versus debridement of any associated labral pathology. All cases of labral tearing were treated with repair versus debridement of the labrum at the discretion of the operating surgeon. Postoperatively, patients were allowed partial weight bearing, with crutches, for 3-4 weeks. Physical therapy was performed to optimize range of motion and regain muscle strength. Aggressive activities were discouraged for 3 months.

Study variables included gender, age, preoperative diagnosis, minimum joint space, LCEA, the presence or absence of subchondral acetabular cysts, and the size of cysts (<1 cm or ≥1 cm). In addition, an attempt was made to contact all patients in the successful cohort to confirm that no additional surgery was performed on the involved hip since the last follow-up visit.

A single sports medicine fellow measured minimum joint space and LCEA on AP radiographs. All preoperative hip MRIs were reviewed by a fellowship trained musculoskeletal radiologist for the presence and size of subchondral acetabular cysts. The radiologist was blinded to both the arthroscopic findings and clinical outcomes.

Due to the small sample size and inability to assume normal data distribution, the Fisher's exact test was selected for analysis of all categorical variables. The Mann-Whitney-Wilcoxon 2-sample rank test was utilized to compare continuous variables. The significance level was set at a p-value = 0.05. Following univariate analysis, all statistically significant study variables were entered into a multivariate logistic regression model to identify independent preoperative predictors of failure and to calculate odds ratios. An independent biostatistician consultant performed all statistical calculations.

Institutional review board approval was obtained for the performance of this retrospective study.

Results

Of the 263 consecutive cases of hip arthroscopy, a total of 68 successful patients, with a minimum 2 year follow-up, and 23 patients who had failed hip arthroscopy met inclusion criteria, for a total of 91 patients. Of these patients, 43 had available for review both preoperative radiographs and MRIs and, thus, formed the patient population for this study. Of the 43 patients, 16 patients were classified as failures and 27 patients were classified as successful, based on our definitions. See Figure 1 for details.

Univariate Analysis

Nine men and 18 women made up the successful cohort, while 5 men and 11 women composed the failure cohort. This difference is not statistically significant (p=1.0). The mean age of the successful cohort was 45.15 years (range, 33 to 65 years), while the mean age of the failure cohort was 51.38 years (range, 33 to 69 years). This difference is not statistically significant (p=0.08). The successful cohort was made up of 2 cases of dysplasia with labral tear, 16 cases of FAI, and 9 cases of labral tear. The failure cohort was made up of 3 cases of dysplasia with labral tear, 12 cases of FAI, and 1 case of labral tear. The difference in preoperative diagnosis was not significant (p=0.10). The mean minimum joint-space was 3.93mm (SD=1.1mm) in the successful

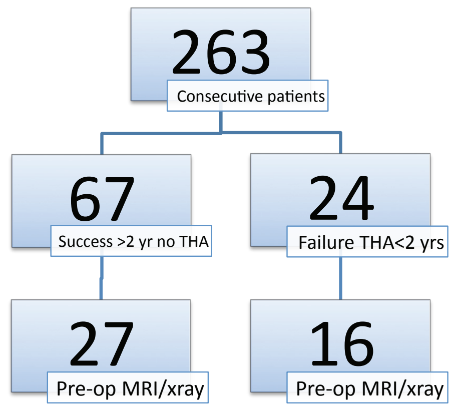


Figure 1. Flowchart of hip arthroscopy Cohorts.

Table 1
Univariate Analysis Results

Variable	Successful (n=27)	Failure (n=16)	P value
Gender	9 male, 18 female	5 male, 11 female	1.0
Age	45.15 years	51.38 years	0.08
Pre-op diagnosis	D 2, FAI 16, L 9	D 3, FAI 12, L 1	0.10
Joint space	3.93 mm	2.63 mm	0.01
LCEA	37.8 °	32.5 °	0.04
Presence of cysts	3/27	12/16	< 0.0001
Size of cyst			
Cyst < 1 cm	2/27	8/16	
Cyst ≥ 1 cm	1/27	4/16	

Abbreviations. D, dysplasia with labral tear; FAI, femoroacetabular impingement; L, labral tear.

cohort and 2.63 mm (SD=1.7mm) in the failure cohort. This difference is statistically significant (p=0.01). The mean LCEA was 37.8° (SD=10.7°) in the successful cohort and 32.5° (SD=10.3°) in the failure cohort. This difference is statistically significant (p=0.04). In the successful cohort, 3 of the 27 patients had acetabular subchondral cysts versus 12 of the 16 patients in the failure cohort having acetabular subchondral cysts. This difference is statistically significant (p<0.0001). In the successful cohort, 2 patients had a cyst measuring <1cm, and 1 patient had a cyst measuring ≥1 cm. In the failure cohort, 8 patients had a cyst measuring <1cm and 4 patients had a cyst measuring ≥1 cm. This difference is not statistically significant (p=0.5). See Table 1 for a summary of univariate results.

Multivariate Analysis

Minimum joint space, LCEA, and the presence of acetabular subchondral cyst were entered into the multivariate logistic regression model. The presence of acetabular subchondral cyst remained the only independent preoperative predictor of failure following hip arthroscopy. Exact odds ratio for acetabular subchondral cyst was 21.4 (confidence interval=3.8, 177). Subjects with at least one acetabular subchondral cyst were 21 times more likely than those without a cyst to experience treatment failure.

Of the 27 successful patients, 24 (89%) were reached via telephone. All confirmed that they had not had any additional surgery to the involved hip since last follow up.

Discussion

Arthroscopic treatment of conditions such as femoroacetabular impingement has proven to be an effective means of alleviating hip pain and may prove to be effective in preventing the need for hip arthroplasty in younger individuals. It has been stated that the severity of chondral lesions is highly correlated with surgical outcome after arthroscopic intervention for early hip disease.[6] With this awareness, it is evident that there are patients in whom the degree of degenerative change at the time of surgery precludes effective arthroscopic treatment. As the field of hip arthroscopy expands, it is critical to identify preoperative predictors of early failure to prevent the unnecessary treatment of patients in whom arthroscopy will be ineffective.

Our results have identified at least one preoperative predictor of early failure following hip arthroscopy. In this retrospective cohort comparison study, the presence of a subchondral acetabular cyst on preoperative MRI was shown to be an independent predictor of failure. While the small sample size produced a wide confidence interval, at a minimum patients with a subchondral acetabular cyst on preoperative MRI are 4 times more likely than those without a cyst to require total hip arthroplasty within 2 years following hip arthroscopy.

Failure of the acetabular subchondral bone, indicated by the presence of a subchondral cyst on MRI, is clearly a painful condition. While FAI decompression and treatment of acetabular rim pathology are therapeutic in the setting of chondromalacia or labral tearing, pain secondary to failure of the acetabular subchondral bone appears to be refractory to arthroscopic treatment. The presence of a subchondral cyst on a preoperative MRI, even in patients with greater than 2 mm joint space on radiographs, should alert the physician to the likelihood of persistent pain following hip arthroscopy and the possibility of rapid progression to THA.

Several other studies have evaluated either preoperative factors or intraoperative findings associated with survivorship after hip arthroscopy. McCarthy et al. retrospectively reviewed 111 cases of hip arthroscopy performed to treat labral pathology. Multivariate analysis showed that patients older than 40 years were 3.6 times more likely to require a THA, and those with Outerbridge grades of III or IV were 20 to 58 times more likely to eventually require a THA. An interesting correlation can be drawn between this larger series and our multivariate analysis. The odds ratio for early THA in patients with a subchondral cyst in our series was 21. This is similar in magnitude to the odds ratio interval of 20 to 58 for THA in patients with grade III or IV changes at the time of surgery obtained by McCarthy et al. It would seem that there is a strong correlation between a preoperative finding of subchondral acetabular cyst on MRI, the intra-operative finding of Outerbridge grade III or IV chondromalacia, and the progression to THA following hip arthroscopy. In fact, in our series, 93% of patients with a subchondral acetabular cyst on MRI were found to have grade IV chondromalacia at the time of surgery.

Horisberger et al. evaluated the outcomes of arthroscopic treatment of FAI in 20 patients with preoperative generalized degenerative changes. In addition to a 50% conversion rate to THA at 1.4 years, the series found a poor correlation between Tonnis grade and the extent of cartilage damage at the time of surgery. Univariate analysis did identify a decreased minimal joint space on plain radiographs as a preoperative predictor of early failure following hip arthroscopy in our study. However, this variable was not significant following multivariate analysis. The average minimal joint space in our failure cohort was 2.6 mm and 13 out of 16 patients in the failure cohort had a joint space of 2 mm or greater. Tonnis grading and minimal joint space measurements are highly subjective. Joint space calculations are subject to measurement errors and magnification errors on non-calibrated radiographs. The Tonnis grade threshold or minimal joint space required to avoid early THA following hip arthroscopy would seem challenging to determine. In contrast, the preoperative presence of a subchondral acetabular cyst on MRI is a much more objective, easily identifiable finding.

A lower average LCEA was noted in our failure cohort. While this finding did not hold up to multivariate analysis, there is a possibility that in a larger series a below average LCEA may reach statistical significance. Clearly patients with a low center edge angle and a subchondral acetabular cyst on MRI are at high risk for THA following hip arthroscopy.

Our study has one major limitation. The sample size was relatively small and minor statistical differences between the 2 groups may exist. Despite the small study size, an independent preoperative predictor of early failure following hip arthroscopy was identified.

Conclusion

The presence of a subchondral acetabular cyst on MRI is associated with a high rate of THA following hip arthroscopy. While other predictors of early failure following hip arthroscopy may exist, we feel our study results should prove useful in counseling patients regarding appropriate treatment options for hip pain.

References

1. Matsuda DK, Carlisle JC, Arthurs SC, Wierks CH, Philippon MJ. Comparative systemic review of the open dislocation, mini-open, and arthroscopic surgeries for femoroacetabular impingement. *Arthroscopy*. 2011;27:252-269.

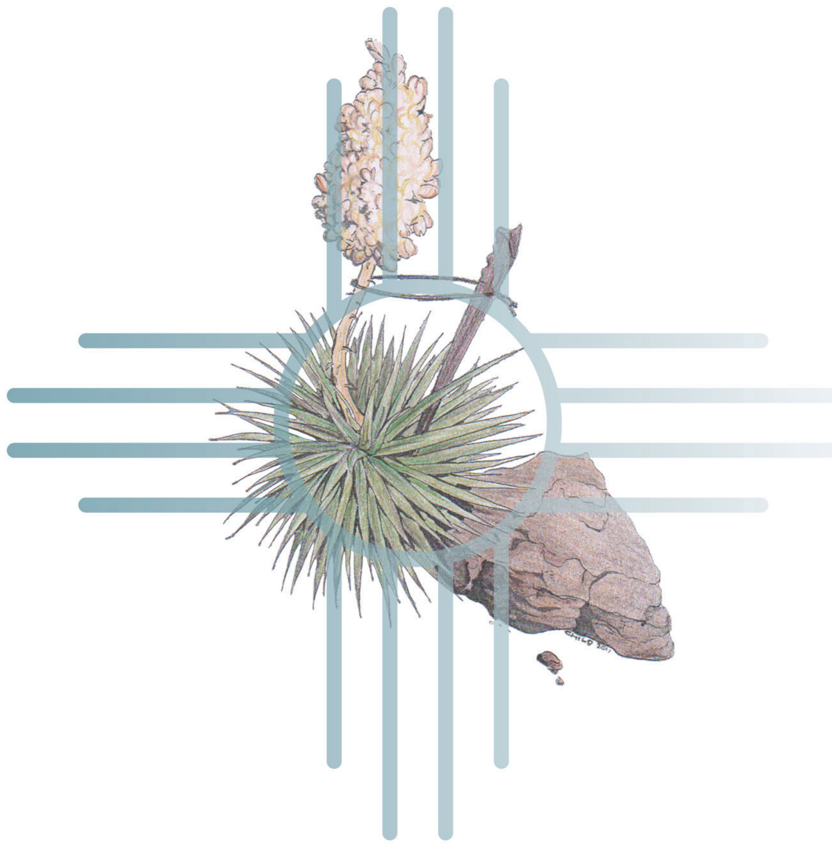
2. Horisberger M, Brunner A, Herzog RF. Arthroscopic treatment of femoral acetabular impingement in patients with generalized degenerative changes. *Arthroscopy*. 2010;26:623-629.

3. McCarthy JC, Jarrett BT, Ojeifo O, Lee J, Bragdon CR. What factors influence long-term survivorship after hip arthroscopy? *Clin Orthop Relat Res.* 2011; 469:362-371.

4. Nepple JJ, Carlisle JC, Nunley RM, Clohisy JC. Clinical and radiographic predictors of intra-articular hip disease in arthroscopy. *Am J Sports Med*. 2011; 39:296-303.

5. Gdalevitch M, Smith K, Tanzer M. Delaination cysts a predictor of acetabular cartilage delamination in hips with a labral tear. *Clin Orthop Relat Res.* 2009; 467:985-991.

6. McCarthy JC. The diagnosis and treatment of labral and chondral injuries. *Instr Course Lect.* 2004;53:573-577.



Case Report

Knee Arthodesis in Navajo Familial Neurogenic Arthropathy

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Abstract

A 16-year-old Native American male with Navajo familial neurogenic arthropathy presenting with a Charcot joint of his right knee was treated with knee arthrodesis and is reviewed 1 year post surgery. Despite complications including peroneal nerve palsy, knee arthrodesis has restored the ability to ambulate. Both Navajo arthropathy and indications for knee arthrodesis in children are rare. As the Navajo population disperses into the greater community, health professionals should be aware of Navajo familial neurogenic arthropathy and treatment options. Traditional Navajo beliefs require a cautious approach when discussing prognosis and possible adverse outcomes.

Introduction

Navajo familial neurogenic arthropathy (NFNA) is a rare form of hereditary sensory autonomic neuropathy found within the Navajo population. It usually manifests during the first two decades of life with unrecognized fractures, Charcot's joints resulting from sensory deficits to deep pain, hypohidrosis and heat intolerance .[1] The orthopedic manifestations secondary to NFNA has been investigated,[2] however, evidence regarding treatment outcomes and prognosis is limited.

Case Report

An 8-year-old Navajo boy presented for pediatric orthopaedic consultation with painless right knee effusion several weeks after injuring his knee while wrestling with his father. The patient had no significant medical history and no family history of musculoskeletal problems. He admitted to sweating little and frequently became overheated. Physical examination revealed a knee effusion, a posterior drawer sign, a positive Lachman sign of approximately 8 millimeters, and a grade I pivot shift. Additionally, the patient exhibited dry, thickened palmar and plantar skin, absent muscle stretch reflexes, and lack of pinprick sensation. Radiographs revealed a large joint effusion about the knee with bony sclerosis and destruction involving the lateral femoral condyle and patella (Figure 1). These findings, coupled with his lack of pain, suggested Charcot arthropathy. Diagnostic arthroscopy confirmed a large osteochondral defect in the lateral femoral condyle, absence of the anterior cruciate ligament, and patellar erosion of uncertain duration.

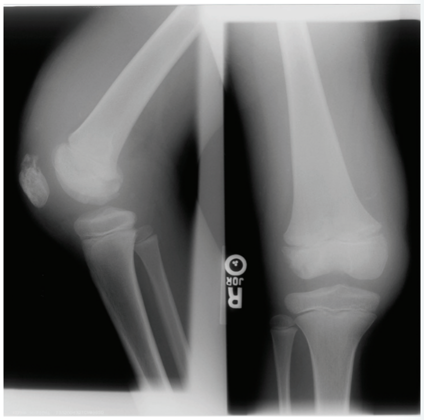


Figure 1. Anteroposterior and lateral radiographs of right knee at age 8.

