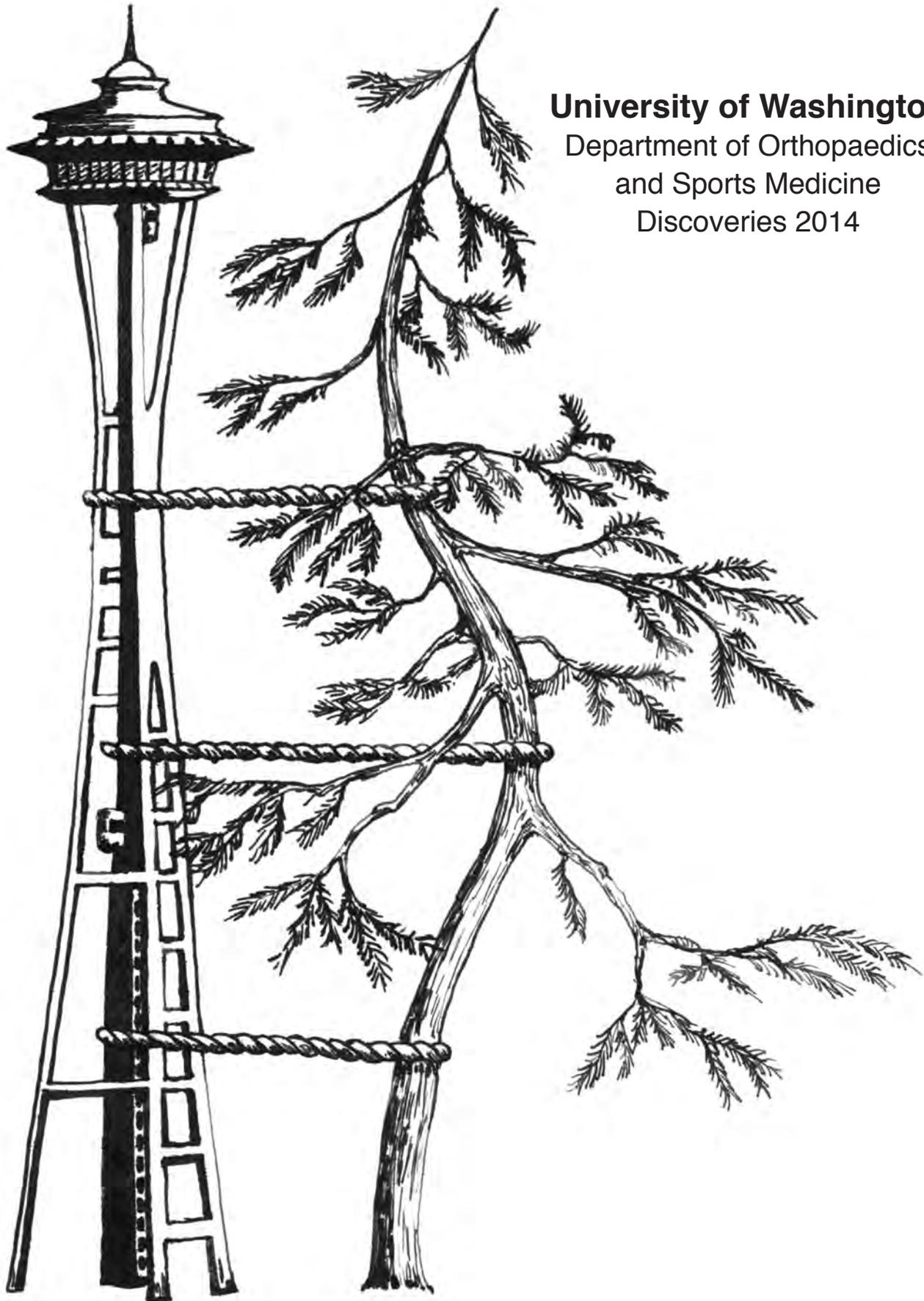


# DISCOVERIES 2014

REVISED EDITION





**University of Washington**  
Department of Orthopaedics  
and Sports Medicine  
Discoveries 2014

EDITOR-IN-CHIEF:

Howard A. Chansky, MD  
chansky@uw.edu

MANAGING EDITOR:

Fred Westerberg  
fwesterb@uw.edu

Front Cover Illustration: The cover photograph shows an immature Magnificent Frigatebird (*Fregata manificenes*) taken by Peter Cavanagh on the volcanic archipelago of Fernando de Noronha, approximately 220 miles off the north-eastern tip of Brazil. This species was formerly called a Man O' War for its behavior of patrolling the ocean and attempting to rob other birds of their food. With a wingspan of approximately seven feet, the Magnificent Frigatebird is unable to land and take off from water so it must find all its food while flying.

Charles Darwin spent several hours on Fernando de Noronha on February 20th, 1832 while he was the naturalist onboard HMS Beagle. His brief journal entry discussed only the remarkable geology of the islands and made no mention of the fauna.

Technical details:

Canon 1DMk IV body. 500mm f/4 lens. 1/4000th second at f/9.0 ISO 800.

A pdf of this publication is available at our website:

[www.orthop.washington.edu](http://www.orthop.washington.edu). Or, connect using the QR code below:



Permission Requests: All inquiries should be directed to the Managing Editor, University of Washington, Department of Orthopaedics and Sports Medicine, 1959 NE Pacific Street, Box 356500, Seattle, WA 98195-6500, or at the email address above.

Note: Please note this edition is a revision of the published version. One article was removed at the author's request. While the validity of the article still stands, the author wishes to publish this research in other publications.

# Contents

---

**1**

Foreword

**2**

Robert G. Veith, MD, 2014 Grateful Alumnus

**3**

Joseph D. Zuckerman, MD, 2014 Distinguished Alumnus

**4**

New Faculty

**7**

Perspective from a New Faculty Member

**8**

Department of Orthopaedics and Sports Medicine Faculty

**13**

Visiting Lecturers

- Propionibacterium Persists in the Skin in Spite of Standard Surgical Preparation **15** Michael J. Lee, MD, Paul S. Pottinger, PhD, Roger E. Bumgarner, PhD, Susan Butler-Wu, PhD, and Frederick A. Matsen III, MD
- Reading Clinical Research: Being a Good Consumer **17** Seth S. Leopold, MD
- Contralateral Bone Loss Following Ipsilateral Nerve Injury: Evidence for a Neuronal Skeletome **19** Laura E. Stoll, MD, Philippe Huber, BS, Ronald Y. Kwon, PhD, DeWayne Threet, BS, Ted S. Gross, PhD, and Steven D. Bain, PhD
- The Newly Described Anterolateral Ligament of the Knee: What is its Function? **21** Erin M. Parsons, MS, Albert O. Gee, MD, and Peter R. Cavanagh, PhD, DSc
- Geriatric (Fragility) Hip Fracture Program - Northwest Hospital & Medical Center **23** Robert S. Clawson, MD
- Tissue Engineered, Scaffold-Free, Human Cartilage Sheets Positively Respond to Low Oxygen Tension Both Mechanically and Biochemically **25** Thomas J. Kean, PhD, G. Adam Whitney, MS, Geoffrey R. Traeger, BS, James E. Dennis, PhD, and Russell J. Fernandes, PhD
- Outcomes of Nonoperative and Operative Treatment of Humeral Shaft Fractures **27** Benjamin Hamilton, MS, Edward Westrick, MD, M. Bradford Henley, MD, MBA, and Reza Firoozabadi, MD, MA
- Transient Muscle Paralysis Predisposes Bone Marrow to Formation of Giant Osteoclasts **30** Brandon J. Ausk, PhD, Leah E. Worton, PhD, DeWayne Threet, BS, Ronald Y. Kwon, PhD, Steven D. Bain, PhD, Edith M. Gardiner, PhD, and Ted S. Gross, PhD

- Chemical and Mechanical Nerve Impairment Inhibit Joint Specification and Bone Formation in the Regenerating Zebrafish Fin **32** Amanda C. Roof, MD, Anthony M. Recidoro, Brandon J. Ausk, PhD, Sundar Srinivasan, PhD, Ted S. Gross, PhD, Edith M. Gardiner, PhD, Steven D. Bain, PhD, Christopher H. Allan, MD, and Ronald Y. Kwon, PhD
- Ankle Arthroplasty with Subtalar Fusion or Tibiotalocalcaneal Fusion for Patients with Concomitant Tibiotalar and Subtalar Arthritis **34** Daniel Thuillier, MD, Bruce J. Sangeorzan, MD, Marisa Benich, MS, and Sigvard T. Hansen, Jr., MD
- Prospective Study Investigating the Prevalence and Evolution of Malnourishment in the Acute Orthopaedic Trauma Patient **36** Benjamin Hamilton, MS, Courtney O'Donnell, MD, Julie Agel, MA, Patricia Kramer, PhD, Stephen K. Benirschke, MD, M. Bradford Henley, MD, MBA, and Reza Firoozabadi, MD, MA
- Regulation of Cruciate Ligament Development and Maintenance by ESET Histone Methyltransferase **39** Albert O. Gee, MD, Michael J. Chen, BA, Sean Haloman, MD, John W. McCornack, BA, Howard A. Chansky, MD, and Liu Yang, PhD
- Posterior Wall Acetabular Fractures and Stability **42** Clay Spitler, MD, Calvin Schlepp, MD, Benjamin Hamilton, MS, Julie Agel, MA, and Reza Firoozabadi, MD, MA
- Risk of Spermatic Cord Injury During Anterior Pelvic Ring and Acetabular Surgery: An Anatomic Study **44** Reza Firoozabadi, MD, MA, Paul Stafford, MD, and Milton L. Routt, Jr., MD
- Nanoengineered 3-Dimensional Tendon Tissue **46** Albert O. Gee, MD, Philip Tatman, Sang-Jun Kim, MD, PhD, and Deok-Ho Kim, PhD
- ESET Histone Methyltransferase is Essential for Fracture Healing in a Mouse Tibia Fracture Model **49** Jacques Hacquebord, MD, Sean Haloman, MD, Andrew Ghatan, MD, Ning Li, BS, Howard A. Chansky, MD, and Liu Yang, PhD
- 2005 and 2013 Health Survey of SRS Member Surgeons Focusing on Thyroid Cancer and Cataract Prevalence – Occupational Radiation Risk? **51** Theodore A. Wagner, MD, Christie L. Benevich, BA, Maria A. Vanushkina, Marc A. Asher, Sue Min Lai, Courtney O'Donnell, MD, Darin J. Davidson, MD, MHSc, and Mark Weidenbaum
- Normal and Misaligned Talonavicular Fusion Alters Cadaveric Foot Pressure and Kinematics **52** Elizabeth P. Wahl, BA, William R. Ledoux, PhD, Eric C. Whittaker, MS, Brian K. Cook, BS, and Bruce J. Sangeorzan, MD
- Effectiveness of the “Spine At Risk” Safety Program **55** Walter F. Kregel III, MD, Courtney O'Donnell, MD, Nicole Burkette-Ikebata, MPH, Emma Satchell, BA, Viviana Bompadre, PhD, and Klane K. White, MD, MSc
- Safety and Efficacy of Reconstruction of the Unstable Sternoclavicular Joint: A Case Series of 12 Patients **56** Andrew J. Pastor, MD, Yaw D. Boachie-Adjei, MD, and Winston J. Warme, MD

Case Report: Acute Total Hip Arthroplasty **60** Conor P. Kleweno, MD  
as Treatment for Intertrochanteric Hip Fracture  
in the Setting of End-Stage Arthritis

**62**

Harborview Medical Center Orthopaedics

**64**

Seattle Children's Hospital Orthopaedics

**65**

University of Washington Medical Center Orthopaedics

**67**

VA Puget Sound Orthopaedics

**69**

Graduating Residents

**71**

Incoming Residents

**73**

ACEs and Fellows

**75**

Research Grants

**77**

Department Publications 2013-2014

**84**

Alumni

**87**

Orthopaedic Alumni Update

**88**

Endowments

# Foreword

---

This issue of Discoveries reflects a time of change and renewal in our department. We have had several transitions this year including the transition in leadership as Dr. Jens Chapman resigned as Chairman to focus on his academic practice and to spend more time with his family. Several incredible stalwarts of the department have retired from clinical practice this year. These much beloved members of our department include Carol Teitz (fortunately Carol will remain at the UW as the Associate Dean for Admissions for the School of Medicine), Theodore "Ted" Greenlee and John Sack. This represents over 100 years of "institutional knowledge" and experience leaving our department.

Drs. Teitz, Greenlee and Sack represent the principles of what has made our department such a force in teaching, clinical care and research. Dr. Teitz was a pioneer in sports medicine in particular and orthopaedics in general, as a female surgeon at a time when that was very unusual. She also helped develop the musculoskeletal core curriculum at the UW School of Medicine. Dr. Greenlee was an extramurally funded academic surgeon and is the only member of our department to have a manuscript published in the journal *Science*. Of course he has also won his share of clinical teaching awards. Dr. Sack was a pioneering community hand surgeon in Seattle and somehow maintained a busy private practice while helping out at Harborview and the VA. He also has his fair share of teaching awards. Each in their own way, Drs. Teitz, Greenlee and Sack were also iconoclasts who challenged accepted wisdom throughout their careers, to the benefits of their patients, trainees and

to orthopaedics.

The traditions established by these departing faculty members will be carried forth and enhanced by our newest generation of talented surgeons and scientists. The department's scientific and clinical future is certainly secure as reflected by the contributions



to the 2014 issue of Discoveries by Drs. Navin Fernando, Conor Kleweno, Ron Kwon, Albert Gee and Reza Firoozabadi. We expect each of these surgeons and scientists to respect the great traditions of our department while also challenging conventional wisdom. They represent the best chance that we have to advance the scientific, educational and clinical realms of Orthopaedics to meet the

evolving needs of society, orthopaedics residents and most importantly patients.

We are fortunate to have a remarkably talented and loyal group of alumni. They have been tightly bound (but we would always welcome closer bonds!) to us and us to them in mutually beneficial ways. As anyone such as myself who moved to Seattle from a different part of the country quickly recognizes, Orthopaedics in this area is practiced at an incredibly high level of sophistication and quality. This is no doubt in great part due to the graduates of our residency and fellowships that remain or return to the region. In this issue of Discoveries we have a brief portrait of Dr. Robert "Rob" Veith, a UW alumni well renowned for his selflessness and compassionate care. Dr. Lyle Sorensen, the Director of the UW Orthopaedic Alumni Association has a report summarizing his perspective of our program and the activities of others of our prominent selfless alumni.

Finally, I would be remiss if I did not express my gratitude to Fred Westerberg, Program Operations Specialist at the UW and a tireless supporter of our department. Without Fred's organizational and editing skills this publication would never see the light of day. Please enjoy our 2014 edition of Discoveries.

Howard A. Chansky, MD  
Professor and Acting Chair

# Robert G. Veith, MD 2014 Grateful Alumnus University of Washington School of Medicine

---



Seattle native Dr. Robert G. Veith has spent his entire professional life dedicated to orthopaedic repair of foot and ankle disorders.