Neurologic consultation was obtained. An MRI of brain and spinal cord revealed a Chiari I malformation. The EMG/NCS results included an absent sural sensory response, a reduced amplitude median sensory response, and an absent galvanic skin response on the palm and dorsum of the foot consistent with autonomic neuropathy. The patient was diagnosed with Navajo familial neurogenic arthropathy based on clinical presentation and nerve conduction.

Initial treatment included brace stabilization with a brief discussion of eventual surgical options. Treatment options were introduced cautiously, because in the Navajo culture a discussion of possible bad outcomes may set into motion the circumstances resulting in that bad outcome, and is considered to bring bad luck.[3] Other cultural considerations include the fact that allograft bone or other cadaver tissue grafts are unacceptable to the traditional Navajo, who has a strong death taboo.[4] Given the progressive nature of neurogenic arthropathy, the only viable surgical options would have been knee arthrodesis or amputation, neither of which was appealing to the family.

The patient was followed periodically from age 8 to age 15, and surgical options were gently explored at each visit. Despite attempts at stabilization using knee-ankle- foot orthoses of various types, the right knee progressively deteriorated. At age 16, the knee was the size of a basketball, and instability was so great that ambulation was impossible. Radiographs revealed massive joint destruction and limb length discrepancy secondary to lateral subluxation of the tibia on the femur (Figure 2).

The grotesque appearance of the knee and inability to walk prompted the family to consider surgery. They preferred an attempt at arthrodesis rather than amputation. Preoperative discussion avoided using direct negative personification such as, "your child could lose

Figure 2. Standing radiograph at age 15, preoperatively.

his leg." Instead, third person references were used, such as, "in some children, a knee fusion does not work and the leg must be amputated."

A knee fusion was performed using a custom intramedullary interlocking nail extending from the trochanter to the distal tibia (Figures 3 and 4). Postoperative complications included a 3-cm skin necrosis on the lateral aspect of the right knee, orthostatic intolerance during recovery due to supraventricular tachycardia, and a peroneal nerve palsy, with numbness to touch and foot drop. Postoperative limb length discrepancy was 6.5 cm.

At 12 months postoperatively, the patient and his family report being very satisfied with the surgical outcome despite persistent peroneal nerve palsy and foot drop. He has no pain and ambulates easily: the limb length discrepancy is not bothersome to him. With knee stiffness and foot drop (he declines orthotic use), the limb length discrepancy facilitates swing-through during gait.

Discussion

Navajo familial neurogenic arthropathy (NFNA) was described by Johnsen in 1993.[1] Found in the Southwest Navajo population, presentation is typically within the first two decades life with unrecognized fractures, Charcot's joints, hypohidrosis and heat intolerance. Associated sensory deficits can vary from no notable deficits to abnormal sensation to deep pain, poor temperature discrimination, and corneal insensitivity. Reflexes usually remain intact, muscle strength is normal, and electromyography and nerve conduction velocities are within normal limits. Sural nerve biopsy reveals reduction in small myelinated and unmyelinated nerve fibers. Family history suggests an autosomal recessive inheritance pattern.

Differential diagnosis includes Navajo neuropathy (NN),[5] and hereditary sensory autonomic neuropathy (HSAN) type IV.[6,7] NFNA is differentiated from these other neuropathies by absences of the

Figure 3. Standing radiograph one year postoperative.

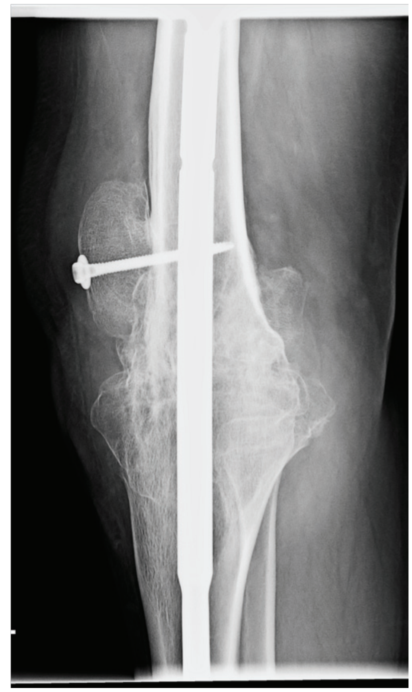


Figure 4. Lateral radiograph one year postoperative.

following: hypotonia, slowed nerve conduction, liver dysfunction, self-mutilating behavior, and mental retardation.[5-7] HSAN-IV has been associated with mutations on the TRKA gene,[8,9] while genetic associations with NFNA have not been identified.

Woiczik and D'Astous at Utah Shriners Hospital first described the orthopaedic manifestations of Navajo familial neurogenic arthropathy with a review of two cases in children.[2] In the second decade of life, these children exhibited Charcot-type arthropathy, heat intolerance, and anhidrosis. Surgical interventions (osteotomy and hemiepiphysiodesis) had suboptimal outcomes and many complications occurred. Physical function declined, with additional deformities of the appendicular and axial bones. Johnsen[1] mentioned arthrodesis as an option in these patients, yet to date, outcomes have not been reported.

Navajo cultural considerations make discussion of surgical treatment options with the patient and family challenging. One should avoid personalizing negative information when talking with patient and family regarding prognosis and surgical risks.[3] The Navajo by nature are reticent, and questioning those perceived as persons of respect is seen as rude[10]: patient-centered communication strategies include allowing ample time for any discussion and the use of "third party language" when discussing possible complications.[1]

By definition, neurogenic arthropathy is a progressive disorder, and involvement may spread to other joints and to the spine. Using culturally appropriate language, patients must be made aware of the progressive nature of NFNA, and must be given reasonable expectations of surgical risks and long-term outcomes.

As the Native American population disperses into the greater community, physicians must be aware of the manifestations of NFNA. Traditional Navajo beliefs necessitate a cautious approach when discussing potential adverse outcomes and the progressive prognosis of the disorder.

Indications for knee arthrodesis in children are rare, but in this instance, the procedure avoided amputation and enabled independent ambulation, for at least the immediate future.

References

1. Johnsen SD, Johnson PC, Stein SR. Familial sensory autonomic neuropathy with arthropathy in Navajo children. *Neurology*. 1993;43:1120-1120.

2. Woiczik MR, D'Astous JL. Orthopaedic manifestations of Navajo familial neurogenic arthropathy. *J Pediatr Orthop*. 2010;30:289-295.

3. Carrese JA, Rhodes LA. Bridging cultural differences in medical practice. *J Gen Intern Med*. 2000;15:92-96.

4. Schwarz MT. Emplacement and contamination: mediation of Navajo identity through excorporated blood. *Body Society*. 2009;15:145-168.

5. Appenzeller O, Kornfeld M, Snyder R. Acromutilating, paralyzing neuropathy with corneal ulceration in Navajo children. *Arch Neurol*. 1976;33:733-738.

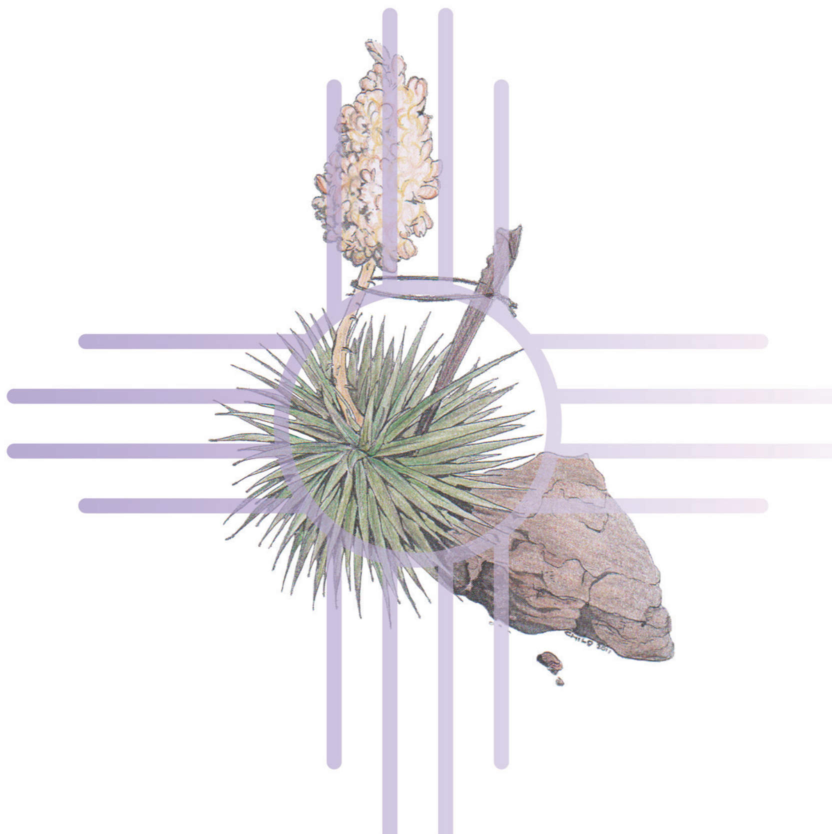
6. Dyck PJ. Neuronal atrophy and degeneration predominantly affecting peripheral sensory and autonomic neurons. In: Dyck PJ, Thomas PK, Griffin JW, Low PA, Poduslo JF, eds. *Peripheral Neuropathy*. Philadelphia, PA: WB Saunders;1993:1065-1093.

7. Swanson AG. Congenital insensitivity to pain with anhidrosis. *Arch Neurol*. 1963;8:299-306.

8. Houlden H, Blake J, Reilly M. Hereditary sensory neuropathies. *Curr Opin Neurol*. 2004;17:569-577.

9. Shatzky S, Moses S, Levy J, et al. Congenital insensitivity to pain with anhidrosis (CIPA) in Israeli-Bedouins: genetic heterogeneity, novel mutations in the TRKA/NGF receptor gene, clinical findings, and results of nerve conduction studies. *Am J Med Genet*. 2000;92:353-360.

10. Carrese JA, Rhodes LA. Western bioethics on the Navajo reservation. *JAMA*. 1995;274:826-829.



Special Interests

Vitamin D: Myth or Magic?

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Orthopaedic surgeons are challenged to "own the bone," yet many are confused by conflicting reports in both scientific literature and lay press regarding the importance and value of Vitamin D. While most Vitamin D researchers recommend routine Vitamin D supplementation, the Institute of Medicine, in 2010, issued a report suggesting that only nominal supplementation with Vitamin D is adequate for good health at all ages.[1]

What advice should we offer patients?

History and Evolution

In evolution, the earliest phytoplankton forms produced provitamin D, and nonvertebrate species produced Vitamin D upon exposure to sun, which served to absorb damaging ultraviolet radiation.

In humans, Vitamin D is actually a hormone produced in the skin upon exposure to UV B radiation. Following hydroxylation in the liver and the kidney, the activated form is essential for absorption of calcium in the gut. Aside from its importance to bone, Vitamin D receptors are found on virtually every cell in the body. Vitamin D sufficiency has been implicated in multiple body systems, from muscle function, to susceptibility to certain cancers such as breast and prostate, to hypertension and psoriasis.

Vitamin D is offered as an evolutionary explanation for racial diversity: black skin, outdoors all day at the equator, produces the perfect amount of Vitamin D for good health. The further north one goes, the paler one's skin need be to produce the needed amount of Vitamin D in a day's sun exposure. In the extreme north and south of the planet, where sunlight is minimal, the primary food source is fish, which is the only naturally occurring food source of Vitamin D.

Modern lifestyle has taken a toll on our Vitamin D metabolism: our agrarian past has given way to indoor occupations. Children no longer play outside from dawn until dusk, but shelter indoors, in front of computers, video games, and televisions. Pollution filters the sun's rays. Where there is sun, sunscreen abounds, and dermatologists tout the importance of avoiding sun exposure at all ages. Increasing life expectancy plays a factor as well: skin loses its capacity to produce Vitamin D beginning at about 50.

Evidence Based Medicine

The medical literature is replete with Vitamin D studies. In most, hypovitaminosis D is implicated as either causative or contributory to human morbidity, from osteoporosis to diabetes. Unfortunately, many of these studies are anecdotal, retrospective, and uncontrolled.

The Institute of Medicine (IOM) issued a report in 2010 that attempted to summarize the known research on Vitamin D, and to offer recommendations that would be safe on universal grounds (see sidebar). The IOM recommended a daily vitamin D intake of 600 IU from ages 1 to 70 and identified a serum 25(OH) D concentration of 20 ng/mL (50 nmol/L) as "the level that is needed for good bone health for practically all individuals." This is despite the fact that Vitamin D needs vary based on body size, obesity, and age.

Also at odds in the medical literature is what Vitamin D serum levels are optimal for good health. Looking at "normal" or "average" levels is meaningless if we accept the fact that modern humans experience less sun exposure than our predecessors: if everyone is Vitamin D deficient, then the "average" level is, by definition, suboptimal.

Serum parathyroid hormone levels rise with serum Vitamin D levels of 15-25 ng/mL (see sidebar regarding Vitamin D facts). Calcium absorption is increased by 65% if the serum level is increased from 25 ng/mL to 34 ng/mL.

While this evidence speaks to minimal Vitamin D sufficiency, a desired Vitamin D level for optimal bone health has not been well established.

In a Journal of Clinical Densitometry editorial titled "Vitamin D and Common Sense," Binkley and Lewiecki[2] note that "our current human genetics are virtually identical to (our) hunter-gatherer ancestors," and suggest that our ancestors serve as the paradigm for current Vitamin D goals. Extrapolating from studies of outdoor workers and tanners (who have been demonstrated to have statistically better bone density), the authors suggest that the "normal" 25 OH Vitamin D level range is from 20 to 60 ng/mL. Given that there are "no reports of Vitamin D toxicity from long-term sun/UVB exposure with levels up to 60 ng/mL," they offer a "moderation-based" target of 40 ng/mL.

Vitamin D: What You Need to Know

What study do I order?

The 25-OH Vitamin D serum test is the only level that assesses Vitamin D status (the 1, 25 OH Vitamin D level may be elevated in the fact of Vitamin D deficiency.) Be sure this is the study you look at.

What's the difference between D2 and D3?

D2 is plant derived, and D3 animal derived. Caution: D2 has only 40% the efficacy of D3, so that 50,000 IU of D2 is equivalent to only 20,000 IU of D3.

How are Vitamin D levels reported in the literature?

Serum Vitamin D is most commonly reported as ng/mL, BUT some studies use nm/L. These are VERY DIFFERENT units. To convert nmoles/L, multiply x 0.4: ergo 20 nmoles/L x 0.4 = 8 ng/mL.

How should Vitamin D be taken?

As a fat soluble vitamin, taking it in divided doses is unnecessary. It can be taken all at once, every other day, once weekly, or even large doses periodically.

What exactly did the Institute of Medicine recommend?

See IOM recommendations.

A University of New Mexico (UNM) study published in 2011 demonstrated that only 14% of children in sunny New Mexico had Vitamin D levels at or above 40 ng/mL.[3] An ongoing study looking at Vitamin D levels in UNM orthopaedic resident physicians demonstrated that 95% (38 of 40 residents studied) had winter Vitamin D levels that were <40 ng/mL.[4]

Vitamin D researchers[5] have suggested that the body uses at least 3000-5000 IU of Vitamin D per day, and that, absent significant sun exposure, an intake of 1000 IU/d is needed by an average adult to maintain a serum level of at least 30 ng/mL.

The final confounding issue is that, given current levels of food fortification, *it is impossible to intake adequate Vitamin D from diet*. To intake 1000 IU of Vitamin D, one would need to drink ten 8-oz. glasses of milk: other dairy products are not routinely fortified. Certain species of fish (not all) offer around 300 IU of D per serving, so three fish meals per day could meet the 1000 IU requirement. Other foods are fortified at negligible levels.

In short, most individuals need Vitamin D supplementation. Vitamin D3, the most biologically potent form, is inexpensive and readily available without prescription, including child-friendly forms such as liquid and gummy preparations.

Conclusion

As orthopaedic surgeons, our task is to optimize bone health in our patients. While we have a variety of tools in our armamentarium, up to and including surgery, we should first and foremost use common sense in our advice to patients. Vitamin D and calcium are the building blocks of the musculoskeletal system. Suggesting complex bone surgery without recommending basic Vitamin D supplementation is analogous to trying to gain internet access using an abacus.

Recommendations

Own the bone, and keep it healthy by recommending at least 1000 IU of Vitamin D supplement per day to every patient. Patients with osteoporosis, obesity, metabolic bone disorder, delayed or nonunion of fracture, seizures, and chronic illness should receive individualized recommendations based on assessment of serum 25 (OH) Vitamin D, with a goal of maintaining the level between 40 and 60 ng/mL.

References

1. Food and Nutrition Board. Dietary reference intakes for calcium and vitamin D [Web page]. Institute of Medicine website. http://www.iom.edu/Reports/2010/Dietary-Reference-Intakes-for-Calcium-and-Vitamin-D/DRI-Values.aspx. Accessed April 25, 2012.
2. Binkley N, Lewiecki M. Vitamin D and common sense. *J Clin Dens*. 2011;14(2):95-99.
3. Szalay EA, Tryon EB, Pleacher MD, Whisler SL. Pediatric vitamin D deficiency in a southwestern luminous climate. *J. Pediatr. Orthop*. 2011;31(4):469-473.
4. Allen L, Godfrey J, Szalay E. Unpublished data.
5. Holick M. The influence of vitamin D on bone health across the life cycle. *J. Nutr*. 2005;135(11):2726S-2727S.

Table 1

Dietary Reference Intakes for Calcium and Vitamin D

	Calcium			Vitamin D		
Life Stage Group	Estimated Average Requirement (mg/day)	Recommended Dietary Allowance (mg/day)	Upper Level Intake (mg/day)	Estimated Average Requirement (IU/day)	Recommended Dietary Allowance (IU/day)	Upper Level Intake (IU/day)
Infants 0 to 6 months	*	*	1000	**	**	1000
Infants 6 to 12 months	*	*	1500	**	**	1500
1-3 years old	500	700	2500	400	600	2500
4-8 years old	800	1000	2500	400	600	3000
9-13 years old	1100	1300	3000	400	600	4000
14-18 years old	1100	1300	3000	400	600	4000
19-30 years old	800	1000	2500	400	600	4000
31-50 years old	800	1000	2500	400	600	4000
51-70 year old males	800	1000	2000	400	600	4000
51-70 year old females	1000	1200	2000	400	600	4000
>70 years old	1000	1200	2000	400	800	4000
14-18 years old, pregnant/lactating	1100	1300	3000	400	600	4000
19-50 years old, Pregnant/lactating	800	1000	2500	400	600	4000

*For infants, Adequate Intake is 200 mg/day for 0 to 6 months of age and 260 mg/day for 6 to 12 months of age.

**For infants, Adequate Intake is 400 IU/day for 0 to 6 months of age and 400 IU/day for 6 to 12 months of age.

Institute of Medicine. (November 2010). [Table of calcium and vitamin D dietary reference intakes for infants, children, and adults]. *Dietary Reference Intakes for Calcium and Vitamin D.* Retrieved from http://www.iom.edu/Reports/2010/Dietary-Reference-Intakes-for-Calcium-and-Vitamin-D/DRI-Values.aspx.

Treating Native Americans and the Importance of Being Culturally Competent

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I am a Native American practitioner. I deal with both the cultural realm of healing and modern medicine when treating my Native American patients, which I find to be a rewarding part of my practice. In this day and age, there are urban Indians who traverse between these two realms of healing and traditional elders who still use the medicine man for healing and guidance. I always seek to find some common ground between the two realms when treating Native Americans.

The doctor is not only working with the patient, but also with the immediate and extended family members when treating Native Americans. There will be one spokesperson selected by the family who will translate and make the decisions for the family. Doctors may also treat traditional elders, who will seek cleansing from spirits before embarking on modern medical therapy.

Native American culture emphasizes that words should be carefully selected and spoken, meaning negative words and thoughts about health become self-fulfilling. The doctor's swift decision making, choice of words, or body language could cause a delay in plans for medical treatment for a Native American patient. The doctor's recommendations for treatment and treatment plans have to be plainly laid out for patients. The doctor needs to remember he or she is not only dealing with the patient, but also with a group of extended family members who will be evaluating the plans and the doctor's knowledge.

The doctor should be prepared by becoming well-informed about the patient, devising a thoughtful treatment plan, and most importantly, explaining any procedures in detail to the patient. Imaging studies, lab reports, and a knowledge of surgery should all be used when talking to the patient.

Native Americans believe they came into this world whole, and would like to leave this world whole. Amputation is difficult to accept because of their cultural beliefs. In this situation, the doctor should explain in detail to the patient about the need for surgery and why it is indicated. The doctor should also explain other options that are available to the patient.

When talking with Native Americans about amputation, the doctor should be honest, quick to get to the point, and willing to listen to patient–offered solutions. Seek to meet the patient halfway. Turn the medical situation into a win-win solution, where both doctor and patient agree on a treatment plan. Some patients will say they need some time to think things over. Give them that time. That time could be used for getting a second opinion, to consult with their family, or for seeking spiritual cleansing from a medicine man.

The remaining and last part to cover with patients is the post-procedure period. Many Native American patients do not want overwhelming amounts of information about what may happen after the procedure, including the recovery period, complications such as infection and pain, additional surgery, wound care, prosthetics, and follow-up care. The main objective is to have a well-thought-out treatment plan. The majority of Native Americans would like to know and understand the steps involved in their care. Helping them to have that knowledge and understanding will make you a well-respected practitioner among the Native American population.

Hip Arthroscopy at the University of New Mexico

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UNM Department of Orthopaedics & Rehabilitation

I have recently returned to UNM to further my interest in the hip. As orthopaedic surgeons, we are a very active cohort. Many of us played football or other sports that led to injuries we will, sooner or later, pay for with total joint arthroplasty. Certainly, we see this with knee and shoulder injuries. The hip is a different entity. While some athletes have a clear traumatic injury to the hip, most of us who develop hip osteoarthritis (OA) have no traumatic history.

The presence of anatomical abnormalities leading to osteoarthritis has been postulated for many years. Early description of femoral deformity as a possible cause by Dr. Harris in 1986 led to the perception that most OA of the hip was a result of underlying abnormalities.[1] There is even some evidence that some of these deformities have a degree of transmissibility.

Hip arthroscopy was first described in 1931 by Burman in a cadaveric study.[2] The first clinical description was in 1939 by Takagi in 4 patients.[3] Early applications were for septic arthritis, Charcot joints, and tuberculous arthritis. The 1980s saw a gradual increase in publications. Since 2003, there have been more than 10 publications each year.

The indications for the procedure have broadened as traction and instrumentation have allowed safer access to the joint. Labral tears, loose bodies, synovial chondromatosis, iliopsoas tendinopathy, adhesive capsulitis, arthritis, synovial chondromatosis, hip abductor tears, and trochanteric bursitis can be treated arthroscopically.

Acetabular labral tears are certainly the most common indication for the procedure but are sometimes difficult to diagnose on MRI. The exam can be very helpful with an audible or palpable click in some patients and impingement signs with pain on flexion, adduction, and internal rotation in many. The fact that this is mostly a secondary process has been appreciated only in the last 10 years.

In treating developmental dysplasia of the hip, Professor Ganz realized that some of his patients were developing problems as a result of overcorrection of the dysplasia.[4] This has become known as femoroacetabular impingement (FAI). Initially, the treatment of the excessive anterior acetabular coverage and femoral head-neck junction deformities was by open surgical dislocation. Arthroscopic techniques or a combined limited open approach and arthroscopy have now been utilized with good results and less morbidity. There have been a number of publications linking the osseous abnormalities seen in FAI with the development of early osteoarthritis.

The abnormalities have been described as the cam deformity where the femoral head-neck offset is diminished, leading to impingement between the acetabular rim and a bony “bump.” This bump will shear the cartilage at the articular margin resulting in eventual delamination of the cartilage from the acetabulum. The pincer abnormality is secondary to overcoverage of the femoral head due to a very deep cup (profunda) or due to acetabular retroversion. Many hips have a combination of both of these entities.

The development of the cam deformity is controversial. Is it a subclinical slipped capital femoral epiphysis? A variant of Osgood-Schlatter’s of the hip? Is it hereditary or activity- related? Are there certain sports that are more likely to cause it? The answers to these questions are presently being investigated. The pincer abnormality, with a center-edge angle of >40°, is more likely developed at an early age and not necessarily influenced by activity.

I have been personally affected by the “drama” of FAI. I have now had both of my hips replaced and have had 2 children with acetabular labral tears. Clearly, there is some hereditary factor. I can only speculate that my hip films as a youth were very similar to those of my son’s at age 19 when he sustained a labral tear and underwent staged bilateral hip arthroscopy. My hip films, taken at age 14 at Columbia-Presbyterian for hip pain, were destroyed. I became asymptomatic until later in life. My daughter had hip films taken at age 13 at Carrie Tingley Hospital and then developed bilateral hip pain with labral tears in her 20s. She has undergone 1 hip arthroscopy. Both of these offspring are doing well but the future of their articulations remains a concern.

There is evidence that acetabular rim trimming, labral repair, and femoral neck osteoplasty can be very effective in treating hip pain and returning patients to activity. Long-term follow-up is not yet available to determine whether our interventions can prevent the development of osteoarthritis. This will take many years to prove. We can only speculate. In most patients, the osseous abnormalities are present in both hips. Often only one side is symptomatic, however. No surgeons have yet recommended that prophylactic surgery should be performed but this could change if it is ever proven that OA is prevented by this procedure.

As a result of this history, I became very interested in treating hip abnormalities. I attended courses and observed multiple surgeries and have been performing hip arthroscopy for the last 3 years. As with any surgery, there is a significant learning curve. I have helped most of my patients but not all have benefited. A few patients have gone on to have total hip arthroplasty. Others had more minor, but persistently symptomatic, cartilage damage.

In our brave new world of intense media scrutiny, hip arthroscopy has been one of the new procedures that has been singled out as being of questionable efficacy. A recent *New York Times* article stressed the fact that there is no clear proof about the effect of the procedure on subsequent OA and no clear proof that the cam deformity does not regrow.[5] The recent treatment of high profile athletes has led to this increased scrutiny, as well.

In the past, our procedures have not been assessed so critically. The world has changed. We are now at the mercy of the insurance industry as to whether new procedures will be recognized or reimbursed. There has been much effort to address the issue of reimbursement and recognition of procedural codes so that we can perform this procedure. This is still evolving, as is the reimbursement for most of our procedures.

How do we justify the development of new surgical techniques? Some techniques are variations on older approaches. Marketing has become an acceptable term in the discussion. We are always looking for ways to make our results better and to help more people but we must be wary of the learning curve and the marketing aspects.

In the academic setting, we must also wrestle with the desire to perform newer techniques and the concern over who should be applying these in their practices. We know there is a learning curve in any procedure that we do. As a resident, I was somewhat doubtful when a learned sage (Tom DeCoster) told me that I wouldn't really know how to perform a surgery until I had done more than 100. I realize that his analysis was correct and has been clearly documented in various studies. In fact, we are always learning and altering our practices to continually seek fewer complications and better outcomes for our patients. We have all witnessed bandwagons come and go. Some we have jumped on (and off), some we have let pass by. It is the nature of our profession that we should continually learn. This activity improves our outcomes – we hope - and wards off senility.

I am hoping that by performing hip arthroscopy, I can prevent patients from having total hips at an early age but it will be difficult to know for many years whether this will be true or false. In the meantime, I will monitor hip scores and improve the immediate future for my patients in pain.

References

1. Harris WH. Etiology of osteoarthritis of the hip. *Clin Orthop Relat Res*. 1986;213:20-33.

2. Burman M. Arthroscopy or the direct visualization of joints. *J Bone Joint Surg.* 1931;4:669–695.

3. Takagi, K. Arthroscopy. *Nippon Seikeigeka Gakkai Zassi.* 1939;14:359-384.

4. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock K. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;417:112-120.

5. Kolata, G. Hip procedure grows popular despite doubt. *New York Times*. November 15, 2011. Available at: http://www.nytimes.com/2011/11/16/health/hip-impingement-grows-popular-but-remains-unproven.html. Accessed on April 22, 2012.

Twenty Years of Knee Dislocations

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Dan Wascher and I began our academic orthopaedic surgery careers around the same time: Dan here at the University of New Mexico (UNM) in 1991 and myself, Bob Schenck, at the University of Texas San Antonio in 1990. We had similar experiences, as we had been trained in knee ligamentous surgery (Dan at the University of California Los Angeles and me with Frank Noyes), and found that trauma-heavy institutions, at that time, treated knee dislocations (multi-ligamentous knee injuries) as an afterthought. Independently, we were able to publish information that although not quite the paradigm shift of antibiotic therapy, gave orthopaedic surgeons a new way to look at knee dislocations (KD). What we both discovered is the wide array of presentations that can be seen when 2 or more ligaments about the knee tear, and that the sports medicine approach may not always be the right approach. An initially more conservative approach to the management of torn knee ligaments can be determined after looking at the patient as a whole, especially with multi-trauma and the possibility of a closed head injury. Furthermore, the status of the neurovascular tree, as well as the soft tissue envelope, can quickly direct the clinician to a limb salvage procedure rather than a ligamentous reconstruction. We both learned that ligamentous reconstructions are challenging, and best performed in one setting where all injured structures are repaired if avulsed or reconstructed if torn in midsubstance. And we learned what Sisto and Warren preached about in their *Clinical Orthopaedics and Related Research* article on knee dislocations: a stiff reconstructed knee is worse than a mobile loose knee.[1]

This review is in part light-hearted, but I want to share with the young orthopaedic surgeon some of the process involved in advancing the field of any clinical academic study. There are challenges, and I would like to reflect upon two ideas Dan and I put together in learning about the patient with a dislocated knee.

First, Dan and Tom DeCoster's paper on the spontaneously reduced knee dislocation was a very creative approach to prove (or disprove) that knee dislocations often go unrecognized.[2] What is seen at presentation of the patient with a bicruciate ligament injury in the emergency room after a fall, motor vehicle accident, or sporting injury, is often relatively normally reduced radiographs of the knee. The concept of a spontaneously reduced knee dislocation was first introduced by Dan and Tom, and to further support that the knee was dislocated at some point in the injury, the risk of neurovascular injury was the same in the patient with a knee dislocated on plain radiographs as in the patient presenting with radiographs showing normal tibio-femoral alignment. Thus the trauma patient with the swollen knee, with relatively normal appearing tibio-femoral knee radiographs should be suspected of having dislocated the knee at one point in time.