After starting his studies at Western Washington University, he graduated with distinction (BS) from Stanford University in 1972. He then returned to the Pacific Northwest to get his medical degree at the University of Washington in 1975. An internal medicine internship at University of California/San Francisco was completed the following year. Dr. Veith completed his residency in orthopaedic surgery in 1981.

He has received numerous professional honors throughout his career. He won the George E. Gamble Honor Scholarship at Stanford University. He was honored to be inducted into the Alpha Omega Alpha Honor Medical Society. He graduated with honors from the University of

Washington School of Medicine where he also won the Esther Whiting Award for the Best Resident Paper “Ipsilateral Fractures of the Femur and Tibia.”

Dr. Veith has been an active member of the American Academy of Orthopaedic Surgeons and American Orthopaedic Foot and Ankle Society, as well as the King County Medical Society, and the Washington State Orthopaedic Association.

He has an extensive history of presenting his research at local and national organizations. He has given lectures on complex unstable fractures of the foot, the treatment of ankle arthritis, and compartmental syndromes. He has taught courses on basic intramedullary nailing, treatment of unstable femoral shaft fracture with closed interlocking nails, and improving clubfoot treatment in developing countries.

His willingness to dedicate his

time to helping those less fortunate can be seen in his overseas work on surgical missions. Whether through the American Orthopedic Foot and Ankle Society Overseas Outreach Fellowship in Vietnam, Mobility Outreach International (formerly Prosthetics Outreach Foundation) in Bangladesh, Vietnam, Sierra Leone, China, and Papua New Guinea, or the Natural Disaster Surgical Relief efforts after the devastating earthquake in Haiti, Dr. Veith has donated his surgical skills, hard work, and time to help those in need.

The choice of 2014 Grateful Alumnus celebrates the many accomplishments of Robert Veith. His selfless dedication to his patients and his boundless generosity set a new standard for all of us.

# Joseph D. Zuckerman, MD 2014 Distinguished Alumnus University of Washington School of Medicine

---



**J**oseph D. Zuckerman, M.D. was born and raised in the suburbs of New York City. After attending Hicksville High School, he received his undergraduate degree from Cornell University in 1974. He attended the Medical College of Wisconsin receiving his M.D. degree in 1978. His Orthopaedic Surgery Residency training was completed at the University of Washington in 1983. He then completed a one year clinical and research fellowship in arthritis surgery at Brigham and Woman's Hospital in Boston. As a result of his interest in shoulder problems, he was a visiting clinician with Robert Cofield, M.D. at the Mayo Clinic following his fellowship. Dr. Zuckerman joined the academic faculty at the Hospital for Joint Diseases in 1984. He was appointed Chief of the Shoulder Service in 1986. In 1990, he became Director of the Orthopaedic Surgery Residency Program, as well as Vice Chairman of the Department. In 1994, he became Chairman of the Department of Orthopaedic Surgery and Surgeon-in-Chief of the Hospital for Joint Diseases. In September 1997, Dr. Zuckerman was appointed Professor and Chairman of the New York University – Hospital for Joint

Diseases Department of Orthopaedic Surgery and he is the holder of the Walter A. L. Thompson Professor of Orthopaedic Surgery chair.

Dr. Zuckerman was chosen as a North American Traveling Fellow in 1985 and an ABC Exchange Fellow in 1991. He has received the Otto Aufranc Award from the Hip Society in 1986. He has been the recipient of a Teacher of the Year Award from the residents at the Hospital for Joint Diseases on five separate occasions and he received the Resident Appreciation Award in 1994 and 1995. Dr. Zuckerman won the Orthopaedic Research and Education Foundation (OREF) Clinical Research Award in 2002. In 2004, he was recognized as "Alumnus of the Year" by the Medical College of Wisconsin. He was honored with the Lifetime Achievement Award from the New York Chapter of the Arthritis Foundation in 2005.

He is a member of the American Academy of Orthopaedic Surgeons and has served as a member of the Board of Directors in 1992 and 1993. He has served as Chairman of the Committee on Surgical Skills Education and the Instructional Course Lecture Committee. In 2009, Dr. Zuckerman

was named the 77th President of the American Academy of Orthopaedic Surgeons. He served as President of the American Shoulder and Elbow Surgeons in 2003-2004.

Dr. Zuckerman's areas of clinical interest include shoulder disorders and hip and knee replacement. His research has focused on hip fractures in elderly patients, as well as basic science and clinical studies of shoulder problems. He has also maintained an interest in socioeconomic issues of orthopaedic surgery.

Dr. Zuckerman is married to Janet (above center), a clinical psychologist and psychoanalyst. He has two sons – Scott (above left) who is a neurosurgery resident at Vanderbilt University and Matthew (above right) who is an architect at Deborah Berke Partners in New York City until he returns in the fall to the Yale School of Architecture M. Arch. Program.

The choice of 2014 Distinguished Alumnus celebrates the many accomplishments of Joseph D. Zuckerman. His impressive career of orthopaedic leadership as well as his years of scholarship has set a high standard for all of us.

## New Faculty



**Sarah D. Beshlian, MD**

Clinical Associate Professor  
Northwest Hospital  
Hand and Wrist  
sarah.beshlian@nwhsea.org

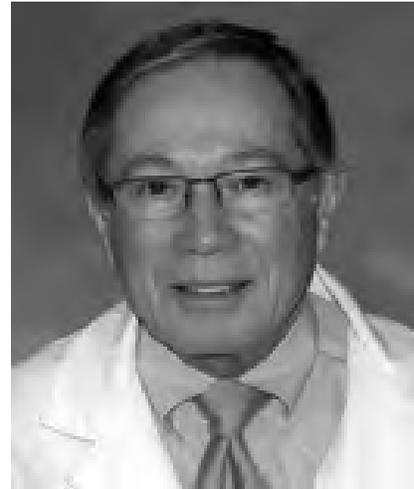
**S**arah Beshlian, MD formally joined our faculty on October 1, 2013. Dr. Beshlian serves as a board-certified/CAQ-qualified hand and upper extremity surgeon at Northwest Hospital and Medical Center. After graduating with a BA in Chemistry from Williams College, Dr. Beshlian completed her medical degree at Northwestern University in Chicago. She spent the first two years of her training at Virginia Mason Medical Center, and finished residency at the University of Rochester Medical Center, followed by subspecialty fellowship training in surgery of the hand at the same institution. Dr. Beshlian practiced from 1994-2000 in Fort Collins, Colorado. She moved to the northwest in 2001, where she practiced at Virginia Mason and Madigan, before joining the faculty at Northwest. Dr. Beshlian is a member of the American Society for Surgery of the Hand, the American Academy of Orthopaedic Surgeons, the Washington State Orthopaedics Association and the Washington State Medical Association. In addition to her local patients, Dr. Beshlian has served international patients as a Health Volunteers Overseas surgeon in Bhutan, Asia.



**John M. Clark, Jr., MD, PhD**

Clinical Professor  
Harborview Medical Center  
Hip and Pelvis

**D**r. John Clark rejoined our faculty as Clinical Professor and Director of Academic Advancement for the Hansjörg Wyss Center for the Advancement of Hip and Pelvis Surgery on July 1, 2014. Dr. Clark completed his MD at the Pritzker School of Medicine in Chicago in 1976, followed by internship and residency training here at the University of Washington. Dr. Clark completed a year as research fellow in joint reconstruction with M.A.R. Freeman, MD, FRCS at the Royal London Hospital in 1982. Dr. Clark initially joined the UW Orthopaedics faculty as Clinical Instructor in August 1982, and left as a Full Professor in 2005. Dr. Clark is affiliated with several regional hospitals including Overlake Hospital, Virginia Mason, Group Health and Seattle Children's.



**Robert S. Clawson, MD**

Clinical Associate Professor  
Northwest Hospital  
Fractures & Trauma  
robert.clawson@nwhsea.org

**D**r. Robert Clawson, a board-certified orthopaedic surgeon, has been a long time friend of the Department, joining the faculty formally on October 1, 2013. Dr. Clawson has been in private practice in North Seattle at Northwest Hospital and Medical Center since 1974. After receiving undergraduate and medical degrees from Louisiana State University, Dr. Clawson spent one year as an intern at Harborview Medical Center before serving our nation as a member of the United States Air Force from 1967-1970. Dr. Clawson is a member of the American Academy of Orthopaedic Surgeons, the Washington State Orthopaedics Association, the Western Orthopaedic Association and the Washington State Medical Association. In 2009, Dr. Clawson has a strong interest in medical history, and produced "Harborview: The Trauma Story", a telling account of the pioneering work in trauma at Harborview during the 1960s and 70s.

## New Faculty



**Tania A. Ferguson, MD**

Associate Professor  
Harborview Medical Center  
Trauma  
taniaf@uw.edu

**T**ania Ferguson, MD joined the faculty on August 1, 2013. Dr. Ferguson completed all of her education in the state of California, undergraduate at UC Santa Cruz, medical school and general surgery internship at UC San Francisco, followed by residency and MAS degree from UC Davis. Dr. Ferguson completed an AO Fellowship in hip and pelvis preservation and reconstruction in Mammoth Lakes, California as well as an additional fellowship in hip, pelvic, and acetabular surgery at the Good Samaritan Hospital in Los Angeles, California. Dr. Ferguson served as Assistant Professor and Director of the Orthopaedic Trauma Fellowship program at the UC Davis Medical Center. Dr. Ferguson is a passionate educator. She was elected Teacher of the Year/Outstanding Faculty of Year at UC Davis in 2007 and again in 2012. Dr. Ferguson is a member of the American Academy of Orthopaedic Surgeons as well as the American Medical Association.



**Navin D. Fernando, MD**

Assistant Professor  
Northwest Hospital  
Adult Reconstructive Surgery  
navinf@uw.edu

**D**r. Navin Fernando joined the faculty on February 4, 2014 to focus on adult reconstruction at Northwest Hospital and Medical Center. Dr. Fernando, a native of Canada, earned his undergraduate degree from the University of Windsor and his medical degree from the University of Western Ontario. Following a traveling internship in general surgery and residency at McMaster University in Ontario, Dr. Fernando completed fellowship training in adult joint reconstruction at the Rothman Institute at Thomas Jefferson University in Philadelphia, PA. Dr. Fernando is a Fellow of the Royal Canadian College of Surgeons as well as a member of the American Academy of Orthopaedic Surgeons.



**Edith M. Gardiner, PhD**

Research Associate Professor  
Harborview Medical Center  
Research  
edigar@uw.edu

**E**dith M. Gardiner, PhD, initially joined the faculty as a Visiting Associate Professor from 2008-2010, and formally joined the faculty in 2010 as Acting Associate Professor based in the Orthopaedic Science Laboratories with Dr. Ted Gross. In 2014, Dr. Gardiner was appointed as Research Associate Professor. Dr. Gardiner studied zoology as an undergrad at Duke University, followed by a Master's in 1982 and PhD in 1988 in Human Genetics, both awarded from Yale University. Following her PhD, Dr. Gardiner spent four years as a post-doc and Yale, and then joined the faculty of the Garvan Institute of Medical Research in Sydney, Australia, where she focused her bone and mineral research program until moving to Seattle permanently in 2010. Dr. Gardiner's major research interests include sympathetic nervous system control of osteoblast and osteocyte differentiation and function; neuropeptide Y involvement in phosphate and calcium homeostatic modulation of bone formation; and Wnt pathway roles in osteoblast and osteocyte regulation and in cancer metastasis to the skeleton.

# New Faculty



## Conor P. Kleweno, MD

Assistant Professor  
Harborview Medical Center  
Trauma  
ckleweno@uw.edu

**C**onor Kleweno, MD joined our faculty as a trauma surgeon based at Harborview Medical Center on October 1, 2013. Dr. Kleweno, a Washington State native, grew up on a 2000-acre wheat farm in the southwest part of the state. After completing his undergraduate degree at the University of Washington as a Washington Scholar, Dr. Kleweno received his medical degree from Harvard University followed by the combined orthopaedic residency program at Harvard. Dr. Kleweno completed fellowship training at the R. Adams Cowley Shock Trauma Center in Baltimore, MD. Dr. Kleweno, a Rhodes Scholar finalist, was voted Overall Outstanding Resident in 2012 by his mentors at Harvard.



## Antoinette Lindberg, MD

Acting Assistant Professor  
Seattle Children's Hospital  
Orthopaedic Oncology  
antoinette.lindberg@seattlechildrens.org

**A**ntoinette Lindberg, MD joined the faculty as Acting Assistant Professor in October, 2012. Dr. Lindberg completed her undergraduate education at the University of Washington, followed by medical school at Columbia University College of Physicians in New York. Dr. Lindberg completed an orthopaedic surgery residency at the USC Department of Orthopaedics in Los Angeles, CA. Dr. Lindberg joined the department initially as a fellow in pediatric orthopaedics followed by a second year of subspecialty training in musculoskeletal oncology. Dr. Lindberg serves as member of the Pediatric Orthopaedic Society of North America as well as the American Academy of Orthopaedic Surgeons.



## Keith Mayo, MD

Clinical Professor  
Harborview Medical Center  
Hip and Pelvis  
mayor@uw.edu

**K**eith Mayo, MD, Hansjörg Wyss Clinical Professor, joined the faculty on February 10, 2014. Dr. Mayo has a highly distinguished career as an orthopaedic surgeon, specializing in pelvic and acetabular trauma. After he received his undergraduate degree from Stanford University, Dr. Mayo completed medical school at the University of Washington, followed by general surgery internship and residency in our Department. Dr. Mayo completed a prestigious fellowship in musculoskeletal trauma and reconstructive surgery in Bern, Switzerland. Dr. Mayo has served on our faculty as well as the faculty at Wayne State University School of Medicine in Detroit, MI and the Saint Joseph Medical Center in Bellingham. After several years in private practice in Tacoma, WA, Dr. Mayo returned to our Department to serve as Director of the Hansjörg Wyss Center for the Advancement of Hip and Pelvis Surgery. Dr. Mayo is the member of numerous professional societies as well as a frequent international lecturer in his areas of expertise.

# Perspective from a New Faculty Member

We are very excited to have Navin Fernando, MD join our faculty. Dr. Fernando just completed his advanced fellowship training in total joint surgery at the Rothman Institute, a world renowned center for adult reconstructive surgery. Navin brings new surgical skills to our department and he is interested in “best practice” protocols and ascertaining the effects of these protocols on surgical outcomes and the cost of care. Dr. Fernando is based at Northwest Hospital and his specialty is joint replacement of the hip and knee.