An excellent case in point is a patient treated at UNM in 1993. He had suffered bilateral knee injuries after being pinned by a car against a wall. His right knee presented dislocated and his left knee was reduced on initial radiographs. Vascular evaluation revealed a transection of the popliteal artery on the reduced left knee. He underwent successful reverse saphenous vein grafting of the popliteal artery with simultaneous external fixation of his left knee. Three days later he had ligamentous reconstruction and repair of the ligamentous injuries to his right knee. Six weeks post-injury he underwent fixator removal from the left knee and at 12 weeks post-injury, he underwent bicruciate reconstruction of the revascularized left knee (Figure 1a-d).

Several authors have shown patients presenting with a completely dislocated knee but with tearing of only one cruciate ligament in case reports or small series. The anterior cruciate ligament (ACL)-intact knee dislocation was described by Dan Cooper and Russ Warren, and usually occurred with a completely torn posterolateral corner.[3] Thus, the use of the term "knee dislocation" didn't imply exactly which ligaments were torn. Dan's discovery of the spontaneously reduced knee dislocation shifted our description of these injuries as multi-ligamentous knee injuries, and on occasion, bicruciate injuries, to differentiate when both the ACL and posterior cruciate ligament (PCL) are torn. Dan and Tom discovered that 20% of their patients with a multi-ligamentous knee injury presented without any radiographic evidence that the knee was dislocated: that is, 20% were noted to have a spontaneously reduced knee dislocation.

Figure 1a-d. Unstable KDIV which was easily closed reduced. While admitted noted increasing knee pain and radiographs revealed subluxation in the brace. Ex-fix versus operative repair considered.

Having been trained by Frank Noyes, I began describing sports knee injuries based on what is torn rather than the long-held view of specific instability patterns. This approach gave me an opportunity to look at KD in a different light. In the early 90s, patients with knee injuries were often described in terms of their pathologic laxity (e.g., anterolateral rotatory instability) rather than the anatomic structure torn. Describing a patient as having a complete ACL and complete medial collateral ligament (MCL) tear gave more accurate information on what was injured needing reconstruction rather than describing the abnormal motion pattern when examining the knee. Both clearly are important, but for descriptive purposes and determining what should be reconstructed, knowing which ligament(s) is (are) torn is paramount to the proper treatment of the unstable knee.

Thus it was a natural progression for me, as I began my KD practice in 1990, to look at which ligament was injured rather than which way the knee was dislocated. For 20 or more years prior to my starting practice, a knee dislocation was described by the position of the dislocated tibia condyles on the femur, (e.g., anterior or posterior). The position classification system was described by Dr. Kennedy, and is still very useful for reduction maneuver, as well as the complex or locked knee dislocation seen with a posterolateral position.[4] However, the position classification gives no information as to surgical planning and does not capture the "reduced" bicruciate knee injury.

I saw very distinctive patterns in my patients and realized there were a finite number of ligamentous injuries that could present. That led to my developing an anatomic classification system described in Table 1.[5] The system is based on an examination under anesthesia and on what is completely torn. Use of magnetic resonance (MR) has been a clear advantage, and KP Reddy and I published a small series of patients in 1996 which showed the usefulness of MR imaging in multi-ligamentous knee injury.[6] But MR overcalls some ligamentous injuries (sprain rather than completely torn); the anatomic system uses clinical examination of what is torn to determine how the knee is classified. Furthermore, using "C" or "N" with the KD numeric quickly conveys the neurovascular status of the patient. Dan came up with a KD V to describe the fracture-dislocation pattern of injury subcategorized by Tilman Moore.[7]

What is so interesting for the academic in me was the amount of time it took for the classification system to be accepted nationally and now worldwide. The original discussion of 13 patients ("A baker's dozen of knee dislocations") was rejected by the American Academy of Orthopaedic Surgery, American Orthopaedic Society for Sports Medicine (AOSSM), Journal of Bone and Joint Surgery, and American Journal of Knee Surgery. I was able to present it at the Western Orthopaedic Association and then published it in the *American Journal of Knee Surgery* in 1994.[5] It was only in 2000 that I was called by Bill Clancy asking me to explain the classification system, whereafter he presented it at the AOSSM and opined that it was the best system to use. It was only this past year when I saw the anatomic classification system described as "Schenck" that I chuckled at how many years it took-17. Our advice to the young academic surgeon is to find an area or areas of interest, extensively review the current state of knowledge based on the literature, study your patients, and be patient as you put forth ideas. Most importantly, get it in print, and as in my case, when Bill Clancy calls, pick up the phone!

Table 1

Anatomic classification of knee dislocations. "C" or "N" with the KD numeric denotes the neurovascular status of the patient.

Class	Injury
KD I	PCL or ACL intact knee dislocation
	Variable collateral involvement
KD II	Both cruciates torn, collaterals intact
KD III	Both cruciates torn, one collateral torn
	Subset M (medial) or L (lateral)
KD IV	All four ligaments torn
KD V	Periarticular fracture-dislocation

Abbreviations. C, arterial injury; N, nerve injury; KD, knee dislocation; PCL, posterior cruciate ligament; ACL, anterior cruciate ligament.

Dan and I began discussing our experience and approach to the dislocated knee at the AOSSM meetings in the late 90s. We had some similar approaches to these complex knee injuries and some differences of opinions. We learned from each other's experiences. This common interest in an unusual problem led to us becoming partners at UNM a few years later. Dan, Tom, and I encourage you to attend meetings and seek out others with a common practice focus. You never know where those connections may lead!

One interesting area is what Dan and I do differently. Our philosophical approach to the PCL is the same: restore what Jack Hughston referred to as "the cornerstone of the knee." But I had some failures early on with transtibial tunnels and performed my first PCL inlay in 1996. I modified Bob Burks' approach to avoid placing the patient in the prone position.[8] Exposure of the back of the tibia while the patient is prone is performed through the interval between the semi-tendinosis and medial head of the gastrocnemious. My modification was to use an "interval" between the posterior aspect of the MCL and pes anserinus (MCL and semitendinous), staying anterior to the gastrocnemius and taking down distal portions of the semi-membranosus. Flexing the knee to 90° while externally rotating the hip (unilateral frog leg position) allows the surgeon to clearly and safely visualize the back of the tibia while standing on the opposite side of the table. And I avoid flipping the patient.

Dan reconstructs the PCL through a transtibial approach and was one of the first to publish this technique using allografts.[9] His use of intraoperative radiographs and his procedure to avoid plunging with the reamer when making the tibial tunnel is technically outstanding. We would be remiss without mentioning Greg Fanelli in discussing this technique and long term follow-up of simultaneously reconstructed bicruciate knee injuries.[10]

The dislocated knee in the trauma patient deserves special discussion. The need to carefully evaluate and temper one's approach to the ligamentous problem is key to avoid infection, stiffness, or limb loss. Jim Stannard and others have described the usefulness of sequential clinical examination in a way to avoid arteriography in the patient with a normal clinical vascular exam.[11] Dan and I are grateful for this advance, but urge a low threshold for arteriography in the uncooperative patient (closed head injury), any evidence of assymetric vascularity, or an ankle brachial index below 0.9. But in the arena of the trauma team, there are usually many resources for consultation by vascular or the trauma service so the descision is by consensus. Certainly, following a normal vascular exam is clinically safe, but the clinician should review Dr. Stannard's original recommendations of repeated vascular checks for 48 hours.

In the area of multi-trauma, we have liberally used external fixation to aid in improved patient mobility, avoid pressure injury from splints in a neuro-compromised patient, maintain joint position in a grossly

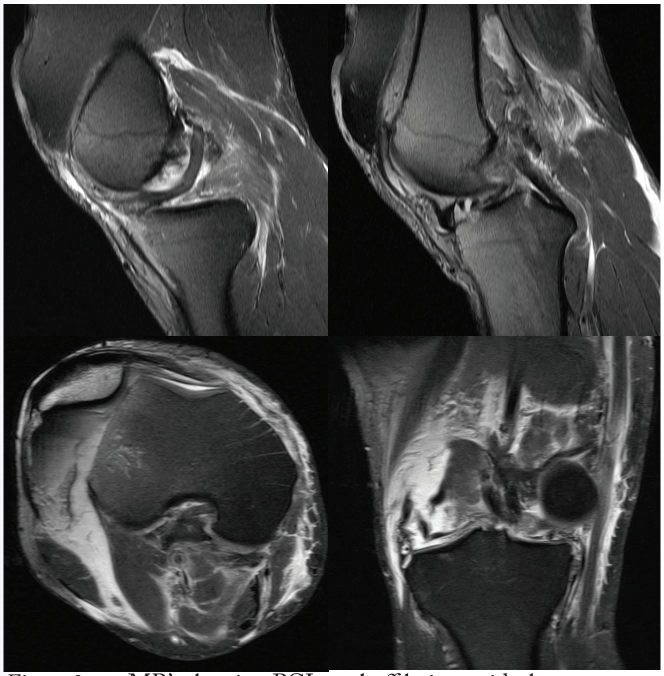

Figure 2a-e. MR's showing PCL peel off lesion, midsubstance ACL, femoral avulsion of posterolateral corner, midsubstance tear of superficial MCL, avulsion of MPFL from femur, locked medial and lateral meniscal tears. With locked meniscal tears felt open reconstruction would be needed for definitive stabilization.

unstable knee, and of course, in the patient with an open knee injury or one requiring revascularization. Tom, Deana Mercer, and I looked at the various external fixation constructs. We found the simplest frame to be one with anterolateral femoral pins in combination with anteromedial tibial pins.[12] Standard external fixation principles apply with the most stable constructs minimizing the bar-to-skin distance and maximizing the crossing bars (Figure 2a-d). External fixation is becoming more popular, as evidenced the recent report by Fred Azar et al. on low energy/morbid obesity knee dislocations. Their recommendation was for external stabilization of the tibio-femoral position in these patients.[13]

It is this mutual interest in knee dislocations that prompted us to obtain IRB approval to conduct a review of patients with knee dislocations who presented to UNM during an 8 year period and present preliminary data concerning the clinical outcomes of these patients after treatment, with a minimum 2 year follow-up. Using selected CPT codes and a trauma registry at UNM, patients were identified who sustained a KD between January 2000 and December 2007, ensuring a minimum 2 year follow-up. Dustin Richter, PGYII, began a retrospective chart review to identify mechanism of injury, injury pattern, associated neurovascular injuries, and treatment of this group of patients with a multi-ligamentous knee injury. Patients were contacted and are currently being evaluated using both subjective and objective measures. Subjective measures include the Lysholm, Tegner activity, VAS, SF-36, and IKDC questionnaires, and a psychosocial questionnaire. Objective measures include ligamentous examination by an independent observer (TN), radiographs to evaluate arthritis and stress radiographs to evaluate posterior laxity, and physical therapy assessment, including hop test, KT-1000 arthrometer, and strength testing utilizing an isokinetic dynamometer.

A total of 101 patients with 102 knee dislocations were identified. Three of these patients are deceased and 1 has a traumatic brain injury. Of the remaining 97 patients, the average age is 39 years (range 19-63) with 74 males (76%) and 23 females (24%). The following injury patterns were seen: 6% KD1, 1% KD2, 75% KD3 (21% KD3L, 54% KD3M), 4% KD4, and 14% KD5. Neurologic and arterial injury were seen in 10% and 4% of cases, respectively. Fifty-six percent of neurologic injuries were associated with a KD3L pattern and 75% of vascular injuries were associated with a KD3M pattern. Twenty-six patients are currently enrolled in the study and 16 have completed evaluation. The average age is 43 years and average time from surgery is 7.25 years. Subjective assessment average scores are: SF-36 physical health = 47.1, Lysholm = 75.6, IKDC = 69.2, VAS involved = 32mm, and VAS uninvolved = 15mm. Six patients have returned to heavy or competitive activity. Radiographic and functional testing results are being compiled. We found that the KD3M is the most common injury pattern seen and is associated with greater risk for vascular injury, whereas KD3L classifications have a higher rate of neurologic injury. Preliminary data shows that patients overall do fairly well post-operatively, with greater than one-third returning to heavy or competitive activity.

In summary, knee dislocations have been a great interest and challenge of ours for the past 20 years. We look forward to further information coming from the current study underway, possibly giving us more insight in the PCL inlay versus transtibial tunnel approach. We hypothesize there will be no difference in how one reconstructs the PCL, but will find improvement in outcomes depending on how well the PCL origin on the tibia is reestablished. We continue to look at the dislocated knee as one of multiple presentations requiring careful judgment in surgical management, and we all continue to learn about this complicated orthopaedic problem.

References

1. Sisto DJ, Warren F. Complete knee dislocation: a follow-up study of operative treatment. *Clin Ortho Relat Res*. 1985;198:94-101.

2. Wascher DC, Dvirnak PC, DeCoster TA. Knee dislocation: initial assessment and implications for treatment. *J Orthop Trauma*. 1997;11(7):525-529.

3. Cooper DE, Speer KP, Wickiewicz TL, Warren RF. Complete knee dislocation without posterior cruciate ligament disruption. A report of four cases and review of the literature. *Clin Orthop Relat Res*. 1992; 284:228-233.

4. Kennedy JC. Complete dislocation of the knee joint. *J Bone Joint Surg [Am]*. 1963;45:889-904.

5. Walker DN, Hardison R, Schenck RC. A baker's dozen of knee dislocations. *Am J Knee Surg*. 1994;7(3):117-124.

6. Reddy PK, Posteraro RH, Schenck RC. The role of MRI in evaluation of the cruciate ligaments in knee dislocations. *Orthopaedics*. 1996;19(2):166-70.

7. Moore TM. Fracture-dislocation of the knee. *Clin Orthop Relat Res*. 1981;156:128-40.

8. Burks RT, Schaffer JJ. A simplified approach to the tibial attachment of the posterior cruciate ligament. *Clin Orthop Relat Res*. 1990;254:216-9.

9. Wascher DC, Becker JR, Dexter JG, Blevins, FT. Reconstruction of the anterior and posterior cruciate ligaments after knee dislocation: results using fresh-frozen nonirradiated allografts. *Am J Sports Med*. 1999;27(2):189-196.

10. Fanelli GC, Edson CJ. Arthroscopically assisted combined anterior and posterior cruciate ligament reconstruction in the multiple ligament injured knee: 2- to 10-year follow-up. *Arthroscopy*. 2002;18(7):703-714.

11. Stannard JP, Sheils TM, Lopez-Ben RR, McGwin G Jr, Robinson JT, Volgas DA. Vascular injuries in knee dislocations following blunt trauma: evaluating the role of physical examination to determine the need for arteriography. *J Bone Joint Surg*. 2004;86:910-915.

12. Mercer D, Firoozbakhsh K, Prevost M, Mulkey P, DeCoster T, Schenck R. Stiffness of knee-spanning external fixation systems for traumatic knee dislocations: a biomechanical study. *J Orthop Trauma*. 2010;24(11):693-696.

13. Azar FM, Brandt JC, Miller RH, Phillips BB. Ultra-low-velocity knee dislocations. *Am J Sports Med*. 2011;39(10):2170-2174.

A Brief History of Medullary Nailing, New Mexico Perspective

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My orthopaedic fracture journey began as a medical student at the University of Missouri in Orthopaedics in 1978 when a patient presented with a transverse femur shaft fracture. The residents were very excited because this was a "nailable" fracture which we proceeded to do. My role was under the table with a crutch pushing on the thigh. I could not see a thing and had little idea what was going on above me. There was blood dripping down onto my head soaking my scrubs. Periodically I would hear a request for "valgus" or some such word. I wasn't sure what that meant or how to achieve it but I would push harder on the crutch and there would be more grunting and hammering from above. After a couple of hours I emerged to see a patient with a stable straight thigh and the orthopaedic surgeons congratulating themselves. At the end of the day we retired to Katy Station for libations and I was hooked on orthopaedic fracture care.

Subsequently I honed that interest during Orthopaedic residency at the University of Vermont and fellowship in trauma and sports medicine at the University of Iowa. I then put what I had learned to work here at the University of New Mexico in 1986 where I've practiced ever since. Over the course of that 34 years I've seen a lot of progress in fracture care and this manuscript will report some of those changes.

General fracture treatment

Clearly the main change in fracture treatment between 1978 and 2012 is the change from closed treatment to operative stabilization as the standard. In general, that has been associated with improvement in quality of reduction at the time of healing, acceleration of return of motion and probably function, prevention of post-traumatic arthritis in many patients with displaced intra-articular fractures, and the saving of lives in multiple trauma patients. Complication rates from operative treatment have also been reduced over that time period.

Intramedullary nails

Dr. George Omer spent a large portion of his military career in the 1960s adjusting the traction on patients with femur shaft fractures. It was like washing the windows on the Empire State Building. By the time the last window was finished the first was already dirty and the window washer needed to start over again. His day was spent adjusting the traction on a 40 patient ward and when he came back the next day the traction had to be adjusted again. Plus 2 new patients came in who had to be put in traction and 2 patients had healed sufficiently to be taken out of traction and put into a cast brace or the like. The next day the whole process would be repeated. Patients stayed in the hospital for 2 to 4 months or longer.

Against this backdrop, the reamed closed medullary nail was gaining popularity. I had been introduced to it in medical school and developed technical skills in residency. I was now applying it to patients at the University of New Mexico (UNM) Hospital where my predecessor, Dr. Fred Hensal, had started the process. There were considerable hurdles to overcome at the time, including operating room access, anesthesia availability, and fluoroscopy technology.

1935-1945

Intramedullary nailing was developed for femur shaft fracture treatment by Gerhard Kuntscher in Germany in the late 1930s. At that time, there was not much transfer of scientific medical knowledge between the United States (US) and Germany. Various stories of the first recognition of this operative treatment exist, including Polish radiologists seeing radiographs of femurs with metal nails in them and escaped American POW's returning with metal nails. Some thought these nails were some sort of German torture device. Kuntscher was actually successfully providing this treatment to regular German patients as well as military injuries for both Allied and Axis soldiers. He kept meticulous notes and drawings of over 2000 patients.

1945-1955

At the end of World War II, Kuntscher was accused of war crimes for experimenting on American POWs with these surgical implants. However, it was discovered that these were placed as treatment for femur shaft fractures and that the patients were doing very well, even better than the English and American treatment of the time of traction followed by casting. Kuntscher was exonerated and his techniques were thought to be of sufficient promise to attempt to utilize them in the US.

The military commissioned an English version of Kuntscher's cumulative work on medullary nailing by Colonel Albee. Centers were chosen in Boston, Baltimore and the Campbell Clinic in Memphis to try these techniques. They could not make the techniques work and the whole concept of medullary nailing fell into disrepute.

Copies of the English translation of Kuntscher's work were crated up and placed in military storage, reminiscent of the final scene in *Indiana Jones and Raiders of the Lost Ark*. They were rediscovered in the late 1990s when the Stryker Corporation started a project to commemorate the 100^{th} anniversary of Kuntscher's birth by translating his works into English. They found that this translation had already been done by Colonel Albee and actually found the original copies in military storage. They arranged to have more copies made and disseminated those to interested surgeons. I discovered that Colonel Albee had retired to Farmington, New Mexico. Unfortunately, I was never able to talk with him as he had died the year before his work was rediscovered.

1955-1965

I refer to this as the Dark Ages of medullary nailing in the United States (US) and certainly New Mexico. The lack of successful implementation of Kuntscher's techniques in the US and poor results with operative treatment of fractures in general made closed treatment the standard of care. No one knows why techniques that worked well for Kuntscher and subsequently worked well for the rest of the world were not effective or accepted at this time. It is a pattern often seen in medical progress. It is also a phenomenon somewhat peculiar to surgical techniques that seems to have escaped the attention of "evidence-based medicine." It may be impossible to conduct effective randomized controlled trials of surgical techniques because of the variability inherently present in surgical treatment, including surgeon skill and experience, availability and effectiveness of adjunctive technology, variability of pathophysiology in trauma, and biological variability in healing response. How many "controlled" trials actually control for surgeon experience? Almost none. It may be impossible, as the surgeon's experience, by definition, changes over the course of the trial.

1965-1975

I refer to this decade as the Renaissance of medullary nailing. Kuntscher and his colleagues had continued their work in Germany. The Arbeitsgemeinschaft für Osteosynthesefragen (AO) group developed effective techniques for operative treatment of fractures in Switzerland. Their approach emphasized rigid plating of fractures, including femur shaft fractures but success raised interest in operative treatment of femur shaft fractures. They initially rejected medullary nailing as violating 2 of their principles, including non-anatomic reduction and non-rigid fixation. Hanson and Street in the US developed solid, fluted nails that were placed after open reduction and were effective for transverse midshaft femur shaft fractures.[1]

1975-1985

This decade featured the rediscovery and implementation of Kuntscher's techniques with particular emphasis on hollow nails that could be placed over guide rods. Kuntscher had also developed medullary reamers over guide pins to allow for the placement of larger diameter nails. These nail characteristics, combined with the development of fluoroscopic radiographic techniques, allowed percutaneous nail placement without opening of the fracture site with associated soft tissue disruption. Kuntscher had also placed an anterior bow to match the natural bow of the femur, in contrast to the straight Hanson Street nails, resulting in easier nail placement and improved alignment and better functional outcomes. Kuntscher nails were slotted and relied upon endosteal contact for control of rotation and length. As the large diameter nail was driven into a tight medullary canal, the endosteal bone would squeeze the slot slightly closed. The natural recoil of the nail to its original shape created friction between the bone and nail which resisted the tendency toward shortening or rotation of the bone around the nail with weight bearing. This expanded the indication for medullary nailing to fractures that were farther from the isthmus or more comminuted. However, the amount of friction that could be obtained was severely limited and only the minority of femur shaft fractures were of a pattern and location to be "nailable." These techniques were introduced to New Mexico by my predecessors, including Drs. George Omer, Jr., Moheb Moneim, and Fred Hensal. Also during this decade, flexible nails were developed by Hans Ender of Austria and gained widespread use for a variety of long bone fractures. Unfortunately they were not very length stable

Figure 1. I've learned many things from my partners and residents. Clever types of fixation tend to be associated with interesting problems.

and become more prominent at complications conference than indications conference.

1985-1995

This was the decade of locking nails, which expanded indications for nailing to almost all femoral shaft factures, not merely nearly transverse fractures near the isthmus. Proximal locking of the nail by placement of a screw through holes in the nail by a nail-mounted guide was developed and provided good fixation of the nail to the proximal fragment. This did not provide a lot of resistance to rotation or shortening as the distal fragment still relied upon friction to resist motion. Brooker Wills developed a system of distal locking.[2] After nail placement, deployable fins were placed inside slots in the nail proximally and passed down the nail from the entry site at the hip. There were slots in the nail distally at 90° from the longitudinal (medial and lateral to the posterior longitudinal slot) and with gentle rotation and tapping the fins would deploy into the distal metaphysis. This provided rotational and length control. Although effective at expanding the indications, there were a myriad of problems encountered. The nail would tend to twist during insertion and the fins could deploy anteriorly and posteriorly and pentrate the cortex and impinge on important soft tissues (Figure 1). The fins could jam and not deploy or not retract, making extraction difficult.

An alternative technique that eventually supplanted fins was the placement of screws through holes in the nail distally by Klemm and Schleman in Germany and Grosse and Kempf in France. The problem with this technique was hitting the hole in the nail with a drill bit placed from the lateral side of the thigh. A variety of techniques were attempted with some success and some problems. Proximal nail-mounted guides were not sufficiently accurate and could not control for the rotational deformation of the nail that occurred during placement. Free-hand fluoroscopically controlled drilling was successful but required a lot of radiation exposure to surgeons and everyone in the operating room. However, with surgical experience and training this technique was eventually successful and gained widespread acceptance both here in New Mexico and around the country.

Also during this time, the AO accepted the utility of medullary nails and "perfected" the technique of Kuntscher with the introduction of partially slotted nails. The closed section proximally allowed use of a threaded introducer, a stronger cylinder to allow proximal locking holes without nail breakage and a thinner walled device to allow a more lateral entry hole, and a more flexible nail to reduce frequency of fracture comminution during nail insertion. AO also had "Herzog wires" for tibia nails that were similar to Brooker Wills fins in that they were passed down the nail from proximally and out through slots in the side of the nail distally to achieve better maintenance of length and rotation.

Intramedullary nails were also developed by a variety of surgeons and manufacturers for other long bones. For closed tibia shaft fractures, nonoperative treatment (cast and bracing) was the standard and good results were achieved. These patients were typically immediately ambulatory and weight bearing, in contrast to patients with femur shaft fractures. The advantages of medullary nailing over nonoperative treatment were not nearly as great in the tibia as femur. For open fractures, the standard alternative was external fixation, as the incidence of infection with nailing was considered too great. Even when medullary nailing was recommended there was considerable debate between reamed and unreamed nails and solid versus cannulated nails and closed section versus open section nails. Reamed nails were thought to have a higher complication rate in open fractures due to disruption of the medullary blood supply to the cortex which had already had its periosteal blood supply disrupted by the trauma. It was thought that the bone could tolerate injury to one, but not both of its primary blood supply. We participated in the decade-long debates of nailing versus closed treatment of tibia shaft fractures as well as reamed vs. unreamed nailing of the tibia.

Early in the decade I recall performing about 2 dozen cast changes for slight malalignment of a college football player with a tibia shaft fracture who went on to heal with good alignment in 14 weeks, had a successful senior year, and a 10 year National Football League (NFL) career. I also recall a Lobo basketball player who was 6 feet 9 inches tall with a grade 1 open tibia shaft fracture sustained when coming down with a rebound during a game at the Pit. We felt he would benefit from nail treatment but the length of his tibia was much longer than any available tibia nails. We overcame this technical problem with a femoral nail custom bent to achieve a proximal (Herzog) curve. He healed without infection. He had excellent function and completed his college basketball career the following year. This case illustrates the need to have special equipment and implants and techniques to successfully treat athletes who tend to be at the extreme end of human anatomy.[3]

There were two Highland High School football players with tibia shaft fractures. The first was an All-State running back who sustained a closed tibia shaft fracture during the final regular season game. He developed a compartment syndrome and was successfully treated with 4 compartment fasciotomy. We debated closed treatment versus external fixation or medullary nailing and eventually selected delayed nailing. His bone and soft tissue healed and he went on to a successful NFL career. This case illustrates the frequency of compartment syndrome associated with tibia fractures in football as well as the potential advantage to the soft tissue of bony stabilization.[3]

Another Highland High School football player was a 300 pound lineman who sustained a grade 3A open tibia shaft fracture when hit by a car while changing a flat tire. He was treated with debridement and external fixation. His soft tissue healed but he had a delayed union with possible indolent infection that persisted for 9 months. A variety of treatment alternatives, including bone resection and transport, medullary nailing, plating, casting, and external fixation were considered. He was in good alignment and the radiographs looked as if he were trying to heal. The soft tissue envelope was sufficiently worrisome that operative treatment was not appealing. I elected to treat him with 3 more months in a long leg cast and he healed solidly. After a year out of football, he was recruited and successfully played 3 years of college football. This case illustrates the importance of recognizing the inherent healing potential of patients and that it is not always necessary or optimal to aggressively operatively treat every situation, even if you have a variety of operative tools at your disposal.[3]

Both antegrade and retrograde nails were developed for humerus shaft fractures. Antegrade nails were more effective but did cause entry site shoulder problems and were not associated with the excellent healing rates and return of function seen with nailing of long bones of the lower extremity. Plating also had its problems, including radial nerve palsy and nonunions. We participated in another decade-long debate regarding nail versus plate for humerus shaft fractures.

During this decade, a high rate of complications was noted with flexible nailing of Ender, particularly problems with loss of reduction and malunions from relatively unstable fixation. As Dr. Richard Miller noted, "The only time I hear about flexible nails is at our M&M conference." Flexible nails generally passed out of favor except for pediatric femur shaft fractures.

This decade also saw the introduction of retrograde femoral nailing. My first case of retrograde femur nail was a young man with a patella fracture, a comminuted femur shaft fracture, and extensive abrasions about the hip. I needed to make an incision at the knee to stabilize his patella and wanted to stabilize his femur but did not think it safe to make a hip incision through the abrasions. There were no femoral nails available with the necessary bend for retrograde insertion so I utilized a long tibia nail. This was also prior to the development of locking holes but there were slots in the tibial nail for longitudinal wires. The patient was placed in the supine postion without use of a fracture table. This was much easier and quicker than standard nailing where positioning on the fracture table took an hour or more.

The distal femur was visualized through an anterior approach and the displaced patella fracture and an intercondylar entry hole was established. A ball-tipped guide was introduced into the medullary canal of the distal femur. With gentle traction the femur reduced easily and the ball-tipped guide placed across the femur shaft fracture under fluoroscopic control. Again, this occurred much easier and faster than typically occurs with antegrade nailing. The medullary canal was reamed and the reamings were removed from the knee joint under direct visualization. The tibia nail was inserted and a transverse Kirshner wire was placed transversely through the distal femur medial and lateral cortex and the slots in the nail to maintain position of the nail in the distal fragment and prevent the nail backing into the knee joint. The proximal fragment had friction interference with the nail in the isthmus of the femur. Locking screws and holes had not yet been developed. The patella was then fixed with tension band wiring.

The patient was placed in a supportive knee brace and allowed to ambulate. Initially, he was non-weight bearing with no knee motion. He progressed to partial and then full weight bearing with active assisted range of motion and then progressive resistance knee motion and healed with excellent function. One year later he had removal of the patellar implant. At that time he also underwent arthroscopic removal of the nail. The insertion site had sealed over with scar tissue and the knee joint surface and internal anatomy looked normal. The nail was removed through a 1.5 centimeter incision in the patellar tendon utilizing the previous skin incision. He was part of a 2 to 10 year follow up of retrograde nailing of femur shaft fractures reported in 2000.[4] At 10 years, he was functioning normally, with equal limb length and no degenerative changes to his knee joint despite the patella fracture retrograde nailing.

This was important information because there was concern at that time that retrograde nailing would cause all sorts of knee joint problems. This case also suggested that retrograde nailing might be easier and quicker than antegrade nailing. This case stimulated work on a more general use of retrograde femoral nailing for femur shaft fractures and we participated by providing some of the earliest cases, techniques, and long term followup.

There are numerous disadvantages to antegrade nailing that can be overcome with retrograde technique and are particularly important in special situations. First it was necessary to develop a good technique. We settled on placement of the nail through the inter-condylar notch in line with the medullary canal and anterior to the femoral attachment of the cruciate ligaments. Although covered by articular cartilage, this area does not contact the patella or tibia and is accessible from an anterior incision. A 10 millimeter (mm) hole in the non-articulating portion of the distal femur compared favorably to the 2 (1 tibia, 1 femoral notch) 10 mm holes placed for ACL reconstruction. These graft tunnels were not thought to be associated with a high rate of articular injury and deterioration.