Howard A. Chansky, MD  
Professor and Acting Chair

I had the pleasure of spending my fellowship in adult joint reconstruction at the Rothman Institute in Philadelphia last year, where I was extensively trained in a variety of minimally invasive total hip arthroplasty techniques, namely the use of direct anterior and Watson-Jones approaches. The rationale for the use of these intermuscular intervals has focused largely on more rapid patient recovery and a more normal restoration of gait mechanics. Many surgeons believe a dedicated physical therapy regimen is also integral to achieving this success, and these regimens have been commonly utilized for “more invasive” traditional approaches such as the Hardinge and posterolateral approach. Despite this common practice, significant controversy exists as to the efficacy of outpatient physiotherapy regimens after total hip arthroplasty. High quality evidence does not currently exist, and given the significant cost associated with outpatient physiotherapy (both to the patient and healthcare system), the efficacy of PT in improving the postoperative course of these patients serves as a relevant clinical question. The S.E.P.T.A. trial (Study to Evaluate Physiotherapy in Total Hip Arthroplasty) was designed to help elucidate this question and received IRB approval with active recruitment of patients in August 2013. The purpose of this study is to determine if outpatient physiotherapy results in improved and/or more rapid achievement of functional outcomes and quality of life in comparison to those patients who do not undergo outpatient physiotherapy after total hip arthroplasty.

The study design consists of a prospective single center randomized controlled trial performed on patients

undergoing total hip arthroplasty at Thomas Jefferson University in Philadelphia, Pennsylvania. Patients undergoing THA will be randomized to undergo either (I) two months of outpatient physiotherapy with 2-3 weekly sessions or (II) no outpatient physiotherapy regimen. All patients will receive an uncemented THA through a modified Hardinge approach. A computerized random number generator will assign treatment group allocation, and treating surgeons as well as those assessing patient outcomes will be blinded to patient group. Standard treatment patients will receive in-home physiotherapy twice weekly for a period of two weeks post discharge (four total sessions) from a designated home care service. Patients in the treatment group receiving two months of additional outpatient physiotherapy will be asked to keep a log to ensure compliance. The primary outcome of hip function will be measured by the Harris Hip Score, with secondary outcomes including the SF-36, the WOMAC and the visual analog scale. Primary and secondary outcomes will be measured pre-operatively, at 4 weeks, 6 months, and 1 year post-operatively.

Initial patient recruitment has been encouraging with preliminary statistical analysis pending. Future directions for this trial include expansion to multiple centers to confirm the external validity of our results in a variety of demographics. As principal investigator for the current trial, I would like to also conduct a parallel trial here at UW enrolling patients who have undergone direct anterior total hip arthroplasty or Watson-Jones approaches to modified physical therapy regimens. Despite my belief in the efficacy of these approaches based on the existing literature, further well-designed trials

should be performed to confirm both the benefit and safety of these techniques in comparison to the “gold standard”. I’m excited to help to contribute to UW Orthopaedics’ tradition of leadership in evidence-based medicine as I begin my career here.

Navin D. Fernando, MD  
Assistant Professor

# Department of Orthopaedics and Sports Medicine Faculty



**Howard A. Chansky, MD**  
Professor and Acting Chair  
VA Puget Sound Health Care System  
Adult Reconstructive Surgery  
chansky@uw.edu



**Sarah D. Beshlian, MD**  
Clinical Associate Professor  
Northwest Hospital  
Hand and Wrist  
sarah.beshlian@nwhsea.org



**Christopher H. Allan, MD**  
Associate Professor  
Harborview Medical Center  
Hand and Wrist  
callan@uw.edu



**Michael E. Brage, MD**  
Associate Professor  
Harborview Medical Center  
Foot and Ankle  
bragem@uw.edu



**Steven D. Bain, PhD**  
Research Associate Professor  
Harborview Medical Center  
Research  
sdbain@uw.edu



**Richard J. Bransford, MD**  
Associate Professor  
Harborview Medical Center  
Spine  
rbransfo@uw.edu



**David P. Barei, MD**  
Professor  
Harborview Medical Center  
Trauma  
barei@uw.edu



**Peter R. Cavanagh, PhD, DSc**  
Professor  
University of Washington Medical Center  
Research  
cavanagh@uw.edu



**Daphne M. Beingessner, MD**  
Associate Professor  
Harborview Medical Center  
Trauma  
daphneb@uw.edu



**Jens R. Chapman, MD**  
Professor  
Harborview Medical Center  
Spine  
jenschap@uw.edu



**Carlo Bellabarba, MD**  
Professor  
Harborview Medical Center  
Spine and Trauma  
cbella@uw.edu



**John M. Clark, Jr., MD, PhD**  
Clinical Professor  
Harborview Medical Center  
Hip and Pelvis



**Stephen K. Benirschke, MD**  
Professor  
Harborview Medical Center  
Foot and Ankle  
beniskb@uw.edu



**Robert S. Clawson, MD**  
Clinical Associate Professor  
Northwest Hospital  
Fractures & Trauma  
robert.clawson@nwhsea.org

# Department of Orthopaedics and Sports Medicine Faculty



**Ernest U. Conrad III, MD**  
Professor  
Seattle Children's Hospital  
Orthopaedic Oncology  
chappie.conrad@seattlechildrens.org



**Navin D. Fernando, MD**  
Assistant Professor  
Northwest Hospital  
Adult Reconstructive Surgery  
navinf@uw.edu



**Mark C. Dales, MD**  
Clinical Associate Professor  
Seattle Children's Hospital  
Spine  
mark.dales@seattlechildrens.org



**Reza Firoozabadi, MD, MA**  
Assistant Professor  
Harborview Medical Center  
Trauma  
rezaf2@uw.edu



**Darin J. Davidson, MD, MHSc**  
Assistant Professor  
University of Washington Medical Center  
Orthopaedic Oncology  
djdavi@uw.edu



**Edith M. Gardiner, PhD**  
Research Associate Professor  
Harborview Medical Center  
Research  
edigar@uw.edu



**Robert P. Dunbar, MD**  
Associate Professor  
Harborview Medical Center  
Trauma  
dunbar@uw.edu



**Albert O. Gee, MD**  
Assistant Professor  
University of Washington Medical Center  
Sports Medicine  
ag112@uw.edu



**David R. Eyre, PhD**  
Professor  
University of Washington Medical Center  
Research  
deyre@uw.edu



**Michael J. Goldberg, MD**  
Clinical Professor  
Seattle Children's Hospital  
Pediatric Orthopaedics  
michael.goldberg@seattlechildrens.org



**Tania A. Ferguson, MD**  
Associate Professor  
Harborview Medical Center  
Trauma  
taniaf@uw.edu



**John R. Green III, MD**  
Associate Professor  
University of Washington Medical Center  
Sports Medicine  
jgreen3@uw.edu



**Russell J. Fernandes, PhD**  
Research Associate Professor  
University of Washington Medical Center  
Research  
rjf@uw.edu



**Ted S. Gross, PhD**  
Professor  
Harborview Medical Center  
Research  
tgross@uw.edu

# Department of Orthopaedics and Sports Medicine Faculty



**Douglas P. Hanel, MD**  
Professor  
Harborview Medical Center  
Hand and Wrist  
dhanel@uw.edu



**Ronald Y. Kwon, PhD**  
Assistant Professor  
Harborview Medical Center  
Research  
ronkwon@uw.edu



**Sigvard T. Hansen, Jr., MD**  
Professor Emeritus  
Harborview Medical Center  
Foot and Ankle  
hansetmd@uw.edu



**Roger V. Larson, MD**  
Associate Professor  
University of Washington Medical Center  
Sports Medicine  
drlarson@uw.edu



**M. Bradford Henley, MD**  
Professor  
Harborview Medical Center  
Trauma  
bhenley@uw.edu



**Michael J. Lee, MD**  
Associate Professor  
University of Washington Medical Center  
Spine  
mjl3000@uw.edu



**Jerry I. Huang, MD**  
Associate Professor  
University of Washington Medical Center  
Hand and Wrist  
jihuang@uw.edu



**Seth S. Leopold, MD**  
Professor  
University of Washington Medical Center  
Adult Reconstructive Surgery  
leopold@uw.edu



**Stephen Kennedy, MD**  
Assistant Professor  
University of Washington Medical Center  
Hand and Wrist  
sajk@uw.edu



**Antoinette Lindberg, MD**  
Acting Assistant Professor  
Seattle Children's Hospital  
Orthopaedic Oncology  
antoinette.lindberg@seattlechildrens.org



**Conor P. Kleweno, MD**  
Assistant Professor  
Harborview Medical Center  
Trauma  
ckleweno@uw.edu



**Paul A. Manner, MD**  
Associate Professor  
University of Washington Medical Center  
Adult Reconstructive Surgery  
pmanner@uw.edu



**Walter F. Kregel III, MD**  
Clinical Associate Professor  
Seattle Children's Hospital  
Spine  
wally.kregel@seattlechildrens.org



**Frederick A. Matsen III, MD**  
Professor  
University of Washington Medical Center  
Shoulder and Elbow  
matsen@uw.edu

# Department of Orthopaedics and Sports Medicine Faculty



**Keith Mayo, MD**  
Clinical Professor  
Harborview Medical Center  
Hip and Pelvis  
mayok@uw.edu



**Sundar Srinivasan, PhD**  
Research Associate Professor  
Harborview Medical Center  
Research  
sundars@u.washington.edu



**Vincent S. Mosca, MD**  
Professor  
Seattle Children's Hospital  
Pediatric Orthopaedics  
vincent.mosca@seattlechildrens.org



**Suzanne E. Steinman, MD**  
Clinical Assistant Professor  
Seattle Children's Hospital  
Pediatric Orthopaedics  
suzanne.steinman@seattlechildrens.org



**Carol A. Mowery, MD**  
Clinical Associate Professor  
Seattle Children's Hospital  
Pediatric Orthopaedics  
carol.mowery@seattlechildrens.org



**Lisa A. Taitzman, MD, MPH**  
Associate Professor  
Harborview Medical Center  
Trauma  
taitzman@uw.edu



**Sean E. Nork, MD**  
Professor  
Harborview Medical Center  
Trauma  
nork@u.washington.edu



**Carol C. Teitz, MD**  
Professor  
University of Washington Medical Center  
Sports Medicine  
teitz@uw.edu



**Bruce J. Sangeorzan, MD**  
Professor  
Harborview Medical Center  
Foot and Ankle  
bsangeor@uw.edu



**Bruce C. Twaddle, BHB, FRACS**  
Professor  
University of Washington Medical Center  
Sports Medicine  
btwaddle@uw.edu



**Gregory A. Schmale, MD**  
Associate Professor  
Seattle Children's Hospital  
Pediatric Orthopaedics  
gregory.schmale@seattlechildrens.org



**Theodore A. Wagner, MD**  
Clinical Professor  
University of Washington Medical Center  
Spine  
wagner@uw.edu



**Douglas G. Smith, MD**  
Professor  
Harborview Medical Center  
Foot and Ankle  
dgsmith@uw.edu



**Winston J. Warme, MD**  
Associate Professor  
University of Washington Medical Center  
Shoulder and Elbow  
warmewj@uw.edu

# Department of Orthopaedics and Sports Medicine Faculty

**Klane K. White, MD, MSc**

Associate Professor  
Seattle Children's Hospital  
Pediatric Orthopaedics  
klane.white@seattlechildrens.org

**Jiann-Jiu Wu, PhD**

Research Professor  
University of Washington Medical Center  
Research  
wujj@uw.edu

---

**Emeritus Faculty**

Stanley J. Bigos, MD  
Professor Emeritus  
Theodore K. Greenlee, Jr., MD  
Associate Professor Emeritus  
Lynn T. Staheli, MD  
Professor Emeritus

**Joint Faculty**

Anthony M. Avellino, MD  
Monique S. Burton, MD  
Randall M. Chesnut, MD  
Armagan Dagal, MD  
Jeffrey B. Friedrich, MD  
Kimberly Harmon, MD  
Mark A. Harrast, MD  
Stanley A. Herring, MD  
Virany H. Hillard, MD  
Thomas Jinguji, MD  
John Lockhart, MD  
John W. O'Kane, MD  
John E. Olerud, MD  
Trent L. Tredway, MD  
Nicholas B. Vedder, MD  
Fangyi Zhang, MD

**Adjunct Faculty**

Roger E. Bumgarner, PhD  
Jack W. Berryman, PhD  
Cora C. Breuner, MD  
Charles H. Chesnut III, MD  
Randal P. Ching, PhD  
Gregory C. Gardner, MD  
Daniel O. Graney, PhD  
Jason Ko, MD  
Grant E. O'Keefe, MD  
Susan M. Ott, MD  
Wendy H. Raskind, MD, PhD  
Michael L. Richardson, MD  
Miqin Zhang, PhD

**Affiliate Faculty**

Julius A. Bishop, MD  
Roland S. Kent, MD  
William R. Ledoux, PhD  
Christopher M. McAndrew, MD  
D. Michael Strong, PhD

**Teaching Associate**

Alexander L. Bertelsen, PA  
EChing V. Bertelsen, PA  
Jill T. Eggers-Knight, PA  
Aaron J. Eusterbrock, PA  
Joseph L. Fiorito, DPM  
Peter C.A. Hall, PA  
Jennifer S. Hamilton, PA  
Margo J.C. Hoppis, PA  
Douglas J. Ichikawa, DPM  
Connie U. Ly, PA  
Jason E. Maris, PA  
Rockwell G. Moulton, DPM  
Nicole A. Patrick, PA  
Amanda L. Pedersen, PA

**Senior Fellow**

David Hudson, PhD  
Leah E. Worton, PhD

# Visiting Lecturers

---

## 2014 LeCocq Lectureship

---

Wednesday & Thursday, April 16-17, 2014



We were happy to have Dr. Reinhold Ganz visit us as the guest lecturer for the 2014 LeCocq Lectureship. On Wednesday April 16th he lectured on “The Femoro-Acetabular Impingement Concept” and that evening, at the 50th Annual John F. LeCocq Dinner, he gave a talk on “All I Really Needed To Know I Learned In Kindergarten”. The next day he spoke on “Femoral Head Size Reducing Osteotomy” as well as “The Capsular Arthroplasty, An Effective But Abandoned Procedure For Young Patients With Hip Dislocation”.

Dr. Reinhold Ganz attended high school in Rastatt, a small Baroque city in southwestern Germany. Interested in bioscience, it was a gut decision to study medicine. In 1964, Dr. Ganz earned his medical degree at the University of Freiburg. After reading books by Friedrich Pauwels, Arthur Steindler, and Harold M. Frost, Dr. Ganz was inspired to continue his career in Orthopaedics. In 1966, he signed up at the Institute of Pathology at the University of Basel in Switzerland, concentrating on bone physiology and biomechanics.

To prepare for Orthopaedics, Dr. Ganz participated in a research fellowship with SM Perren at the Laboratory of Biomechanics in Davos, Switzerland. In 1970, under the guidance of Maurice E. Müller, he started the residency program at the University of Berne. After 10 years, Dr. Ganz became a full clinical professor in 1981. Although he retired in 2004, his work in orthopaedics did not stop. For three years Dr. Ganz held a consultancy position at the Balgrist University Hospital in Zurich specializing in hip surgery.

At the same time, he was part of an ongoing mentorship in joint preserving hip surgery for a North-Italian group. In the early years of this group, Dr. Ganz focused on biological internal fixation of fractures. By 1980 his focus shifted to the preservation of the natural hip joint. The group was supported by a number of fellows, mainly sent by the M.E. Müller Foundation of North America. With this collaboration, significant advances were accomplished, most profoundly the development of a new periacetabular osteotomy for the dysplastic hip and the concept of femoroacetabular impingement (FAI).

Dr. Ganz currently has three major ongoing activities including Bernese Periacetabular Osteotomy, proximal femoral osteotomies, and FAI. Introduced in 1984, the Bernese Periacetabular Osteotomy has achieved high acceptance. It is documented by a multitude of publications, including a recent report on 20 years of results. Dr. Ganz hopes to obtain a better understanding of complications such as nerve lesions and on the improvement of clinical and imaging scoring for a more relevant reporting of results. Dr. Ganz’s second focus is based on cadaveric studies of the vascular supply to the hip. Through this, a new class of efficient intraarticular corrections of the femur have been designed. These osteotomies include relative lengthening of the femoral neck, subcapital reorientation, true femoral neck osteotomy, and osteotomy to reduce the size of the femoral head. The different osteotomies are being clinically tested, the indication adapted and the results continuously reported. Finally, the roots of FAI date back to the early 1990s, when its pathophysiology could be described for a group of femoral neck fractures healed in retrotilt. Validation of the concept however was only possible with the safe surgical dislocation of the hip. Dr. Ganz’s specific focus is on epidemiology, clinical screening, open and arthroscopic surgery, and adapting a clinical and image scoring systems of deformity and extent of osteoarthritis.

## Visiting Lecturers

---

### 2014 Resident Research Day

---

June 27, 2014



**W**e were happy to host Charles Saltzman, MD as the guest lecturer for our Resident Research Day on June 27, 2014.

Dr. Charles Saltzman is the Chairman of Orthopaedics at the University of Utah where he serves as the LS Peery Presidential Endowed Professor.

For over two decades, Dr. Saltzman has focused on improving physical function of patients with limited mobility. His primary interests include care of patients with ankle arthritis, athletic injuries of the leg, ankle and foot, and those with tendon, ligament, cartilage or bone problems of their feet. He has helped develop new methods for treatment of ankle arthritis (ankle fusion & ankle replacement), midfoot arthritis, ankle/hindfoot arthroscopy and forefoot problems.

Dr. Saltzman serves nationally in many roles including Director of the American Board of Orthopaedic Surgery, Vice President of the International Federation of Foot and Ankle Societies, Past President of the American Orthopaedic Foot and Ankle Society, Immediate Past Chairman of the Managerial Board of Foot and Ankle International, Co-Editor of the premier subspecialty textbook "Surgery of Foot and Ankle" and President of the Association of Bone and Joint Surgeons.

# Propionibacterium Persists in the Skin in Spite of Standard Surgical Preparation

Michael J. Lee, MD, Paul S. Pottinger, PhD, Roger E. Bumgarner, PhD,  
Susan Butler-Wu, PhD, and Frederick A. Matsen III, MD

*Propionibacterium* is commonly cultured in specimens harvested at the time of revision of failed surgeries. Prior studies have shown that *Propionibacterium* may persist on the skin surface after surgical preparation, but the source of these persistent organisms is unclear. We hypothesized that *Propionibacterium* persist in the dermis after surgical preparation of the skin surface.

Ten healthy male volunteers underwent surgical skin preparation of the upper back with the ChlorPrep kits used in the operating room. Two dermal 3mm dermal punch biopsies were then obtained through the prepared skin and cultured for *Propionibacterium*.

Seven (70%) of the volunteers had positive dermal cultures for *Propionibacterium* in spite of the ChlorPrep skin preparation. The average time to positive cultures was 6.78 days.

This study suggests the possibility that *Propionibacterium* in the dermal hair bulbs and sebaceous glands may be the source of the bacteria found in the wounds at revision surgery. Wound contamination by *Propionibacterium* may best be managed by strategies directed at bacteria in as well as on the skin.

## Introduction

Surgeons use antiseptic agents to sterilize the skin surface in an attempt to prevent infection of the surgical site. It is increasingly recognized that in spite of standard surgical preparation, infection by organisms normally found on the patient's skin, such as *Propionibacterium*, can complicate shoulder, hip and knee joint arthroplasty as well as spine surgery. Recent investigations have indicated that while the combination of 2% chlorhexidine gluconate and 70% isopropyl alcohol is an effective preoperative skin preparation against coagulase-negative staphylococcus, it appears to be less effective against *Propionibacterium*, an anaerobic organism that normally inhabits the sebaceous glands and hair bulbs of the dermis— locations that may be out of reach of surgical skin preparation solutions. When these dermal structures are transected by the surgical incision, *Propionibacterium* may be released into the surgical field. Recent studies have examined skin surface cultures after various surgical skin preparations and reported *Propionibacterium*-positive culture rates ranging from 7 to 29%. *Propionibacterium* are frequently recovered from deep specimens harvested at the time of revision for failed shoulder and spine surgery, especially if appropriate culture methods are used. This study tests the hypothesis that – after a standard

surgical preparation of the skin surface of the upper back in normal male subjects – viable *Propionibacterium* remain in the dermis, as indicated by positive cultures for these organisms from dermal punch biopsies.

## Materials / Methods

- Ten healthy male volunteers over the age of 18 years (mean = 50, range = 35-70)
- Surgical skin preparation with ChlorPrep (2% chlorhexidine gluconate and 70% isopropyl alcohol)
- Two 3mm dermal punch biopsies were obtained under sterile conditions using a commercially available kit
- Biopsies were cultured for *Propionibacterium* according to our previously published protocol

## Results

- Seven of the ten (70%) volunteers had positive dermal *Propionibacterium* cultures; four grew *Propionibacterium* from each of the two punch biopsies, three grew *Propionibacterium* from one of the two punch biopsies and three grew *Propionibacterium* from neither.
- The average time to positivity for the cultures was 6.78 days (std dev 0.83, range 6-8 days)

## Discussion

This is the first study to show that *Propionibacterium* can persist in the dermis after a surgical skin preparation of the epidermis.

The potential importance of *Propionibacterium* has recently come to the attention of orthopaedic surgeons. In spine surgery, 20-85% of delayed surgical site infections have been culture positive for *Propionibacterium*. *Propionibacterium* has been commonly cultured at the time of revision shoulder arthroplasty surgery. Pottinger et al reported 108 of 193 shoulder revisions to be associated with positive cultures. Of these, 70% were positive for *Propionibacterium*. Humeral loosening and glenoid wear were associated with a greater than 300% increase in likelihood of a positive *Propionibacterium* culture.

Prior studies have pointed out that standard surgical skin preparation does not eliminate *Propionibacterium* from the surgical field. McLorinan et al found that in spine surgery, cultures for *Propionibacterium* were positive in 29.1% of skin samples, 21.5% of tissue samples, and 16.5% of wound washings. Saltzman et al reported that following surgical skin preparation, *Propionibacterium* was isolated from 17% of the anterior and posterior shoulder skin cultures. Levy et al found that in 42% of a series of 55 shoulders having primary shoulder arthroplasty, *Propionibacterium* were found in deep cultures. An association

between positive deep cultures for *Propionibacterium* and positive dermal cultures for *Propionibacterium* during revision shoulder surgery has been previously reported.

The results of the present study may help account for the presence of this organism in surgical wounds in spite of standard surgical preparation. *Propionibacterium* may be released into the wound at the time when the skin incision transects the dermal glands and bulbs, enabling these organisms to contaminate implanted orthopaedic devices and potentially form an antibiotic-resistant biofilm on them.

While this study does not prove a pathogenetic role for *Propionibacterium* it does suggest that strategies for preventing *Propionibacterium* contamination of surgical wounds may need to address the bacteria residing in as well as those residing on the skin. Such strategies may include intravenous Ceftriaxone and Vancomycin, vigorous wound irrigation, and the application of topical Vancomycin powder into the wound before closure.

## References

1. McLorinan GC, Glenn JV, McMullan MG, Patrick S. *Propionibacterium* acnes wound contamination at the time of spinal surgery. *Clin Orthop Relat Res*. 2005 Aug;(437):67-73.
2. Pottinger P, Butler-Wu S, Neradilek MB, Merritt A, Bertelsen A, Jette JL, Warme WJ, Matsen FA 3rd. Prognostic factors for bacterial cultures positive for *Propionibacterium acnes* and other organisms in a large series of revision shoulder arthroplasties performed for stiffness, pain, or loosening. *J Bone Joint Surg Am*. 2012 Nov 21;94(22):2075-83.
3. Saltzman MD, Marecek GS, Edwards SL, Kalainov DM. Infection after shoulder surgery. *J Am Acad Orthop Surg*. 2011 Apr;19(4):208-18.
4. Saltzman MD, Nuber GW, Gryzlo SM, Marecek GS, Koh JL. Efficacy of surgical preparation solutions in shoulder surgery. *J Bone Joint Surg Am*. 2009 Aug;91(8):1949-53.
5. Matsen FA 3rd, Butler-Wu S, Carofino BC, Jette JL, Bertelsen A, Bumgarner R. Origin of propionibacterium in surgical wounds and evidence-based approach for culturing propionibacterium from surgical sites. *J Bone Joint Surg Am*. 2013 Dec 4;95(23):e1811-7.
6. Bémer P, Corvec S, Tariel S, Asseray N, Boutoille D, Langlois C, Tequi B, Drugeon H, Passuti N, Touchais S. Significance of *Propionibacterium acnes*-positive samples in spinal instrumentation. *Spine (Phila Pa 1976)*. 2008 Dec 15;33(26):E971-6.
7. Butler-Wu SM, Burns EM, Pottinger PS, Magaret AS, Rakeman JL, Matsen FA 3rd, Cookson BT. Optimization of periprosthetic culture for diagnosis of *Propionibacterium acnes* prosthetic joint infection. *J Clin Microbiol*. 2011 Jul;49(7):2490-5.

# Reading Clinical Research: Being a Good Consumer

Seth S. Leopold, MD

*Note from the Chairman:* We are fortunate that our own Dr. Seth Leopold serves as the Editor-in-Chief of *Clinical Orthopaedics and Related Research*. I have asked Dr. Leopold to give us his perspective on leading such a prestigious journal. In addition, by virtue of his position he has a unique perspective on reading scientific articles, a skill that for most orthopedic surgeons is employed far more often than writing scientific reports.

Howard Chansky, MD

Editor in Chief, Discoveries 2014

Professor and Acting Chair

UW Department of Orthopaedics and Sports Medicine

Universities place a great deal of value on the production of peer-reviewed publications. Academic reputations are made on the quantity and quality of papers professors publish in first-tier medical journals. Promotions depend on them. Even the name of this annual report – *Discoveries* – suggests the subtle but unmistakable primacy that good departments like ours place on this important element of scholarship.

As the editor-in-chief of a large, general-interest orthopaedic journal, my success is tied to content producers: Those who generate good research papers – discoveries – and send them to *Clinical Orthopaedics and Related Research*. But the reality is, most of us will never make a transformative discovery. Yet we all need to be able to tell a helpful paper from one that is badly flawed, or even misleading. Our patients depend on us to use this skill before we call upon any other.

This skill can be taught, and it can be learned. While sometimes the fine points of a paper will be challenging for some readers to understand (though good editing should minimize this problem, if not eliminate it), the fundamentals of reading clinical research are not complex. In fact, looking out for just three kinds of bias – selection bias, transfer bias (insufficient follow-up), and assessor bias – will vastly decrease the likelihood of being misled by what one reads in articles about the treatments we use.

## Selection Bias

In case series (that is, studies without control or comparator groups), selection bias comes into play when

authors apply a novel intervention to some patients, but not others. This is more the norm than the exception, and it is no surprise that it should be: For example, early in one's experience with a new surgical approach, one might reasonably choose to avoid heavyset patients, patients with difficult deformities, or patients whose ability to comply with particular restrictions is in doubt. The problem arises when authors don't characterize their indications clearly, and when they provide overly broad endorsements that don't reflect the narrow selection criteria they employed.

In studies with comparator groups (historical control groups or prospective cohorts), selection bias applies when the groups being compared are dissimilar at baseline. Randomization helps, but only a small minority of orthopaedic clinical research studies are randomized, a fact unlikely to change anytime soon. If important differences exist between the control and treatment groups, there is no easy way to attribute the results to the effect of the intervention.

Given that most of what we read will suffer from some degree of selection bias, we should reasonably expect – and carefully screen what we read for – the following key elements, which all good studies should provide: (1) The number of patients treated during the study period for the condition in question, (2) the proportion of those patients treated with the approach being considered, (3) clear criteria that explain how the authors determined those patients' suitability for that approach, and, for studies that include control groups, (4) some data to convince the reader that the study cohorts were

similar in all important respects at baseline. Finally, studies with narrow indications or inclusion criteria should not generalize their findings to patient populations different from those they evaluated.

## Transfer Bias and Insufficient Follow-up

It is unsurprising that patients are lost to follow-up in the course of clinical research. What continues to surprise me as I evaluate clinical research for the journal I edit is the frequency with which this essential element goes unreported.

Here is the problem: The health status of patients who fail to return for follow-up is likely to be worse than those who do<sup>1, 2</sup>. When researchers don't account for all patients in a clinical series, readers generally should consider the report a "best case" scenario of what is possible with an approach, rather than a typical or realistic appraisal. Studies losing a substantial proportion of those initially treated can be misleading; we can draw no inference from a study that reports 95% success in 45% of the patients treated a particular way. While a worst-case analysis – assuming that all of the unaccounted-for patients have failed – often is too severe an approach, it is naïve and dangerous to assume, as so many studies seem to, that the missing all are doing fine.

In studies that have two or more treatment groups, the question of differential loss to follow-up between the cohorts comes into play. If a greater proportion of patients in one group are missing, one needs to consider the possibility that, once again, they are not doing comparably well to those who

have returned for evaluation.

Finally, recognize that it is much easier to demonstrate efficacy than it is to prove a treatment is safe. Small studies at short-term follow-up sometimes can suggest a treatment is promising, but more time and larger populations are needed to detect reoperations, complications of treatment, or less-common adverse effects. This issue, as much as any other, has driven many of the more spectacular recent failures we have seen, including metal-on-metal total hip replacement, recombinant human BMP, and cardiac risk associated with the use of certain non-steroidal anti-inflammatory drugs. It takes much larger studies, and much longer follow-up durations, to establish safety than it does to demonstrate preliminary efficacy.

#### **Assessor Bias**

Who evaluated the patient, the relationship of the evaluator to the approach, drug, or device being studied, and the tools (s)he used for the job contribute to assessor (or assessment) bias. Surgeons evaluating their own clinical results, designers and consultants assessing products whose success they are vested in, and outcomes tools that are unvalidated, unsophisticated, or incompletely described are common examples of this problem.