Success with this entry site was also seen with retrograde nails for distal femur fractures introduced by Green, Seligson, and Henry (GSH nail). These were short nails with multiple transverse locking screws based on Huckstep nails from Australia. We were among the first to utilize the GSH nail for distal femur fractures proximal to total knee replacements with good results and published results with Drs. Jabczenski and Crawford that are still referenced today.[5] We also studied the mechanics of nail versus plate for distal femur fractures with Drs. Behzadi and Firoozbakhsh which are also commonly referenced today.[6]

1995-2005

During this decade, the Russell-Taylor nail became available and commonly used. This was a closed section nail with proximal and distal locking holes. The proximal holes allow two fixation options, either from the greater trochanter to the lesser trochanter or "reconstruction" mode from the lateral cortex into the femoral head and neck. The technique of over-reaming with use of smaller diameter statically locked nails became standard. We no longer relied upon friction interference of the nail with the endosteum. Nails were slid or tapped into place rather than being forcefully driven into place. There was less tendency for the nails to deform during insertion and distally locking was easier. It became recognized that statically locked nails did not always cause nonunion, and typically healed without dynamization or locking screw removal. Static locking became standard for nearly all femur shaft fractures and resulted in improved results with more precise restoration of length, rotation, and alignment than had been achieved previously.

The Alta nail system was also used during this decade. It incorporated the new technology of titanium, allowing an implant which was stronger but less stiff than stainless steel. It was also a closed section nail with proximal and distal transverse locking. Titanium nails were particularly attractive for use in the tibia where a small diameter nail could be placed in the tight medullary canal with less endosteal reaming, but with sufficient strength without too much stiffness to avoid nail breakage with nonunion.

During this decade, we participated in the debates of operative versus non-operative, plate versus nail, unreamed versus reamed nails, and nail versus external fixation for open fractures. Reamed nailing became accepted treatment for closed tibia shaft fractures as well as grades 1 and 2 open tibia shaft fractures. External fixation retained a role for more severe open tibia shaft fractures and there are selected indications for unreamed nails, plates, and nonoperative treatments.

For the humerus shaft, a variety of problems with nails persisted. The distal medullary canal is not very long or wide, especially from anterior to posterior (AP), in contrast to the long bones of the lower extremity, femur and tibia. Most of the nails were the same diameter proximally and distally and did not match the anatomy of the humerus medullary canal, which was large proximally and small distally. This resulted in nails that were too tight in the distal fragment. A variety of problems ensued, including distraction at the fracture site and nonunion since the nail would not advance into the distal part of the distal fragment. Distal cortical penetration also occurred anterior due to the small AP canal diameter. Thermal injury from cortical damage from reaming occurred.

At the same time, plates were enhanced by locking technology. This was important in the humerus, which has less cortical bone than the lower extremity long bones. Humerus shaft fractures are also more common than femur or tibia in elderly patients where osteoporosis is common. Plates became preferred to nails in the upper extremity long bones in general and for the humerus shaft in particular.

Femur shaft fractures in the elderly were the focus of a UNM report demonstrating that medullary nails were effective but that there is a high rate of mortality similar to that seen with proximal femur fractures in the elderly.[7] This mortality rate previously had not been prominent in the orthopaedic literature.

Removal of medullary nails has been a controversial issue that was addressed in a *Journal of Trauma* article from UNM written with Dr. Miller.[8] We demonstrated that there were significant risks with nail removal, including postop hematoma formation, refracture, and a low but significant incidence of infection. It was also difficult to objective demonstrate an improvement in subjective symptoms like pain with cold weather after nail removal. Over the course of the decade, removal of nails went from being performed in 90% of cases and routinely indicated to being done with much more selectivity. This article is commonly referenced to support that change. We now leave in the majority of nails.

If nails are going to be removed, it is much easier to do so between 12 and 24 months. After that, bony remodeling and incorporation may make nail removal extremely difficult and associated with a very high rate of complication. Incarcerated (unable to be extracted) nails, equipment breakage, and even bone extraction have been encountered. Specialized equipment to extract nails becomes increasingly hard to recognize and acquire. One of my patients with an Alta nail with a torx head screw and nail cap returned to England where surgeons twice attempted to remove the nail and were unsuccessful.

The first time they did not recognize the need for specialized equipment and were unsuccessful. The second time they had the torx head screwdriver but could not get access due to bony overgrowth. The patient did return to me where I recommended nail retention but she very much wanted it out and I agreed to make an attempt with the understanding that I would stop if the bone destruction was going to be too great. With appropriate preparation, torx headed screwdrivers, osteotomes and bone removal devices, fluoroscopy, adequate soft tissue dissection and visualization, and patience we were able to remove the nail and locking screws without too much bone injury. She recovered and was happy.

This case illustrates that nail removal should be selectively done in the window between 12 and 24 months after implantation and only after adequate preparation and planning.[9] It also illustrates that no one looks good removing implants and that surgeons should always consider the potential difficulties of future removal when placing orthopedic implants, especially if there are unusual features like a new type of screw head.

During this decade the short retrograde nails (GSH) were demonstrated to have problems with instability and passed out of favor. Locking plates have largely supplanted them for distal femur fractures, although long retrograde nails have been shown to be efficacious.

Retrograde nailing of femur shaft fractures gained acceptance during this decade, almost equal to antegrade nailing in reports from a variety of centers, including UNM.[4] Retrograde nailing has been shown to be easier and faster than antegrade nailing, although both give excellent long term outcome. In certain situations retrograde nailing may be better than antegrade nailing. These include ipsilateral acetabular fractures where it is important to maintain a pristine soft tissue environment for operative approaches to the acetabulum. Associated spine fractures that preclude positioning on a fracture table are another indication for retrograde nailing. Very large patients may be difficult to position on a fracture table and proximal obesity may make access to the greater trochanter so difficult that retrograde nailing is preferred.

There is less pelvic radiation with retrograde nailing and this may benefit pregnant patients with femur shaft fractures. Bilateral femur shaft fractures typically require 2 different positions for antegrade nailing but can be achieved through a single supine position for retrograde nailing. In general, antegrade technique is preferred for fractures of the proximal third of the shaft and retrograde technique for fractures of the distal third of the shaft. Middle third fractures can be treated with either technique.

Entry site problems occur with both antegrade and retrograde techniques in about equal frequency. With antegrade technique there is scar and occasional heterotopic bone formation in the gluteal muscles, some reports of gait disturbance from hip muscle dysfunction, and hip pain from nail prominence over the greater trochanter. For retrograde techniques there can be knee pain or stiffness and injury to the articular surface of the femur or patella from aberrant entry site or nail prominence.

The objection that retrograde nailing somehow "ruins" the knee has been overcome with decades of experience. Malreduction can occur if it is not recognized that fracture reduction must be obtained prior to drilling the entry site. This is particularly true for more proximal fracture (subtrochanteric) with antegrade nails and more distal fractures with retrograde nails. There were some reports of a slightly higher rate of delayed union with retrograde nails but this was at a time when typical retrograde nails were smaller diameter than antegrade. With equal diameter nails the union rate appears equal in the 2 groups.

The optimal location and pattern of proximal locking has also been a concern with retrograde nailing. There was widespread concern for injuring the femoral artery with an anterior to posterior proximal locking screw. With Dr. Brown, we were able to demonstrate and publish the location of the femoral artery relative to proximal locking screws for retrograde femoral nails and the safe corridor for their placement.[4] As Dr. Moed said, "You are more likely to poke yourself in the eye with the drill bit than to injure the patient's femoral artery." Our publication demonstrated there was a wide safe corridor for screw placement. That, combined with extensive nationwide experience with retrograde femoral nailing over 2 decades has virtually eliminated that particular objection to retrograde femoral nailing.

Nailing for trauma reconstruction includes femoral shortening and de-rotations. Dr. Winquist developed an intramedullary saw that can cut the femur from inside the medullary canal by sequentially hand rotating a transverse saw blade. A cam mechanism progressively increases the diameter of the saw while the operator simultaneously spins the blade within the medullary canal. A notch is cut in the endosteum and progressively expanded to a transcortical cut until the bone is osteotomized. De-rotation can then be performed to correct deformity and a nail placed to maintain reduction and provide stability during healing. Femoral shortening can also be performed by making two cuts at predetermined sites, splitting and displacing the intercalary piece, shortening the femur, and stabilizing it with a medullary nails. I have used both of these techniques to good effect. Femoral de-rotation and shortening with intramedullary saw and nail provide a good alternative to open osteotomies and plating or other more complicated techniques for limb length equalization like Ilizarov lengthening with distraction osteogenesis.

Indications for nail removal evolved during this decade. In an article co-authored with Dr. Miller, we reported the results of nail removal in the *Journal of Orthopaedic Trauma* that is widely cited.[8] Previously 90% of implants were removed mostly for theoretical future "risks" and the thought that the implant inherently caused pain. More recently, 90% of implants are retained with removal indicated for specific situations such as infection with healed fracture or prominence of implant causing symptomatic irritation of overlying soft tissue.

2005-2012

In the last 7 years, reamed medullary nailing of tibia shaft fractures has moved from accepted to standard treatment. However, we should not forget that tibia shaft fractures tend to heal biologically and can be successfully treated non-operatively. The advantages of operative treatment are a more reliable and probably better reduction that probably has some benefit to patients generally. There is also an earlier return to function, as it is far easier to mobilize and return to work earlier with a nail. There is a recognized incidence of knee pain although this tends to improve once the fracture heals. Suprapatellar nailing has been suggested to reduce this problem as well.

Although nails are successful at achieving adequate reduction and reductions generally superior to closed treatment there are still some problems. Gross malreductions do still occur, especially with more proximal or distal fractures of the tibia shaft treated by nailing. A variety of techniques to overcome this tendency have gained acceptance, including nailing in a semi-extended position, use of reduction clamps and temporary plates prior to nailing, and use of blocking screws. A small amount of distraction in a statically locked nail is well tolerated in the femur but may result in a nonunion in the tibia and should be avoided. I believe there is a role for dynamization of statically locked nails demonstrating delayed union, especially in the tibia. I recommend it to most patients who I see referred with delayed or nonunions as a simple outpatient procedure that often results in healing. It does not seem to be generally standard, based on the number of patients I have seen referred with delayed unions who have undynamized locked nails. There is also under-utilization of the dynamic locking slot available in many nail systems.

Subtle malreductions occur commonly, as we generally recommend restoration of length, rotation, and alignment for medullary nails and not true anatomic reduction. Some orthopaedists believe these subtle malreductions are the source of significant patient morbidity. I know of one orthopaedic traumatologist from this camp who had his own closed tibia shaft fracture treated with a Taylor Spatial frame in order to achieve a more anatomic reduction. Time will tell if the problems of knee pain and subtle malreduction are sufficient to move the pendulum away from medullary nailing as the standard treatment of tibia shaft fractures.

Medullary nailing of open tibia shaft fractures has now gained widespread acceptance and use of nails in more severe Grade 3 B and C fractures continues to grow. The infection rate appears to be no higher, and possibly lower, than external fixation (XF) and other alternatives. Staged reconstruction with initial external fixation converted in a few days or weeks to nails is a common protocol. In 2012, nails and XF are both reasonable options for skeletal stabilization of severe open tibia shaft fractures, although the trend is toward nails and away from fixators.

The last 7 years have shown a recognition of a role for damage control orthopaedics in some severely injured patients with multiple trauma, including femur shaft fractures. It has always been recognized that there was pathophysiology associated with placement of a medullary nail, including blood loss, soft tissue dissection and injury, and displacement of medullary contents into the blood stream with pathological implications for remote organs, including the heart, lungs and brain. It was thought these processes were tolerated by most patients and the benefits of long bone stabilization in restoring an upright chest and early ambulation more than offset the physiological costs. There may be some patients who are severely injured who cannot tolerate these effects and medullary nailing will push them beyond their physiological tolerance, increasing the rate of pulmonary compromise and death. For these patients, damage control orthopedics is recommended.

It has followed principles developed in general surgery for multiply-traumatized patients. For these patients, initial treatment of the femur shaft fracture may be an external fixator which restores mechanical stability of the thigh with minimal soft tissue dissection, blood loss, time, or medullary disruption. After a few days or weeks of general support, when the patient's condition is more stable, the fixator can be changed to a medullary nail. Other techniques of damage control orthopaedics might be the use smaller diameter nails to minimize reaming and blood loss and delayed placement of distal locking screws to shorten the operative time of initial stabilization. Retrograde rather than antegrade nailing can be achieved in less time with less blood loss and may be preferred in the multiply traumatized patients. Delayed treatment of less important injuries and prioritization of injury stabilization are tenets of damage control in contrast to total early care.

Another use of medullary nails for reconstruction is lengthening over a nail or the intramedullary skeletal kinetic distractor (ISKD). With this technique, an intramedullary osteotomy is performed with the intramedulary saw developed by Winquist described earlier. A medullary nail with distal and proximal telescoping components is placed. With torque applied a one way ratchet allows the nail to progressively lengthen which pulls the bone apart at a slow rate and creates a distraction osteogenesis gap that fills with bone and lengthens the femur. The nail then serves to stabilize the construct, maintain alignment, and allow ambulation during consolidation phase of the regenerate. Lengthening over a nail can be a good alternative to lengthening with an external fixator, especially when there is no need to simultaneous correct angular deformity.

Intramedullary nails work so well they have gained worldwide applicability, including third world countries with limited technical infrastructure. The Surgical Implant Generation Network (SIGN) nail project has been particularly effective in dissemination of medullary nailing techniques throughout the world.

Conclusion

It is interesting to note that the first half of my career was spent as an advocate for operative treatment for a variety of fractures against the setting of non-operative treatment being prevalent to the point of ubiquitous. The latter half of my career has been spent advocating "rational" operative treatment and consideration for less aggressive interventions in certain situations, when the most popular approach seems to be operative treatment of nearly everything. As Dr. Brown, my former partner and fellow Iowa alum said, "They should give a funeral for non-operative treatment of fractures." I replied, "No one would attend."

Intramedullary nails have been a tremendous advancement in the care of trauma patients, and one of the greatest contributions from the field of Orthopaedics in the past 50 years. They are very effective at restoring length and alignment and early mobilization of the patient with low complication rates and excellent results in comparison to the alternatives. They were a harbinger of many important advances in orthopaedics, including operative treatment of fractures and minimally invasive surgery to minimize injury and facilitate functional recovery. Medullary nails are perhaps the best example of respect for biology of healing while overcoming the mechanical disruption that occurs with long bone fractures. It has been my good fortune to participate in the application of this technology to the trauma victims of the state of New Mexico and the southwest region over the past 25 years. That knowledge has also been shared with over 100 residents and fellows from our training programs, as well as other surgeons from continuing medical education courses and publications.

References

1. Street DM, Hansen HH, Brewer BJ. The medullary nail: presentation of a new type and report of a case. *Arch Surg*.1947;55(4):423-432.

2. White, GM, Healy WL, Brumback RJ, Burgess AR, Brooker AF. The treatment of fractures of the femoral shaft with the Brooker-Wills distal locking intramedullary nail. *J Bone Joint Surg*. July 1986;68(6):865-876.