While not the same thing as assessor bias, the issue of effect size versus “statistical significance” is worth mentioning, as misunderstandings on this point can result in the same kinds of misleading conclusions that assessor bias can cause. Given adequate sample size, studies can discern small (even clinically unimportant) differences between treatment groups. Too many readers continue to be swayed by p-values alone. Don’t be. Look past the p-value, and consider the actual data. How large was the effect? Was it large enough to justify the risks, costs, and uncertainties associated with a novel treatment?

As the editor of a journal, I try hard to account for these three kinds of bias in all clinical research papers that pertain to treatments. As a consumer, I don’t take seriously any studies that fail to do so. Readers should ask at least this much from the journals they depend on to guide their clinical decisions.

#### **References**

1. Norquist BM, Goldberg BA, Matsen FA3rd. Challenges in evaluating patients lost to followup in clinical studies of rotator cuff tears. *J Bone Joint Surg Am.* 2000;82-A:838-842.
2. Murray DW, Britton AR, Bulstrode CJK. Loss to follow-up matters. *J Bone Joint Surg Br.* 1997;79-B:254-257.

# Contralateral Bone Loss Following Ipsilateral Nerve Injury: Evidence for a Neuronal Skeletome

Laura E. Stoll, MD, Philippe Huber, BS, Ronald Y. Kwon, PhD, DeWayne Threet, BS, Ted S. Gross, PhD, and Steven D. Bain, PhD

Over the last decade, our knowledge of how nerve, muscle, and bone interact to cooperatively regulate bone homeostasis has changed dramatically. Understanding the mechanisms underlying this relation holds potential to enable novel treatment of a variety of musculoskeletal pathologies. This study addresses one aspect of this relation, the potential for direct involvement of peripheral sensory nerves in the regulation of bone homeostasis.

## Introduction

Peripheral nerve injury (PNI) is a frequent complication of orthopaedic trauma that can lead to muscle atrophy, sensory impairment and chronic pain [1]. Bone loss has also been associated with nerve damage and has been attributed to reductions in mechanical loading due to paralysis, immobilization, and/or inactivity, but in the absence of muscle atrophy or motor damage the mechanism of bone loss is unclear [2]. As bone is abundantly innervated, even modest interruption of neuronal signaling has potential to influence skeletal homeostasis [3, 4, 5]. In this context, previous studies in our group have demonstrated that PNI leads to significant bone loss without concomitant muscle atrophy [6]. Given

these observations and recent data suggesting a role for sensory nerves in bone remodeling [7], we hypothesized that sensory nerves may play a role in bone loss following PNI. To explore this hypothesis, we assessed bone loss in the proximal tibia following PNI in TRPV1 KO mice, which have altered pain responses due to sensory nerve deficits [8].

## Materials and Methods

- Sixteen-week-old TRPV1 knockout (KO) female mice and control mice (C57 female) underwent baseline micro-CT scans of both left and right proximal tibia.
- Mice were randomized to PNI of the right sciatic nerve or

sham surgery. For PNI we placed a sterile, silastic tube atraumatically around the sciatic nerve [9]. During sham surgery, the nerve was exposed, but not manipulated.

- Micro-CT scans were subsequently obtained on day 14 and day 28. The ipsilateral humerus was also scanned.
- Standard image analysis procedures were used to determine cancellous bone morphology parameters for the proximal tibia (bone volume/total volume; BV/TV).
- Mice underwent gait analysis on d0 and d8 to quantify peak ground reaction forces (GRF) as a control for possible effects of PNI on altered weight bearing. For imaging data, ANOVA analysis was conducted across groups.

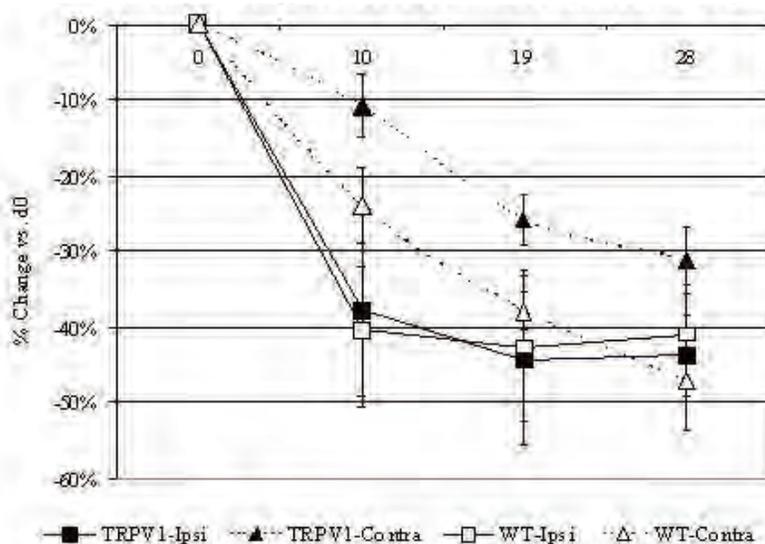


Figure 1: Contralateral Response to PNI is Attenuated in TRPV1 KO Mice. PNI in WT and TRPV1 KO mice led to significant loss of cancellous bone in both the ipsi and contralateral proximal tibiae, suggesting homeostatic linkage between the two sites. Surprisingly, contralateral bone loss was partly attenuated in TRPV1 KO mice, suggesting that sensory innervation may play a role in the bilateral cross talk. Finally, there were no bone changes in the ipsilateral humerus (data not shown), providing evidence that PNI did not trigger systemic bone loss.

## Results

- PNI resulted in a -40.9% decrease in BV/TV of the ipsilateral proximal tibia in WT mice within 4 weeks ( $p < 0.01$ ). TRPV1 KO mice demonstrated an equivalent -44.9% decrease in metaphyseal BV/TV ( $p < 0.01$ ). Interestingly, WT mice also experienced a -47.0% decrease in BV/TV of the proximal tibia of the contralateral limb, while contralateral bone loss in TRPV1 KO mice was attenuated by 30.5% (Figure 1).
- There were no changes in BV/TV in the ipsilateral humerus (data not shown), demonstrating the absence of a systemic effect due to PNI.
- Peak GRF measured at d8

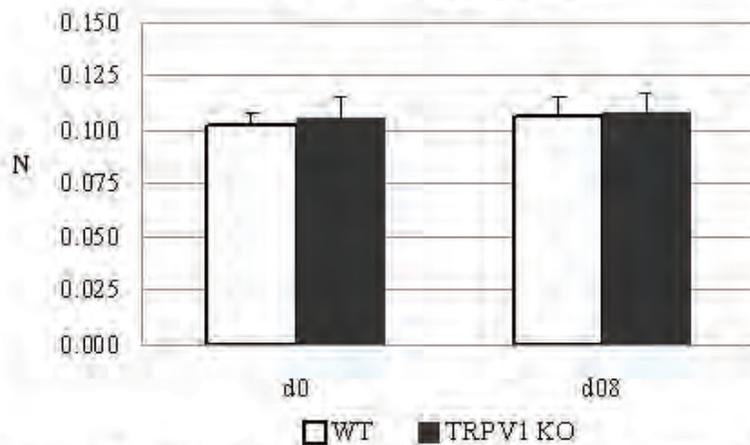


Figure 2: Peak GRF of Right Hind Limb. There were no changes in peak GRF between WT and TRPV1 KO mice after PNI, providing evidence that weight bearing was not altered by nerve injury.

following PNI were no different from peak GRF measured at d0, providing evidence that weight-bearing was not altered by nerve injury (Figure 2).

#### Discussion

Taken together, these results indicate that ipsilateral bone loss following PNI is a consequence of altered neuronal signaling and is unrelated to changes in mechanical loading. However, given that ipsilateral bone loss in WT and TRPV1 KO mice following PNI was equivalent, the TRPV1 receptor does not appear to play a significant role in the ipsilateral osteopenia. However, the magnitude of contralateral bone loss in this model is a novel and unexpected observation and, in the absence of changes in weight bearing, raises the provocative question of how the left tibia so closely mirrored bone loss in the right tibia. In this context, the attenuation of contralateral bone loss in TRPV1 KO mice would be consistent with a role for sensory nerve pathways in bilateral “cross-talk” between ipsilateral and contralateral tibia. Furthermore, the findings in our model display surprising similarity to reports of contralateral osteopenia in patients with chronic regional pain syndrome [10, 11]. Given the recent findings that demonstrate a direct role of sensory nerves in skeletal homeostasis [7], we speculate that sensory innervation of bone maps skeletal morphology in much the same way that sensory nerves map the dermatome. Given this linkage, we speculate that nerve injury induced alterations to a neuronal “Skeletome”

at one level has potential to alter bone homeostasis at distant sites.

#### References

1. Noble, et al., J Trauma 1998. 45:116-122
2. Whiteside, et al., Bone 2006. 38:387-93
3. Elefteriou, Arch Biochem Biophys 2008. 473:231-236
4. Imai, et al., Microsc Res Tech 2002. 58:61-69
5. Togari, Microsc Res Tech 2002. 58:77-84.
6. Bain, et al., Trans Ortho Res Soc. 36:392.
7. Fukuda, et al., Nature 2013. 497:490-493.
8. Caterina, et al., Science 2000. 288:306-313.
9. Mosconi, et al., Pain 1996. 64:37-57.
10. Veldman, et al., Lancet 1993. 342:1012-1016.
11. Karacan, et al., J Bone Miner Metab 2004. 22:44-47.

#### Acknowledgments

These studies were supported by funds from Sigvard T. Hansen, Jr. Endowed Chair and the Zimmer Fracture Biology Professorship.

# The Newly Described Anterolateral Ligament of the Knee: What is its Function?

Erin M. Parsons, MS, Albert O. Gee, MD, and Peter R. Cavanagh, PhD, DSc

Recent anatomic investigation has identified a new anterolateral ligament (ALL) of the knee. The purpose of this study was to test the biomechanical contributions of the ALL in a cadaver model under robotic simulation. Twelve cadaveric knees were flexed from 0° to 90° and loaded with 134 N of anterior force on the tibia and subsequently with 5 Nm of internal rotation force (with no anterior drawer). The *in situ* forces in the anterior cruciate ligament, the lateral collateral ligament, and the ALL were determined by the principle of superposition. The ALL was a primary resistor of internal rotation moments ( $p=0.018$ ) at flexion angles of 60° and 75°. It did not have a role in resisting anterior drawer at any flexion angle. This study demonstrates that the ALL is a primary contributor to resisting internal rotation at higher angles of knee flexion. The ALL, in conjunction with the anterior cruciate ligament, appears to have a role in rotational stability of the knee and this may have important clinical implications for reconstruction of the injured knee.

## Introduction

A new ligament termed the anterolateral ligament (ALL) of the knee has been recently described by Claes et al.<sup>1</sup> Its existence was originally postulated by Ségond, whose eponymous avulsion fracture of the anterior lateral tibia has been associated with internal rotation injuries of the knee and is believed to be pathognomonic for an ACL tear<sup>3</sup>. The ALL attaches between the lateral femoral epicondyle and the proximal tibia, posterior to Gerdy's tubercle. In full extension, the ALL is parallel with the lateral collateral ligament (LCL). In flexion greater than 30°, the ALL can be seen at an oblique angle to the LCL (Figure

1). Given the anatomical orientation of the ALL, previous researchers have hypothesized that the ALL may contribute to resisting internal rotation and stabilizing the knee joint.

The purpose of this study was to describe the biomechanical function of the ALL in a cadaveric model using robotic simulation. Specifically, we aimed to compare the *in situ* forces in the anterior cruciate ligament (ACL), the LCL, and the ALL under anterior drawer and internal rotation at various angles of flexion.

## Methods

- Twelve cadaveric knees (mean age 76.3 years, range 35-92

years) were dissected by the same surgeon (AOG). The iliotibial (IT) band was reflected and the ALL was identified (Figure 1).

- The specimen was then prepared for robotic testing<sup>4</sup>. The knee was subjected to 134 N of anteriorly directed force, simulating an anterior drawer test, followed by 5 Nm of internal rotation force with no anterior drawer at flexion angles of 0, 15, 25, 35, 45, 60, 75, and 90 degrees. The positions of the robot were recorded throughout the trajectory at a frequency of 20 Hz.
- The recorded positions of the robot were then re-executed on the same knee in four states: (1) the intact state; after transection of the (2) ALL; (3) LCL; and (4) ACL. The order in which the ligaments were transected was block randomized for all twelve specimens to minimize the effects of tissue degradation subsequent to repeated loading.
- By the principle of superposition<sup>5</sup>, the *in situ* force contribution of each ligament was calculated by subtracting the force vectors recorded in each state. The percent force contribution of each ligament was calculated by dividing the magnitude of the force vector in the altered state by that in the intact state.

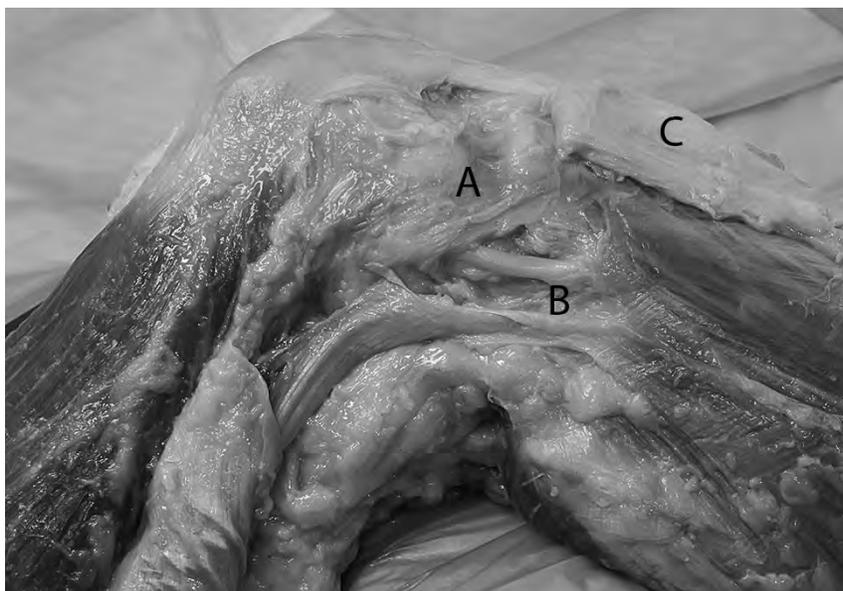


Figure 1: Right knee dissection showing (A) anterolateral ligament; (B) lateral collateral ligament; (C) iliotibial band reflected.

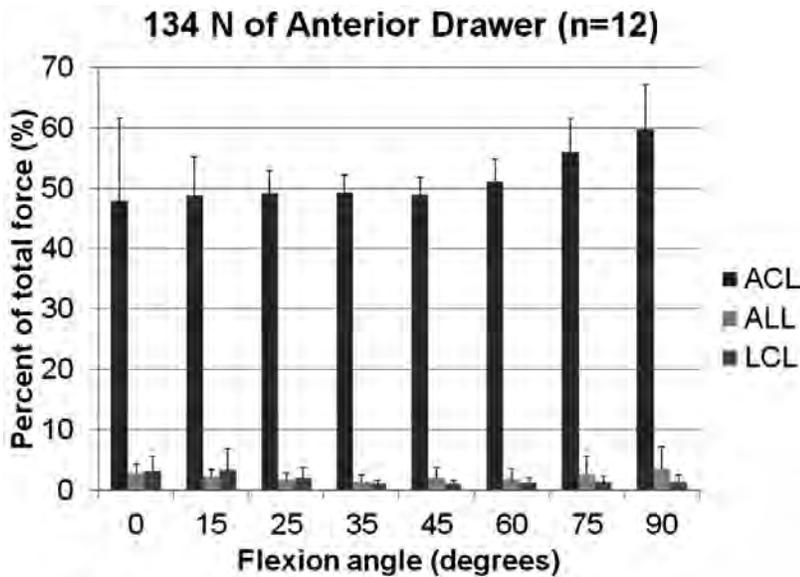


Figure 2: Percentage of force contribution of each ligament resisting 134 N of anterior drawer force at each angle of flexion.

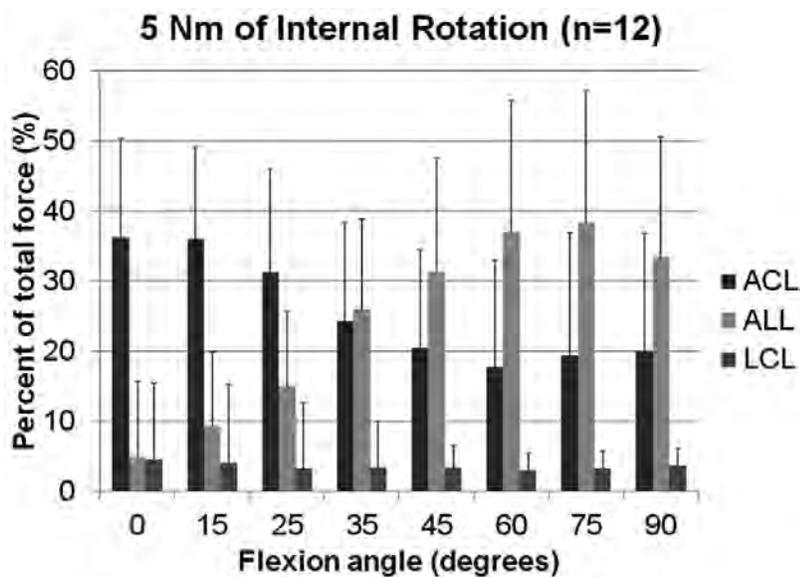


Figure 3: Percentage of force contribution of each ligament resisting 5 Nm of internal rotation at each angle of flexion.

- Statistical analysis was performed using SPSS software. A two-way repeated measures ANOVA was used to determine the difference in force contributions between ligaments at different angles of flexion. Tukey's HSD post hoc test was used to determine differences within groups. Statistical significance was set at  $p=0.05$ .

### Results

During anterior drawer, the ACL experienced significantly higher forces ( $p<0.001$ ) than either the LCL or the ALL at all angles of flexion (Figure 2). The LCL and the ALL forces were not significantly different from each other under anterior loads at all angles of flexion.

During internal rotation, the ACL had significantly higher forces at 0° and 15° of flexion than either the LCL or the ALL ( $p<0.001$ ). The ALL provided increasing contributions to

resist internal rotation moments as the knee flexion angle increased. At 60° and 75° of flexion the contribution was significantly higher than either the LCL or the ALL ( $p<0.001$ ). The LCL forces did not change due to the flexion angle ( $p = 0.699$ ).

### Discussion

The existence of the ALL was originally surmised by Ségond and most recently confirmed by Claes et al. Prior work has hypothesized that the ALL likely functions as a stabilizer for internal rotation due to its anatomical orientation and position<sup>2</sup>. In this study, we confirmed the existence of the ALL through anatomical dissection in all but one of our specimens and provide evidence to demonstrate its role in resisting internal tibial rotation at flexion angles greater than 45°. Unlike the ACL, the ALL does not have a role in resisting anterior tibial translation at any angle knee flexion. Further investigation into this new ligament is needed to further characterize its function, to determine its clinical role in the knee, and to explore its reconstruction after knee injury.

### References

- Claes S, Vereecke E, Maes M, et al. Anatomy of the anterolateral ligament of the knee. *J Anat.* 2013;223:321-328. PMID: 23906341
- Fairclough J, Hayashi K, Toumi H, et al. The functional anatomy of the iliotibial band during flexion and extension of the knee: implications for understanding iliotibial band syndrome. *J Anat.* 2006;208:309-316. PMID: 16533314
- Hess T, Rupp S, Hopf T, et al. Lateral tibial avulsion fractures and disruptions to the anterior cruciate ligament. A clinical study of their incidence and correlation. *Clin Orthop Relat Res.* 1994;:193-197. PMID: 8194233
- Noble LD, Colbrunn RW, Lee DG, et al. Design and validation of a general purpose robotic testing system for musculoskeletal applications. *J Biomech Eng.* 2010;132:025001. PMID: 20370251
- Woo SLY, Fox RJ, Sakane M, et al. Biomechanics of the ACL: Measurements of in situ force in the ACL and knee kinematics. *Knee.* 1998;5:267-288.

# Geriatric (Fragility) Hip Fracture Program - Northwest Hospital & Medical Center

Robert S. Clawson, MD

Osteoporosis is the most common cause of fracture in the United States, with 43 million individuals over age 50 suffering from osteoporosis or osteopenia of the hip. By 2020, one in two Americans over 50 is expected to have or to be at risk of developing osteoporosis of the hip. Hip fractures can have devastating consequences for both individuals and their family members. For example, the risk of mortality is between 4 times greater among hip fracture patients during the first three months after the fracture than in individuals of similar age who have not suffered a fracture. Nationally, direct care annual expenditures for osteoporosis and fracture care are estimated to be in the range of \$12 - \$18 billion in 2002 dollars. [1] Historically, Northwest Hospital's primary service area has produced relatively high volumes of geriatric hip fractures (Figure 1). These factors indicate the importance and viability of a program designed to reduce post-hip-fracture mortality, complications and readmissions.

## Introduction

The role of the UW Department of Orthopaedics and Sports Medicine in treating hip fracture repair has been profound. D.K. Clawson, MD, the first department chair, invented the sliding hip screw which, after further modification by his resident Robert Winquist, MD, became the most implanted device in orthopaedic fracture care worldwide. So, it is fitting for the UW Department of Orthopaedics and Sports Medicine and UW Medicine's Northwest Hospital to now be involved in taking hip fracture care to a new level.

When Northwest Hospital joined the UW Medicine health system in 2010, the UW Department of Orthopaedics and Sports Medicine in particular, embraced the affiliation by partnering with Northwest Hospital to expand clinical care in joint replacement and upper extremity orthopaedics. In addition, the Department has collaborated with Northwest Hospital in the creation of a geriatric hip fracture program with the goal of reducing mortality and post-operative complications, shortening length of stay and increasing functional outcomes. It is based on a program created by orthopaedic surgeon Stephen Kates, MD at the University of Rochester, which reduced length of stay for hip fractures from more than

six days to 4.2 days and significantly decreased readmissions and infections. Dr. Kates conducted Grand Rounds at UW in February 2013, and his visit was the final impetus for moving forward with our own program.

## Co-Management and Alignment

To start, a multi-disciplinary team at UW Medicine developed a new algorithm for geriatric hip fracture treatment based on Kates' model that seeks to evaluate, operate and repair geriatric hip fractures within 24 hours of ED arrival and to return patients to physical activity as soon as possible following surgery. The algorithm drives treatment through the entire continuum of care, from pre-hospitalization to ED management to OR to post-operative care, discharge and rehabilitation therapy.

It hinges on a co-management model between orthopaedic surgeons and hospitalists that addresses stable fixation of the fracture, the patients' medical co-morbidities, and osteoporosis and future fall risk. Administration has been a key partner in developing this model by facilitating collaboration among orthopaedic surgeons, hospitalists, rheumatologists, emergency physicians, physical and occupational therapists and many other

members of the hospital's care team. Urgent surgery, postoperative care and post-discharge follow-up are the program's hallmarks.

In a historical aside, Dr. D.K. Clawson recognized as a resident that preoperative medical assessment and urgent surgery for hip fractures brought better results. Thus, an old idea has become new again in the chronology of hip fracture care.

## Preliminary Results

In his 2004 report, the Surgeon General called upon the healthcare community to develop a variety of prevention measures and strategies to monitor bone health within communities [1].

The American Orthopaedic Association [2] has embraced care coordination, as an essential strategy to accomplish this prevention and monitoring challenge. Evidence supports that coordinated care generally improves clinical outcomes [3] and produces benefits specific to hip fracture repair, [4] [5].

Since the November 2013 launch of the Fragility (Hip) Fracture Program at Northwest Hospital, both LOS (Figure 2) and ED-to-surgery time (Figure 3) have improved.

## Discussion

Research has demonstrated that optimal outcomes are achieved when hip fractures in the elderly are repaired within 24 to 36 hours of fracture. Northwest Hospital clinicians and administration have revised operative/peri-operative protocol and order-sets

Hip Fractures	2011	2012	2013	Grand Total
Cases By Year	144	128	128	400

Figure 1: Northwest Hospital Fracture Statistics.

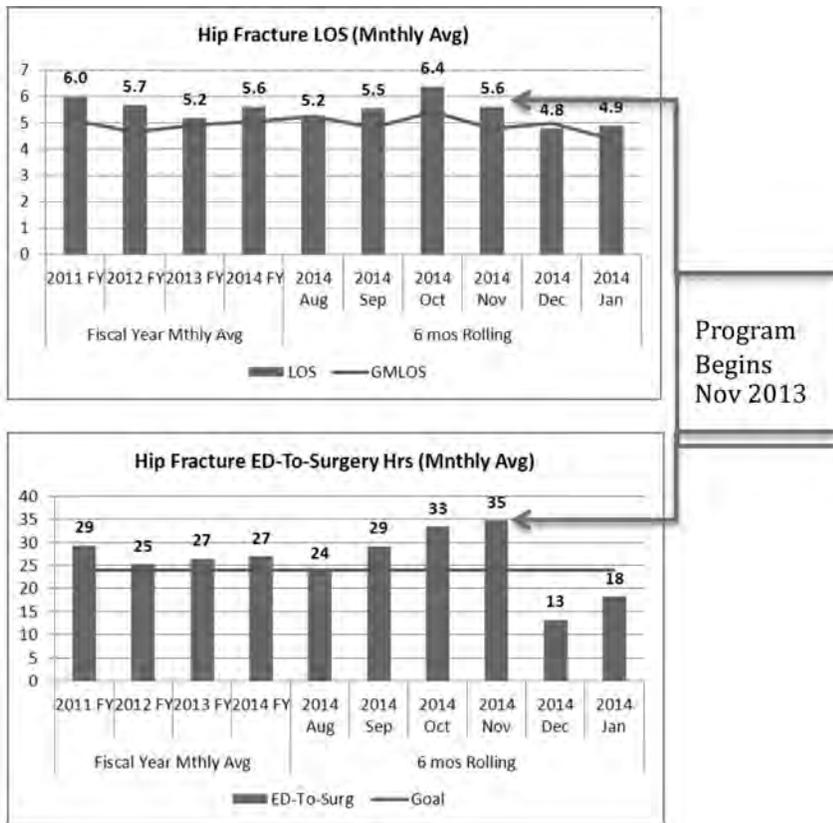


Figure 2: (top) Northwest Hospital Hip Fx LOS. Figure 3: (bottom)NWH ED to Surgery Hrs (Monthly Average).

to meet this best-practice objective.

Measurement of outcomes in hip fracture is an ongoing challenge. Discharge of these patients to rehabilitation and skilled nursing facilities complicates standardization of therapy protocols. The risk of another fragility fracture doubles with each such fracture sustained in the elderly. Steps to prevent future fractures demand fall prevention. Northwest Hospital instituted a SAGE (Safety and Gait Enhancement) program in 1996. Its documented results have proven effective in preventing further falls and should be expanded.

The Department of Rheumatology also envisions a medical approach to treatment of the underlying osteoporosis that continues pharmacological treatment, which, if not already in place, would be started immediately post-op.

Prompt surgery, medical management of osteoporosis, and appropriate physical therapy with an ongoing fall prevention emphasis are the steps to achieving the "Holy Grail" of fragility fracture care: prevention of the next fracture.

UW Medicine and Northwest Hospital expect to expand the Fragility

Fracture Program to include other types of osteoporosis- and age-related fragility fractures, such as those of the wrist, spine and shoulder, as well as participation by orthopaedic residents. The program would expose residents to the concept of co-management in orthopaedic trauma and disease.

Furthermore, physician and hospital leaders are committed to collaboration with skilled nursing facilities and community providers around post-discharge care, to ensure this bone-health initiative meets the Affordable Care Act's "Triple Aim": 1) improve the health of the population we serve; 2) improve the individual's experience of healthcare; and 3) deliver care at optimal cost. Expansion into the post-discharge care-continuum will include communication and monitoring of medications and activity interventions that promote bone health.

#### Bibliography

1. Thompson, "Bone Health and Osteoporosis," US Department of Health and Human Services, Rockville, MD, 2004.
2. L. Tossi, R. GlickLich, K. Kannan and K. Koval, "The American

Orthopaedic Association's "Own the Bone" Initiative to Prevent Secondary Fractures," J Bone Joint Surg Am, pp. 163-73, 2008.

3. A. Fisher, M. Davis, S. Rebenach, S. Sivakumaran, P. Smith and M. Budge, "Outcomes for Older Patients with Hip Fracture: The Impact of Orthopedic and Geriatric Co-Care," J Orthop Trauma, pp. 172-8, 2006.

4. M. Phy, D. Vanness, L. 3. Melton, K. Long, C. Schleck, P. Huddleston and J. Huddleston, "Effects of a Hospitalist Model on Elderly Patients With Hip Fracture," Arch Intern Med, pp. 796-801, 2005.

5. S. Kates, D. Mendelson and S. Friedman, "Co-managed Care for Fragility Hip Fracture (Rochester Model)," Osteoporos Int., pp. Supp: 621-5, 2010.

# Tissue Engineered, Scaffold-Free, Human Cartilage Sheets Positively Respond to Low Oxygen Tension Both Mechanically and Biochemically

Thomas J. Kean, PhD<sup>1</sup>, G. Adam Whitney<sup>1</sup>, MS, Geoffrey R. Traeger, BS,  
James E. Dennis, PhD<sup>1</sup>, and Russell J. Fernandes, PhD

Cartilage tissue has been recalcitrant to tissue engineering approaches. Although improvements have been made in tissue culture, it is unclear what impact increased glycosaminoglycan, collagen and collagen crosslinks has on stiffness. Low oxygen tension and longer culture periods both served to increase matrix components but the foremost correlation was found between compressive stiffness and the ratio of glycosaminoglycan and collagen.