3. DeCoster TA, Stevens MA, Albright JP. Sports fractures. *Iowa Orthop J*. 1994; 14:81-84.

4. Hutchinson KB, DeCoster TA, Brown GA, Crawford MK, Robinson B. Retrograde nailing of femur shaft fractures through the intercondylar notch for specific indication: 10 years' experience. *Surg Technol Int*.2000;9:259-265.

5. Jabczenski FF, Crawford M.Retrograde intramedullary nailing of supracondylar femur fractures above total knee arthroplasty: a preliminary report of four cases. *J Arthroplasty.* February 1995;10(1):95-101.

6. Firoozbakhsh KK, Behzadi K, DeCoster TA, Moneim MS, Naraghi FF. Mechanics of retrograde nail versus plate fixation for supracondylar femur fractures. *J Orthop Trauma.*April 1995; 9(2):152-157.

7. DeCoster TA, Miller RA. Closed locked intramedullary nailing of femoral shaft fractures in the elderly. *Iowa Orthop J*. 2003;23:43-45.

8. Miller R, Renwick SE, DeCoster TA, Shonnard P, Jabczenski F. Removal of intramedullary rods after femoral shaft fracture. *J Orthop Trauma*. December 1992;6(4):460-463.

9. DeCoster TA, Xing Z. Femur shaft fractures. In: Bulstrode C, Buckwalter J, Carr A, Marsh L, Fairbank J, Wilson-MacDonald J, Bowden G, eds. *Oxford Textbook of Orthopaedics and Trauma.* New York, NY: Oxford University Press; 2002:2240-2252.

Evolution of the Management of the Dislocated Knee: A Trauma Perspective

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Tom, Dan, and I (RCS) thought it would be interesting, historically to look at the differing perspectives on the evaluation and treatment of the dislocated knee, especially with the perspective of a trauma surgeon. We all believe there are many ways to treat knee dislocations, and often the perspective of the sports medicine orthopaedic surgeon will result in a totally different approach to treatment than what is seen from the perspective of the orthopaedic traumatologist. Using my (TAD) 35 years from residency to recent retirement at the University of New Mexico (UNM) gives a great insight to the changes in management of what was once thought a rare event. On a side note, I am happy to announce that although retired, I will continue on at UNM on a part-time basis.

Phase 0 (training 1976-1985)

In the 1980s, knee dislocations were considered a rare event. Most of the literature emanated from trauma centers and military experience.[1] It was said that the average orthopaedist could expect to see 1 case of knee dislocation in his or her entire career. It was known that knee dislocations were associated with popliteal artery injuries and that under-recognition, delay, and under-treatment of knee dislocations were common and associated with poor outcomes, including amputation of dysvascular limbs. The anterior knee dislocation was felt to have the highest incidence of arterial injury.[2]

Phase I (1985-1995)

In my second year of practice in 1987, I treated 3 cases of knee dislocations. They ran the gamut of high energy, open injury with obvious nerve and artery injuries to lower energy, closed injury with gross instability but more subtle associated injuries. Diagnosis at that time was universally based on plain radiographs demonstrating no contact between the articular surfaces of the distal femur and proximal tibia. Arteriography was considered essential because of the known association with arterial injury. Closed reduction was usually readily accomplished by realigning the limb with gentle axial traction and knee extension. Early popliteal artery repair or bypass was typically performed and external fixation spanning the knee was developed to maintain reduction. However, many surgeons stabilized such a knee temporarily with large Steinman pins crossing the knee through the femoral notch/tibial eminence. A good outcome was considered limb salvage with a reduced knee joint. Rehabilitation and long term results of range of motion and stability were not the focus of the literature.

My small series of knee dislocations in a short period of time suggested that the literature description of this problem did not entirely match our experience. The first observation was that knee dislocations were much more common (3 in 1 year) than suggested by the literature (1 in a career of 35 years). The second was that knee dislocations were not all high energy injuries but a wider spectrum of mechanism of injury. However, our attempts at publication of this experience were not well received by editors at that time. We did publish the more general topic of knee ligament injuries ipsilateral to femur shaft fractures in 1989.[3] At that time, we recommended a good ligament exam of the knee following nailing of femur shaft fractures with particular attention to vascular status if bicruciate ligament injury was diagnosed.

The late 1980s was also when effective procedures of knee ligament reconstruction and arthroscopic techniques were being developed by sports medicine. Anterior cruciate ligament (ACL) reconstruction had moved from extra-articular tenodesis and fascia lata intra-articular grafts to more substantial bone-patellar tendon-bone grafts with arthroscopic technique, and results were improving dramatically.

In the early 1990s, treatment of knee dislocations began to include more aggressive repair of torn structures and early reconstruction of the anterior cruciate ligament and later, the posterior cruciate ligament (PCL). Dr. Wascher and others at UNM Hospital, Dr. Schenck at the University of Texas San Antonio, and other orthopaedists elsewhere began to apply these ligament reconstruction techniques to patients with knee dislocations. The goal was to improve the long term stability without causing excessive stiffness. We attempted to report the results in sports and trauma literature but, again, editorial resistance was encountered.

Phase II (1995-2000)

Finally, in 1997, we combined forces and were successful at first publishing in *Journal of Orthopaedic Trauma* the results of the UNM experience.[4] Our main conclusions were: 1) knee dislocations were much more frequent than previous literature suggested, and 2) there was a range of energy mechanism from low (stepping off a curb) to medium (twisting injury to the knee in sports) to high (motor vehicle wreck).

Many knee dislocations actually presented with the joint reduced. We showed that bicruciate ligament tears (anterior and posterior cruciate ligaments both torn at the same time) were equivalent to knee dislocations. We postulated that in order to tear both the ACL and PCL simultaneously, the knee must have been dislocated at some point during the injury displacement. Evidence to support this theory was the fact that the knee could always be dislocated in the operating room under anesthesia when treating bicruciate ligament tears and further, that the rate of popliteal artery injury was the same in the bicruciate ligament tear population and the knee dislocation (by radiograph) population. This broadened definition partially accounted for the increase in frequency of knee dislocations.

Arteriography was not always essential. To be fair, I freely admit that I feel stronger about this than Drs. Wascher or Schenck. When an obvious arterial insufficiency accompanied a knee dislocation, it was not necessary to obtain an arteriogram because the key to successful outcome was timely vascular reconstruction. An arteriogram only delayed surgery and did not add useful information. Also, when a reliable vascular physical exam was repeatably normal, the incidence of clinically significant arterial injury was zero, thus angiogram was not necessary. Those recommendations initially were not palatable to reviewers but, with subsequent orthopaedic and vascular literature reporting the same conclusions, have made their way into treatment recommendations.[5,6] As Dr. Schenck stated, if there is any doubt as to the arterial status of the limb, then an arteriogram is recommended, or if unavailable, arterial exploration and reconstruction. Clearly, delay for obtaining an arteriogram in the presence of an avascular limb is best avoided by performing a surgical exploration and arterial repair/reconstruction.

It was my observation that the pattern of injury for knee dislocations was different from what had been described in earlier literature and in the developing literature on multiple ligamentous injuries of the knee. The differences are the frequency of associated injuries, the nature of the patients sustaining these injuries (mechanism, level of sports activity, and rehabilitation reliability), and the problems they encounter. Knee dislocations commonly have associated injuries involving tendon avulsions, the patella, nerves, capsule, tissue loss, and other extremity injuries.

Open knee dislocations often involve tissue loss, not merely tearing. One particular patient from southern Colorado had the medial side of his knee skived off in a garbage truck injury. He lost not only the medial skin but all the soft tissue and 2 centimeters of his proximal tibia, as well as tearing both cruciate ligaments and injuring his popliteal artery. Initial treatment was debridement, popliteal artery bypass, and external fixation. This was followed by a musculocutaneous free flap and then an osteochondral-ligamentous patella with quad tendon allograft to restore the proximal tibia, including joint surface (patella), with attachment of the quad tendon to the femur to reconstruct a medial collateral ligament. This resulted in a successful salvage with reasonable function and a decade of referrals from south central Colorado.

Tendon avulsions are the rule rather than exception in knee dislocations. These may involve the quadriceps off the patella, the patella tendon off the tibia tubercle, the iliotibial band off Gerdy's tubercle, and biceps off the proximal fibula. Soft tissue disruption of tendon attachments of the popliteus and hamstrings have also commonly been seen.

Although knee dislocation specifically refers to the tibia-femur articulation, knee dislocations commonly involve patella injury. Quadriceps and patella tendon injuries can be bony avulsions or soft tissue disruptions. Articular cartilage injuries with loose bodies occur. Patello-femoral ligament disruptions occur and often are seen in a spectrum with KDIIIM ligamentous injuries (both medial collateral ligament (MCL) and medial patellofemoral ligaments torn resulting in a dislocation of both tibio-femoral and patella-femoral joints). Buttonholing of the distal femur through the capsule and patello femoral ligament may prevent closed reduction. Even open reduction can be difficult, as the structures preventing reduction may be hard to identify and correct. Delay in such open reduction of the posterolateral knee dislocation with medial furrowing of the skin routinely results in soft tissue necrosis.

Although nerve injuries can be associated with any ligament injury to the knee, they are much more frequent in knee dislocations and may involve the peroneal or tibial nerve. Nerve injuries associated with knee dislocations are commonly stretch injuries with an extensive zone of injury. Peroneal nerve injuries may be treated with decompression but results of nerve repairs and grafts are generally poor. Tibial nerve injuries cause even greater dysfunction. Lacerations of the tibial nerve do respond somewhat better to nerve repair, although the recovery is prolonged and incomplete.

The capsule of the knee is always torn with knee dislocations. Although capsular injury has not received much attention in knee ligament reconstruction, there may be a role for acute repair in the knee dislocation setting. There is typically a tissue sleeve avulsion around the proximal tibia and the tissue itself. Its correct anatomic location can be identified surgically in the acute setting. Repair allows some restoration of alignment of the articular surfaces and some stability to the joint, although this technique has not gained widespread popularity. The specific anatomic location of the capsule attachment to the proximal tibia was reported in the *Journal of Orthopaedic Trauma* in 1999[7] and was re-published as a classic article of clinical significance in 2004.[8] The specific capsular anatomy was noted to be significant clinically in the 1995 report of knee sepsis resulting from a pin track in the proximal tibia.[9] Repairs of soft tissue avulsions around the knee may be possible and effective in acute knee dislocations, whereas they are not generally possible or effective in more chronic treatment of knee ligament injury patients.

Phase III (2000- 2010)

The early descriptions of knee dislocations lacked anatomic specificity of injured structures. The direction the tibia was displaced relative to the femur was used to classify knee dislocations. This was similar to other joint dislocations. However, the torn ligaments were not named and no particular patterns were reported. This is where Dr. Schenck's knee dislocation classification scheme was very helpful, as it required an initial description of the status of the 4 main ligaments of the knee: ACL, PCL, LCL, MCL.[10] The advent of readily available MRI in the late 1990s to supplement the specific ligament injury diagnosed on clinical exam was crucial to providing reliability and specificity to this anatomic ligament injury as the basis for classification of knee dislocations. It has been a great pleasure observing the routine use of the "KD#" classification in daily rounds by the residents at UNM Hospital. It has reinforced just how common this injury is, as hardly a week goes by without at least 1 patient on the inpatient list with this injury. It is also gratifying to see the improved clinical assessment, designation, and treatment of the specific anatomic injury.

Rehabilitation after serious knee injury is important to restore motion and avoid stiffness. The degree of compliance in trauma patients with knee dislocations is often not as great as an injured football player or other sports injury patient. The trauma patients may not even come back to clinic, much less participate in physical therapy sessions several times a week for months. It is clear that a stiff knee is worse than an unstable knee. A stiff knee is more disabling to the patient and is harder for the orthopedic surgeon to treat. Trauma patients often have injuries to other extremities which further limit their ability to focus on rehabilitation of the knee and tend to increase the incidence of stiffness, especially after operative stabilization of the injured knee ligaments. The daily activity of trauma patients and the amount of time spent doing activities involving running and twisting may be much less than the average sports patient.

There may be some patients with knee dislocations who are best treated with reduction and stabilization in a reduced position with a spanning external fixator. They recover from their overall injuries for 6 weeks and then have the fixator removed in the operating room with a gentle closed manipulation of the knee followed by bracing and rehabilitation. If they have subsequent difficulty with instability, then a delayed reconstruction of the unstable ligaments can be performed.

As Dr. Schenck has mentioned, Dr. Mercer reported what we consider to be the optimal pin and frame configuration for knee spanning external fixation in the *Journal of Orthopaedic Trauma*.[11] There is a tendency for the tibia to sag posteriorly that may go unrecognized, thus it is important to confirm a good joint reduction radiographically at the end of the case when applying an external fixator for knee dislocation.

There have been numerous other publications from UNM, including "The Ten Commandments of Knee Dislocation" in 2001,[12] "Multiple Ligamentous Injuries of the Knee in the Athlete" by the American Academy of Orthopaedic Surgery in 2002,[13] Orthopedic Knowledge Online topic on Knee Dislocation in 2004[14] and the update in 2011,[15] and the Orthopedic Trauma Association Fracture and Dislocation Classification in 2007.[16] All of these provide a current perspective on the evaluation and management of knee dislocations.

Current

The definitive treatment of knee dislocation is now firmly in the realm of sports medicine. Initial treatment still often occurs with general orthopaedists and trauma orthopaedists. Recognition that bicruciate ligament tears are the equivalent of knee dislocations has become accepted. A high index of suspicion for popliteal artery injury and appropriate use of angiography in the initial evaluation is standard. Early bicruciate ligament is the usual treatment, although there is an accepted role for staged treatment with external fixation in some patients. The goal of restoring full function to the knee with normal stability and motion remains a quest, but overall outcomes have improved over the past 3 decades.

As Dr. Schenck pointed out, there are trials and tribulations in an academic career and pursuing scholarly activity in orthopaedics. Current dogmas have a tendency to fade and popularity of techniques and concepts are cyclical. Perseverance and continued clinical correlation and modification of your opinion based on observed patterns, outcomes, and other published literature and podium presentations will result in overcoming the trials and celebrating the tribulations.

References

1. Debakey ME, Simeone FA. Battle injuries of the arteries in World War II : an analysis of 2,471 cases. *Ann Surg.* April 1946;123(4):534–579.

2. Green NE, Allen BL. Vascular injuries associated with dislocation of the knee. *J Bone Joint Surg [Am]*. 1972;59(2):236-239.

3. DeCoster TA, Teter KE. Knee ligament injuries ipsilateral to femoral shaft fractures. *Iowa Orthop J* . 1989;9:98-99.

4. Wascher DC, Dvirnak PC, Decoster TA. Knee dislocation: initial assessment and implications for treatment. *J Orthop Trauma*. October 1997;11(7):525-529.

5. Stannard JP, Sheils TM, Lopez-Ben RR, McGwin G Jr, Robinson JT, Volgas DA. Vascular injuries in knee dislocations following blunt trauma: evaluating the role of physical examination to determine the need for arteriography. *J Bone Joint Surg*. May 2004;86:910-915.

6. Mills WJ, Barei DP, McNair P. The value of the ankle-brachial pressure index for diagnosing arterial injury after knee dislocation: a prospective study. *J Trauma*. June 2004;56(6):1261-1265.

7. DeCoster TA, Crawford MK, Kraut MA. Safe extracapsular placement of proximal tibia transfixation pins. *J Orthop Trauma*. May 1999;13(4):236-240.

8. DeCoster TA, Crawford MK, Kraut MA. Safe extracapsular placement of proximal tibia transfixation pins. *J Orthop Trauma*. 2004;18(8 Suppl):S43-47.