## Introduction

Cartilage tissue has poor intrinsic repair capacity. Tissue engineering could potentially address this through *in vitro* culture methods to produce functional cartilage tissue. We, and others, have investigated media supplements and growth factors to improve the expansion and redifferentiation of the expanded chondrocytes (Henderson, 2007). What has not been examined is how the increase in extracellular matrix components relates to the stiffness of the human cartilage produced. We have developed methods to significantly improve the expansion of human chondrocytes whilst maintaining their differentiation capacity by their culture on devitalized synoviocyte matrix. Using these methods, we attempted to produce sheets of human chondrocyte-derived cartilage and investigated the effect of low oxygen tension and duration of culture on cartilage quality in terms of compressive stiffness and biochemical content. It was hypothesized that low oxygen tension and increased culture duration would improve the mechanical properties of the tissue engineered cartilage.

## Methods

Human chondrocytes were expanded under low oxygen tension (5%) on synoviocyte matrix in DMEM-LG/FBS (10%). Cells were trypsinized and seeded at high density ( $4.4 \times 10^6$  cells/cm<sup>2</sup>) in a custom biochamber. Cell sheets formed within the biochamber were cultured at either atmospheric oxygen tension (21%) or low oxygen tension (5%) in defined chondrogenic medium (DMEM-HG containing ITS+premix, dexamethasone (100

nM), ascorbate-2-phosphate (120  $\mu$ M), MEM NEAA, Pen/Strep, glutamax, TGF $\beta$ 1 10 ng/ml) for 21 days and 46-56 days with media changes every other day. At the end of culture, 5 mm biopsy punches were taken for biochemical (glycosaminoglycan (GAG), hydroxyproline (Hyp), collagen cross-link content (hydroxylslyl pyridinoline + lysyl pyridinoline; HP+LP; moles/mole collagen)), histological, and mechanical assessment (equilibrium modulus). Three separate experiments were performed with chondrocytes from 2 donors. A paired t-test was used to test for statistical significance at  $p < 0.05$ .

## Results

There was a significant increase in collagen content after longer duration in culture (A) at both 5% and 21% O<sub>2</sub>, and trivalent pyridinoline cross-link content was significantly increased (B) at 5% O<sub>2</sub> ( $p < 0.05$ ). Differentiation under 5% oxygen tension appeared to increase or maintain GAG accumulation (C). There was a significant correlation between the equilibrium modulus and the GAG/Hyp ratio (D). Compressive stiffness appeared to decrease with increased culture time and to be greater at lower oxygen tension (E). These observations were also supported by Safranin-O staining and immunohistochemistry. Sheets showed strong GAG and type II collagen staining when cultured under 5% oxygen tension (F) with no type X collagen staining (data not shown). Sheets had an average thickness of  $587 \mu\text{m} \pm 118$  at 5% O<sub>2</sub> and  $387 \mu\text{m} \pm 139$  at 21% O<sub>2</sub> ( $p < 0.05$ ).

## Discussion

Scaffold-free human tissue engineered cartilage sheets were successfully formed under all culture conditions. Although subjective assessment of the sheets (physical handling) seemed to indicate that longer culture durations gave stronger sheets, this was not supported by the equilibrium moduli, which was surprising. However, the results show an increase in both total collagen content and collagen cross-link content. Makris et al. (2013) also found that hypoxia increased collagen crosslinks in tissue engineered bovine cartilage constructs but that they also found weak correlations to compressive mechanical properties. Future studies will examine whether increased collagen and collagen cross-linking causes an increase in tensile strength which may account for the subjective impression of increased overall strength.

## Significance

Current joint replacement technologies have a limited lifetime and result in large bone loss during revision. However, human chondrocytes expand poorly on tissue culture plastic and dedifferentiate resulting in weak cartilage constructs. Engineering cartilage to resurface the bone in a joint is thus an extremely challenging, but promising, endeavor that shows potential to limit revisions. Investigation into the mechanical and biochemical attributes of normal and tissue engineered cartilage is important in identifying how these properties correlate so that manipulations to improve them can result in structurally sound replacement tissue.

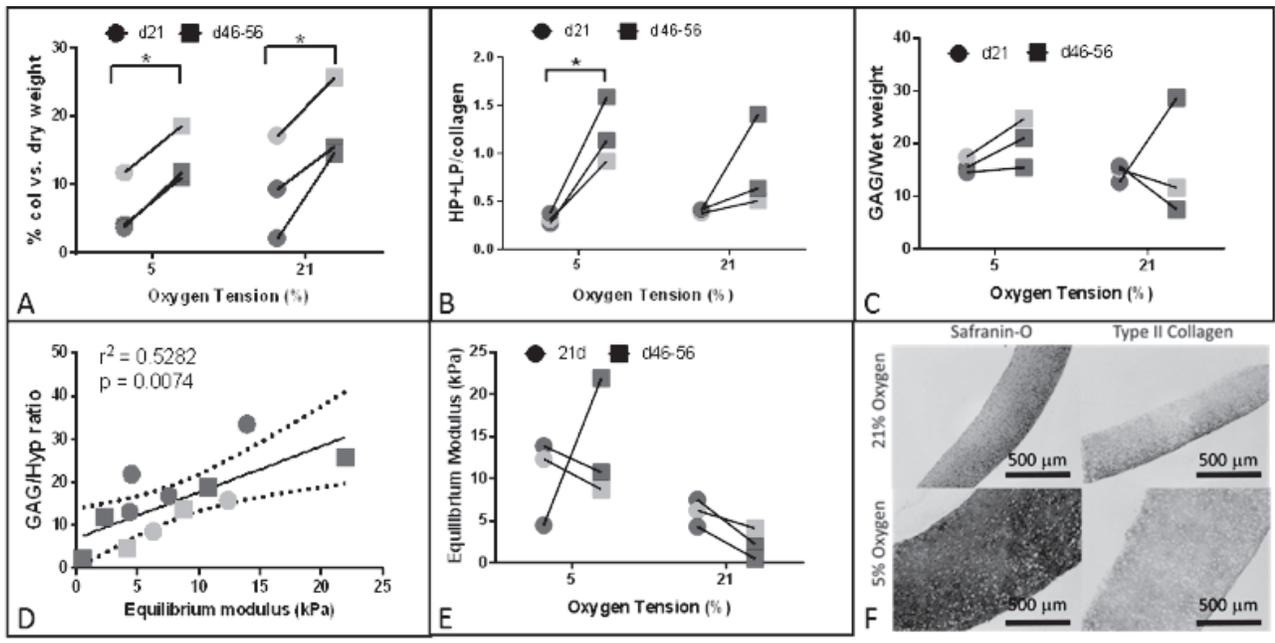


Figure 1: Each experiment is represented by a different color, maintained throughout the charts. A) Collagen content of sheets cultured at 5% and 21% O<sub>2</sub>; B) Collagen cross-link density of sheets cultured at 5% and 21% O<sub>2</sub>; C) GAG content of sheets cultured at 5% and 21% O<sub>2</sub>; D) Correlation of compressive stiffness with GAG/Hyp ratio; E) Compressive stiffness of sheets cultured at 5% and 21% O<sub>2</sub>; F) Histological analysis of sheets for GAG (Safranin-O) and type II collagen (scale bar = 500μm; \* =  $p < 0.05$ , paired t-test).

## References

- Henderson, J.H., N.M. Ginley, A.I. Caplan, C. Niyibizi, and J.E. Dennis, Low oxygen tension during incubation periods of chondrocyte expansion is sufficient to enhance postexpansion chondrogenesis. *Tissue Eng Part A*, 16, 5, 1585, 2010.
- Makris, E.A., J.C. Hu, and K.A. Athanasiou, Hypoxia-induced collagen crosslinking as a mechanism for enhancing mechanical properties of engineered articular cartilage. *Osteoarthritis Cartilage*, 21, 4, 2013.

<sup>1</sup>Benaroya Research Institute, Seattle, WA

# Outcomes of Nonoperative and Operative Treatment of Humeral Shaft Fractures

Benjamin Hamilton, MS, Edward Westrick, MD, M. Bradford Henley, MD, MBA,  
and Reza Firoozabadi, MD, MA

Fractures of the humeral shaft have traditionally been treated conservatively with functional bracing; however, certain clinical scenarios call for operative intervention. There is still disagreement over the optimal approach to treat humeral shaft fractures and there are few existing studies evaluating nonoperative and operative management of these injuries. The primary aim of this study was to retrospectively determine if the incidence of non-union, nerve palsy, infection rates, and time to union were significantly different between operative versus non-operative approaches to humeral shaft fractures. Two hundred ninety-six adult patients with a humeral shaft fracture who satisfied inclusion criteria were treated with either a functional brace or operatively (compression plating, intramedullary nailing, or external fixation). The occurrence of nonunion (23.2% vs 10.2%;  $P=.006$ ) was statistically significant and more common in the nonoperative group. Infection rates were higher for the operative versus non-operative group (3.5% vs 0%;  $P=.000$ ) and this may reflect the large majority of open fractures that were treated operatively. Radial nerve palsy was also more common in the operative group (20% vs 36%;  $P=.02$ ). Only 2 cases (1%) of radial nerve palsy seen in the operative group were iatrogenic, with both being transient. No significant difference in time to union was found between the 2 groups. Conservative treatment of humeral shaft fractures had a significantly higher rate of nonunion, while operative treatment was associated with a low incidence of iatrogenic nerve palsy and higher rates of infection. Despite potential complications of operative treatment, the significant difference in nonunion rates seen in this study may indicate a shift from the current standard of non-operative treatment.

## Introduction

Fractures of the humeral shaft carry a high mortality rate and are frequently the result of severe trauma. They are also common, composing between 1-7.8% of all fractures and approximately 27% of fractures involving the bone.<sup>1</sup>

The preferred treatment of humeral shaft fractures has historically been non-operative management with functional bracing.<sup>2</sup> While this treatment has been shown to achieve a union rate of nearly 95%, complications of non-operative management include nonunion, malunion, and persistent radial nerve deficits.<sup>3-5</sup>

Operative management of humeral shaft fractures is considered for specific situations including polytraumatized patients and open fractures. Currently, the most common fixation methods are compression plating, interlocking intramedullary (IM) nails, and external fixation. The advantage of open reduction with plate fixation is visualization of the fracture site and high likelihood of anatomic reduction. However, disadvantages include extensive dissection, potential injury to the radial nerve, risk of infection, and the possible need for plate removal at a later date. IM stabilization offers an approach requiring less soft tissue

disruption with preservation of the fracture hematoma though it may be performed with an open reduction too. Disadvantages include potentially higher rate of complications (shoulder pain, reoperation) when compared with compression plates.

There are limitations of both operative and non-operative treatment, and controversy remains over the ideal approach. The aim of this study was to compare operative versus non-

operative management of humeral shaft fractures by examining time to radiographic union, rates of nonunion, and rates of complications.

## Patients and Methods

- This was a retrospective review of a prospectively collected trauma database. In total, 505 patients with humeral shaft fractures treated between Jan 2000 & Oct 2012 were

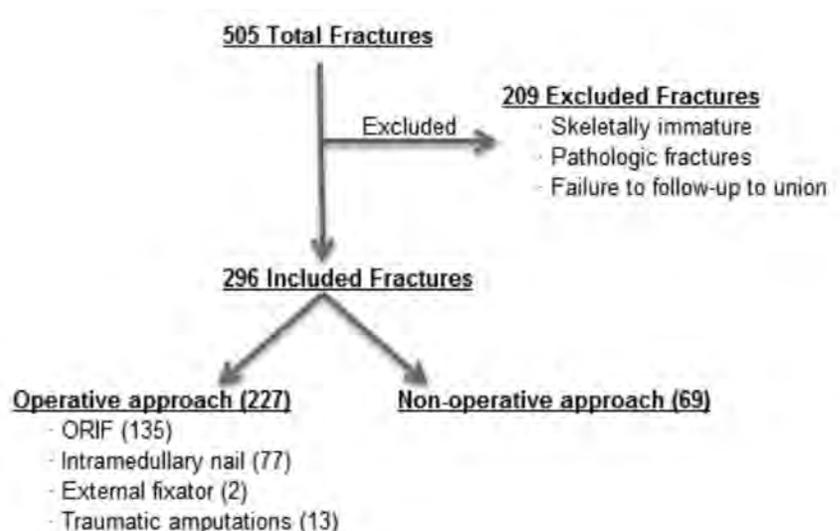


Figure 1: Exclusion Flowsheet.

Characteristics of the Study Population by Type of Treatment				
	Overall (N=296)	Non-operative (N=69)	Operative (N=227)	P-value
Male	186 (63%)	34 (49%)	152 (67%)	0.008
Age*	33 (22-47)	42 (21-60)	31 (22-46)	0.018
Left Side Affected	152 (51%)	37 (54%)	115 (51%)	0.899
Open Fracture	99 (33%)	7 (10%)	92 (41%)	0.000
<b>Concomitant Injuries</b>				
Monotrauma	78 (26%)	30 (44%)	48 (21%)	0.000
Polytrauma	218 (74%)	39 (56%)	179 (79%)	
<b>Trauma Mechanism</b>				
Low Energy	31 (11%)	19 (28%)	12 (6%)	0.000
High Energy	216 (76%)	46 (67%)	170 (79%)	
Other	39 (14%)	4 (6%)	35 (90%)	

\* Data are shown as median with the first and third quartiles given within brackets

Table 1: Characteristics of the Study Population by Treatment Type.

- identified.
- Humeral shaft fractures were classified by a fellowship-trained orthopaedic traumatologist according to the AO/OTA<sup>6</sup> classification.
- The chart and radiographs were reviewed and the following items documented: patient demographics, injury mechanism, associated injuries, time to radiographic union, nerve palsy, and nonunion.
- Radiological union was defined as cortical bridging of at least three out of four cortices on orthogonal views, with disappearance of the fracture lines; clinical union as absence of pain at the fracture site with return to full activities; and nonunion as failure of radiological union at 6 months, requiring surgical intervention.
- Mechanism of injury was classified as low energy (ie fall from standing), high-energy

(ie MVC, fall from height), or "other" (ie low-velocity GSW).

### Results

- Out of 505 patients, 209 were excluded from the study (Figure 1). Of the 296 patients included, 227 fractures were treated operatively, including 13 traumatic amputations. In the operative group, 63.1% of the patients were treated using bridge plating, 36.0% using intramedullary nailing, and 0.9% using external fixation. Sixty nine fractures were treated non-operatively with functional bracing. This is displayed in Figure 1.
- The majority of patients were male, and there was a significant difference between treatment groups; Table 1 shows the characteristics of the study population by treatment type. There was also a significant difference in age between groups.