9. Stevens MA, DeCoster TA, Garcia F, Sell JJ. Septic knee from Ilizarov transfixation tibial pin. *Iowa Orthop J*. 1995;15:217-220.

10. Walker DN, Hardison R, Schenck RC. A baker's dozen of knee dislocations. *Am J Knee Surg*. 1994;7(3):117-124.

11. Mercer D, Firoozbakhsh K, Prevost M, Mulkey P, DeCoster TA, Schenck R. Stiffness of knee-spanning external fixation systems for traumatic knee dislocations: a biomechanical study. *J Orthop Trauma*. November 2010;24(11):693-696.

12. Wascher DC, DeCoster TA, Schenck RC Jr. The ten commandments of knee dislocations. *Orthopedic Special Edition*. 2001;7(2).

13. Schenck, RC, ed. Multiple ligamentous injuries of the knee in the athlete. Illinois: AAOS, 2002.

14. Richter DL, DeCoster TA, Stannard J, et al. Knee Dislocation. AAOS website: Orthopaedic Knowledge Online. 2004.

15. Richter DL, DeCoster TA, Stannard J, et al. Controversies and future directions. AAOS website: Orthopaedic Knowledge Online. 2011;9(7).

16. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium – 2007. *J Orthop Trauma*. 2007;21(Supplement):S1-S133.

Department History
Stephanie Cartier

Providing quality orthopaedic treatment for all New Mexicans, regardless of ability to pay, is the central mission of the University of New Mexico Department of Orthopaedics and Rehabilitation. Every aspect of the program reflects that mission, and the department has made great strides since its inception nearly 40 years ago to offer the most comprehensive care available in the state.

Founded in 1970 with the hiring of the first department chair, Dr. George Omer Jr., an internationally recognized leader in hand surgery, the UNM Department of Orthopaedics and Rehabilitation has a long tradition of excellence. Omer and Dr. Moheb Moneim, the second chair of the department, gradually built a diverse team of orthopaedic experts to provide outstanding treatment. "This program is successful because of the vision of our previous leaders, and our program continues to be clinically strong," said Dr. Robert Schenck Jr., the current chair of the department. "We have been able to find the right mix of people who enjoy being orthopaedic physicians, each with a unique personality, but who share the same common denominator of commitment to our mission of patient care for all patients from all walks of life."

With 32 faculty members in every orthopaedic specialty, as well as in physical therapy, the department offers an exceptional range of care. Every physician has completed highly specialized fellowship training in his or her area of expertise, and the department is home to some of the only such specialists in the state.

Academics are central to the program, and provide a tremendous benefit for patients. "We are a teaching facility. Our primary reason for being here, other than being a safety net for patients, is the education of residents and medical students. Because of that, we need a wide variety of procedures for their experience," said Schenck. "With that, we have a lot of resources for patient care and expertise for patient care management."

Over the years, the residency program has made remarkable achievements, and is consistently listed as one of the best orthopaedic residencies in the West by the Residency Review Committee. The 5-year program is training 25 residents in all aspects of orthopaedic surgery, with collaborations throughout the region.

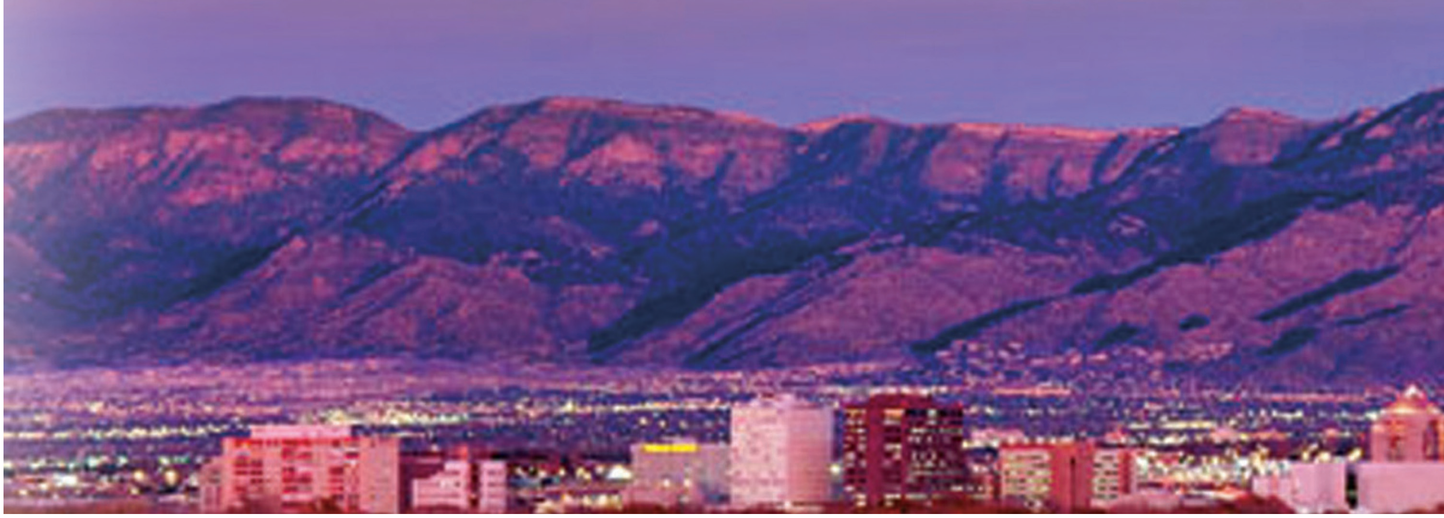
As an academic center, the department is heavily invested in research, and has plans to expand efforts in the next 5 to 10 years. Current strengths are focused on clinical activities, biomechanical studies, and patient outcomes. The department collaborates with UNM Main Campus and has had tremendous success with civil engineering.

The pediatric orthopaedic team is studying bone metabolism and bone health in children and adults to determine ways to combat osteoporosis and vitamin D deficiency. They are also examining the impact of cultural diversity on care and outcomes, based on New Mexico's unique cultural mix of Native Americans, Hispanics, and Whites.

Cutting-edge research, combined with top-notch faculty representing every orthopaedic specialty and a nationally recognized residency program have helped to enrich care offered to all residents of New Mexico. The UNM orthopaedic team has 5 clinics, including general orthopaedics, faculty, sports medicine, Lobo Athletics, and pediatrics, and operates in 3 facilities.

With such outstanding accomplishments, growth is inevitable. UNM and the UNM Health Sciences Center are building a hospital and clinic based on the West side, the Sandoval Regional Medical Center. "Our team looks forward to creating, in conjunction with the UNM Health Sciences Center, a strong orthopaedic presence on the West side to complement what is currently being built by Presbyterian," said Schenck. The new medical center is scheduled to open in the summer of 2012.

While looking to the future with anticipation, Schenck, who has been Chair of the Department since 2006, is also focused on what worked to build the program, and insists on building on that foundation. "Integrity comes first; it's the basis of everything we do. Second, we are committed to being open to new ideas as we advance. Third, we are working to cultivate excellent physicians, but encouraging humility. With those three things, I believe we can completely move forward to where we want to be in the future," said Schenck. "This is a very exciting time for our team. We have great satisfaction in what we do, the patients we care for and how we provide care with our own practices as well as working with residents. We in the department feel very fortunate that we can work here."



University of New Mexico Department of Orthopaedic Surgery Alumni

Residents

Aboka, Alexander	2011
Achterman,Christopher	1977
Adams, Brook	2011
Adler, Zachary	2007
Agarwala, Amit	2002
Alyea, Alan	1986
Balduini, Frederick	1981
Barmada, Adam	2001
Bear, Jan	1991
Becker, Jeremy	1997
Behzadi, Kambiz	1994
Benson, Robert	1973
Benson, Eric	2007
Bergeson, Ryan	2008
Bernasek, Thomas	1986
Blackwood, C. Brian	2011
Bloome, David	2001
Burner, William	1980
Burney, Dwight	1980
Burwell, Dudley	1987
Butler, Dale	1973
Campbell, Everett	1973
Cashmore, Bourck	1997
Castillo, Richard	1988
Child, Zachary	2011
Cleary, Joel	1985
Cohen, Mitchell	1992
Cole, Harry	1992
Conklin, Matthew	1988
Conrad, Clayton	2009
Cook, Geoffrey	1988
Cortese, David	2005
Crawford, Mark	1994
Dona, Grant	1993
Downey, Daniel	1992
Durrani, Shakeel	2010
Dvirnak, Paul	1996
Echols, Paul	1978
Eglinton, Daniel	1983
Fahey, James	1978
Ferries, James	1995
Ferro, Thomas	1990
FitzPatrick, Jennifer	2010
Franco, John	2003
Garza, Orlando	1977
Goodman, Robert	1980
Griffiths, Stan	1989
Grimes, Speight	2004
Hanosh, Christopher	2001
Hartman, Gregg	1997
Hayes, Robert	1975
Hayes, William	1996
Heetderks, David	1990
Helpenstell, Thomas	1991
Hensal, Fredrick	1982
Huberty, David	2005
Ilic, Sergio	1977
Izadi, Kayvon	2008
Jabczenski, Felix	1989
Johnson, Robert	1981
Kaltenbaugh, Orie	1978
Kane, Daniel	1977
Khoury, David	2007
Klein, Roger	1984
Kloberdanz, Dennis	1988
Korthauer, Ken	1985
Kosty, John	1983
Lansing, Letitia	2010
Larson, Loren	2006
Latimer, Earl	1993
Lee, Robert	1995
Lieber, Corey	2006
Looby, Peter	1995
Lubin, Joel*	2001
Manweiler, Julia	2009
Marcus, Norman	1983
Marshall, Charley	2005
Martinez, Roberto	1984
Matt, Victoria	2002
McAdams, Timothy	2000
McClellan, Victoria	1984
McEnnerney, Thomas	1984
McGee, Kevin	2008
McGinty, Laurel*	1991
McGuire, Michael	1995
McKinley, Matthew	1998
Mercer, Deana	2008
Miller, Richard	1990
Milner, Brent	2003
Minor, Frank	1982
Montgomery, Rosalyn	1991
Moore, Kris	2008
Motamedi, Ali	1998
Munger, David	1969
Naraghi, Fred	1981
Newcomer, Joseph	1998
Ochsner, Lockwood	1986
Paterson, Andrew	2004
Paton, William	1977
Patton, Matt	2002
Peer, Chris	2005
Pflum, Eugene	1976
Phelps, Dennis	1985
Pike, Gregg	2004
Racca, Jeffrey	2000
Redmon, Shannah	2009
Renwick, Stephen	1994
Reyna, Jose	1983
Richards, Allison	2002
Robinson, Brian	1998
Rork, Peter	1984
Roth, Kenneth	1967
Rothman, Michael	1974
Schaab, Peter	1990
Schwarting, Ted	2003
Shafer, Jonathan	2006
Shantharam, Sanagaram	1992
Shonnard, Paul	1995
Silva, Selina	2010
Simpson, Robert	1976
Slauterbeck, James	1993
Smith, Jason	2007
Smith, Dean	2000
Smith, Christopher	1974
Sotta, Robert	1987
Southwell, Richard	1980
Summa, Christopher	1995
Teter, Kenneth	1993
Thomas, Eric*	2004
Treme, Gehron	2006
Tripuraneni, Krishna	2009
Troop, Randall	1989
VanBuskirk, Cathleen	1999
Vance, Tedman	1999
Veitch, John	1978
Veitch, Andrew	2003
Verploeg, Eric	1987
Verska, Joseph	1994
Webb, David	1977
White, Richard	1979
Wiemann, John	2011
Willis, Michael	2000
Witmer, Bruce	1982
Yaste, Jeffrey	2009

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Hand Surgery Fellows

Adamany, Damon	2007
Afifi, Ahmed	2008
Aldridge, Jeffrey	1987
Blair, William	1979
Bolger, John	1980
Buchman, Mark	1989
Capen, David	1975
Castaneda, Edwin	1988
Dalton, Anthony	1980
de Carvalho, Alex	2005
Doherty, William	1993
Duncan, Gregory	1992
Eiser, Thomas	1979
Espirtu, Edgardo	1985
Fahmy, Hani	1993
Ford, Ronald	1997
Freeh, Eric	1983
Fraser, Bonnie	2007
Garst, Jeffrey	1994
Gerstner, David	1988
Gobeille, Richard	1985
Gordon, Douglas	1987
Gross, Dominic	1997
Hamilton, Conrad	2011
Hofammann, Karl	1983
Howey, Thomas	1992
Hudson, Patrick	1978
Hurley, Davis	2003
Hussain, Tariq	2002
Inhofe, Perry	1994
Irey, William	1982
Johnson, Glenn	1998
Johnson, Jann	1984
Johnston, David	1995
Joseph, Terrell	2006
Kelly, Jon	1993
Koester, Alan	1995
Lakshman, Shankar	2004
Langford, Scott	2000
Larsen, Kenna	2009
Lehman, Thomas	2002
Luce, Paul	1999
Mercer, Deana	2010
Mikola, Elizabeth	2001
Miller, Gary	1986
Miller, Steven	2009
Morrow, Robert	1980
Mourikas, Anastasos	2004
Murdock, Louis	1996
Mustapha, Abdul	2000
Narsete, Thomas	1981
Niedermeier, William	1979
Oschwald, Don	1985
Pennino, Ralph	1986
Pokorny, Jeffrey	2002
Prabhakar, Ram	1980
Pribyl, Charles	1989
Richards, Allison	2008
Rosquete, Hector	1990
Saide, Robert	1983
Salah, Ehab	2005
Serota, Joseph	1983
Shirali, Swati	1999
Sleeper, Richard	1988
Swanson, Scott	2010
Taylor, Steven	2006
Tegtmeier, Ronald	1976
Teter, Kenneth	1993
Torkelson, Erik	1984
Voit, Gregory	1996
Walsh, Catherine	2011
Weinberg, Howard	1978
Yi, InSok	1998
Yoo, Robert	1977
Young, Steven	2001
Yu, Elmer	1979

Sports Medicine Fellows

Abraham, Roy	2006
Jasko, John	2010
Kiburz, A. John	2009
Mann, John	2010
Natividad, Toribio	2011
Passerelli, Ralph	2007
Sparks, Brad	2008
Veazey, Brad	2007

Trauma Fellows

Bozorgnia, Shahram	2008
de Carvalho, Max	2011
Figueiredo, Fabio	2007
Homedan, Shehada	2006
Matt, Victoria	2005
Molk, Gary	2010
Xing, Zhiqing	2009

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Thank You Sandia Orthopaedic Alumni Society

One of the advantages of publishing at the University of New Mexico is the breadth and availability of expertise throughout the institution to call on for assistance. This issue of the *University of New Mexico Orthopaedics Research Journal* was made possible through the support, guidance, and expertise of many parts of the UNM community. The editorial board and journal staff would like to acknowledge, with gratitude, invaluable assistance from the UNM Health Sciences Library and Informatics Center, eScholar Innovation Center, Department of English Language and Literature Professional Writing Program, *New Mexico Law Review*, and Health Sciences Center Office of Research.

In a category alone is the Sandia Orthopaedics Alumni Society, whose generous support made the journal possible. We thank the members of SOAS for their continuing contributions to the UNM Department of Orthopaedics and Rehabilitation's mission of education and service. The ongoing connection between SOAS and the department nurtures the strength and vitality of the residency and fellowship programs now and into the future.

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