- Overall, nerve palsies were identified in 98 (33%) of patients at the time of presentation. Eighty-four (37%) operative patients had nerve palsies, with 82 diagnosed preoperatively. Fourteen (20%) non-operative patients sustained nerve palsies. One non-operative and 14 operative palsies resulted in permanent dysfunction. Of the two iatrogenic post-operative nerve palsies, neither was permanent.
- The overall nonunion rate was 13% as seen in Table 3. 23.2% of fractures treated with functional bracing required a surgical intervention. Excluding the 13 traumatic amputations, the nonunion rate was 10.2% in operative fractures. Of the 22 nonunions seen in the operative group, 6 were associated with infection.

### Discussion

The demographic data and mechanism of injury at our institution differ from previously published epidemiologic studies on humeral shaft fractures. Our patient population is considerably younger, with a mean age of 36.4, compared with means of 62.7<sup>2</sup> reported by Ekholm et al and 56.1<sup>1</sup> in the most recent epidemiologic study by Bercik et al. Additionally, we have a different gender preference, consisting of 63% males compared with 39%<sup>2</sup> and 45.9%<sup>1</sup> in the literature.

The other unique aspect of our patient population is seen in the mechanisms of injury. A high-energy mechanism was identified in 76% of our patients, compared with 17%<sup>4</sup> and 55%<sup>5</sup> in similar studies. We also report a higher incidence of non-operative nonunion and a significantly higher incidence of nerve palsy. Table 4 highlights results of recent studies of operative versus non-operative management, as well as the Sarmiento study of functional bracing, compared with the results from our institution.

Previous studies report non-union rates of 9-19%<sup>4,5</sup> for operatively treated patients with which the 10.2% in our study is in agreement. Rates for non-operative treatment have ranged from 2-21%<sup>3,5</sup> in the literature. This is in contrast with a non-union rate for non-operative patients of 23.2%

Consolidation Time in Weeks from Day of Humeral Shaft Fracture by AO type and Treatment				
	Overall	Non-operative	Operative	P-value
<b>A</b>	<b>14 (10-23)</b>	<b>17 (13-28)</b>	<b>13 (9-21)</b>	<b>0.301</b>
A1	13 (11-22)			
A2	14 (9-22)			
<b>A3</b>	<b>14 (10-26)</b>	<b>28 (N=17)</b>	<b>25 (N=68)</b>	<b>0.430</b>
<b>B</b>	<b>14 (11-25)</b>	<b>16 (12-25)</b>	<b>14 (11-25)</b>	<b>0.73</b>
B1	17 (11-27)			
B2	14 (11-25)			
B3	12 (9-27)			
<b>C</b>	<b>18 (9-23)</b>	<b>22 (9-33)</b>	<b>18 (9-23)</b>	<b>0.839</b>
C1	16 (9-19)			
C2	14 (10-17)			
C3	22 (9-32)			

Table 2: Time to Radiographic Union in Weeks from the Day of Injury.

**Nonunion and Infection in Patients with Humeral Shaft Fractures by Type of Treatment**

	Overall	Non-Operative	Operative	P-value
<b>Nonunion</b>	38 (13%)	16 (23.2%)*	22 (10.2%)* <sup>‡</sup>	0.006
<b>Infection</b>	8 (2.7%)	0	8 (3.5%) <sup>‡</sup>	0.000

<sup>‡</sup> 5/16 tobacco or uncontrolled DM

\*13 Traumatic/Acute amputations excluded from nonunion analysis

<sup>‡</sup>6/22 Nonunions infected (4/6 DM, tobacco, or immune compromise)

Table 3: Rates of Nonunion and Infection in Patients by Treatment Type.

in our study, one of the highest rates reported. The high rate of nonunion may be due to soft tissue trauma resulting from a high-energy mechanism, even in patients with isolated injuries. The significant difference in the nonunion rates between the operative and non-operative group seen in our study is in agreement with Denard et al<sup>5</sup>, who also found nonunion rates for functional bracing to be significantly higher than for operative treatment. Our study also demonstrated a significantly higher incidence of infection following an operation as compared to non-operative treatment (3.5% vs 0%, p=0.000), with 6 of the 22 noted operative nonunions associated with infection.

As a result of high variability in AO/OTA subtypes, no statistical difference was seen in time to radiographic union between operative and non-operative intervention. The trend was toward faster healing with surgery for all subtypes, and this may be clinically significant. Likewise, no statistical difference was seen in nonunion rates between subtypes. Simple transverse fractures required the longest healing time and had the highest nonunion rates of all subtypes, but these results lacked statistical significance.

The rate of pre-intervention radial nerve palsy is the highest reported for both operative (37%) and non-operative (20%) treatment and likely reflects

the predominance of high-energy mechanisms of injury in our population. There were 9 radial nerve transections and 1 median nerve transection identified at the time of exploration. Only 2 of 84 radial nerve palsies seen in the operative group were iatrogenic, with both being transient.

In conclusion, this study of largely polytraumatized patients showed a higher nerve palsy rate for both operative and non-operative treatment. Closed treatment of humeral shaft fractures had a significantly higher rate of nonunion while operative intervention showed a trend toward faster time to union, low incidence of iatrogenic nerve palsy, and lower incidence of nonunion. This suggests a shift from the current standard of non-operative treatment. However, our study population was younger and with a greater predominance of high-energy injuries, lending itself to an operative approach. Further well-designed, randomized clinical trials comparing non-operative and operative treatments are necessary to adequately investigate the controversy surrounding optimal treatment of humeral shaft fractures, especially in younger patients exposed to high energy mechanisms.

## References

1. Bercik MJ, TJoumakaris FP, Pepe M, et al. Humerus fractures at a regional

trauma center: An epidemiologic study. Orthopedics Jul 2013;36(7):891-897.

2. Ekholm R, Adami J, Tidermark J, et al. Fractures of the shaft of the humerus. An epidemiological study of 401 fractures. J Bone Joint Surg Br 2006;88(11):1469-73

3. Sarmiento A, Zagorski JB, Zych GA, et al. Functional bracing for the treatment of fractures of the humeral diaphysis. J Bone Joint Surg Am. 2000; 82(4):478-486.

4. Mahabier K, Vogels L, Punt B, et al. Humeral Shaft Fractures: Retrospective Results of Non-operative and Operative Treatment in 186 Patients. Injury. 2012; 44(4):427-30.

5. Denard A Jr., Richards J, Obremskey W, et al. Outcome of nonoperative vs operative treatment of humeral shaft fractures: a retrospective study of 213 patients. Orthopedics Aug 2010;33(8)

6. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium – 2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma. 2007;21(10):S1-S133.

**Comparison of Recent and Historical Humeral Shaft Studies**

Author	Cases	High Energy	Nonunion	Nerve Palsy
Sarmiento et al. (2000)	620	16% <sup>‡</sup>	3% Non-op N/A Op	11% Non-op N/A Op
Mahabier et al. (2012)	186	17%	18.7% Non-op 18.9% Op	8.8% Non-op 5.3% Op
Denard et al. (2010)	213	55%	20.6% Non-op 8.7% Op	9.5% Non-op 2.7% Op
<b>Current (2013) Study</b>	<b>296</b>	<b>&gt;75%</b>	<b>23.2% Non-op 10.2% Op</b>	<b>20% Non-op 37% Op</b>

<sup>‡</sup>34% low velocity GSW

Table 4: Comparison of studies on Operative Versus Non-operative Management.

# Transient Muscle Paralysis Predisposes Bone Marrow to Formation of Giant Osteoclasts

Brandon J. Ausk, PhD, Leah E. Worton, PhD, DeWayne Threet, BS, Ronald Y. Kwon, PhD, Steven D. Bain, PhD, Edith M. Gardiner, PhD, and Ted S. Gross, PhD

This project identified enhanced osteoclast fusion as an important mechanism for focal bone loss induced by transient muscle paralysis. From a clinical perspective, this finding provides potential evidence for the timing and targets of therapeutics aimed at blocking bone degradation in models of muscle/nerve dysfunction that range from sarcopenia to spinal cord injury.

## Introduction

Transient paralysis of the calf muscles via Botulinum Toxin A (BTxA) induces profound bone loss in the adjacent tibia diaphysis. Recently, we observed that the induced endocortical bone resorption was homogenous along the long axis of the tibia and was temporally confined to the second week post-paralysis, suggesting that *de novo* osteoclastogenesis was responsible for the bone loss in this region [1]. Given the time required for *de novo* osteoclast formation *in vivo*, we hypothesized that transient muscle paralysis would alter the osteoclastogenic potential of adjacent tibia marrow within 7 days of paralysis.

## Methods

To test this hypothesis, we first performed a primary marrow culture experiment in which groups of mice (n=2/grp, 16wk female C57) received a single injection of BTxA (2 Units/100 g) in their right calf muscles and had their right tibia marrow harvested on days 1, 3, 7, or 14 post-paralysis. Whole marrow was lysed and seeded on chamber well slides (cell density of  $1.53 \times 10^4/\text{cm}^2$ ) in culture medium with 50 ng/ml M-CSF and 10 ng/ml RANKL, with cells fixed and stained for tartrate resistant acid phosphatase (TRAP) on day 8 of culture. For each group, normal osteoclasts (i.e., TRAP-positive cells w/ 3+ nuclei) and giant osteoclasts (i.e., TRAP-positive cells w/ 20+ nuclei) were quantified on a per well basis. The experiment was replicated (total combined group size of n=4/grp), with data normalized within each experiment to identically treated marrow from treatment naïve mice (n=2/exp).

We then performed a follow-up *in vivo* experiment to quantify transient

gene expression in the marrow of the experimental tibia following BTxA injection. Groups of female C57 mice (n=6/grp; 16 wk) were injected with BTxA in their right calf muscles on day 0 and sacrificed on days 1, 3 or 7. Post sacrifice, whole marrow was flushed from the right tibia, total RNA extracted and cDNA synthesized. cDNA from the marrow of treatment naïve mice (n=6) was prepared identically and served as controls. We analyzed the mRNA of interest (focusing primarily on a suite of osteoclast fusion genes) relative

to the housekeeping gene HPRT using quantitative RT-PCR. Significant differences in osteoclast formation or gene expression were calculated using 1-way ANOVA with Tukey post-hoc tests.

## Results

Transient muscle paralysis did not alter the number of normal osteoclasts formed in marrow culture at any time point post-paralysis (Figure 1). In fact, there were non-significant decreases in normal osteoclast number at all post-

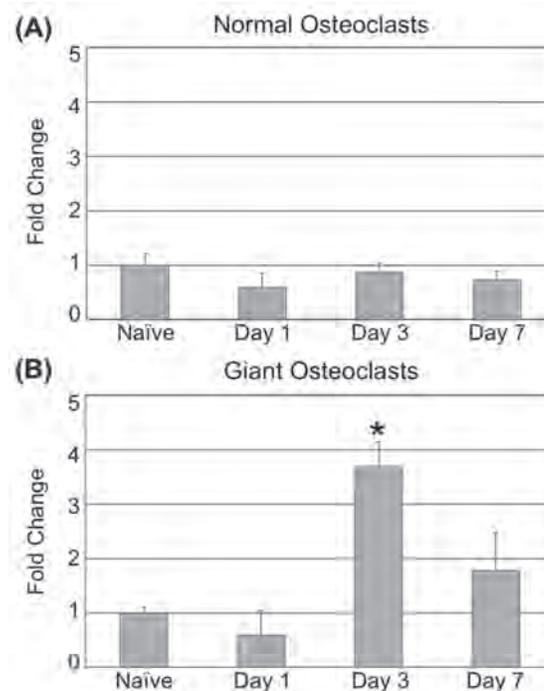


Figure 1: The osteoclastogenic potential of bone marrow altered on day 3 following muscle paralysis: Calf muscle paralysis augmented the osteoclastic potential of tibial marrow through enhanced osteoclast fusion, but not increased osteoclast number. In whole tibia marrow cultured from Naïve mice and from mice at various time points following muscle paralysis, no significant differences were observed in the total number of osteoclasts (A, mean + s.e., p=0.52). However, giant osteoclast formation was enhanced in marrow harvested 3 days following paralysis (B, \* significantly greater than Naïve and Day 1 groups, all p<0.01).

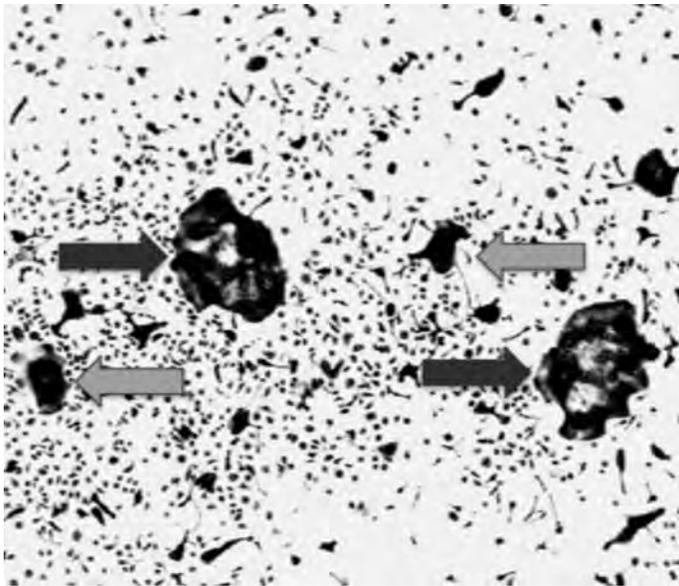


Figure 2: TRAP stained osteoclasts and giant osteoclasts from primary marrow culture: Representative cell culture image from bone marrow harvested 3 days after transient muscle paralysis and cultured for 8 additional days. Two giant osteoclasts are indicated by darker arrows, with multiple smaller osteoclasts also evident (two are highlighted with lighter arrows). Under the described culture conditions, marrow from Naïve mice generated  $96.8 \pm 26.7$  (mean  $\pm$  s.e.) normal osteoclasts/well, which included  $2.50 \pm 0.96$  giant osteoclasts/well.

paralysis time points compared to naïve control cultures (range 0.42 to 0.87 fold change compared to naïve). However, giant osteoclast formation was acutely upregulated 3 days following muscle paralysis. Marrow harvested 3 days after BTxA injection produced  $3.69 \pm 0.45$  times more giant osteoclast than naïve control marrow (Figure 1 and 2). These results suggested that muscle paralysis acutely alters the marrow environment toward induction of osteoclast fusion. Temporal gene expression patterns within the tibia marrow following muscle paralysis were temporally consistent with the data from the osteoclast culture experiment. Specifically, we observed that four osteoclast fusion related genes were significantly upregulated 3 days following paralysis compared to naïve control mice (RANKL: 173%, TNF: 299%, DC-STAMP: 344% and OC-STAMP: 318%) while one was downregulated (CD47: -88%). Additionally, CD44 demonstrated decreased expression on day 3 (-31%), but this alteration did not reach statistical significance. No gene investigated was significantly different from naïve control mice on days 1 or 7.

### Discussion

These data demonstrated that transient calf muscle paralysis rapidly alters the osteoclastogenic potential

of bone marrow in the adjacent tibia. This observation is consistent both with our previous studies and those of others [2,3]. The timing of enhanced expression of pro-fusion genes (day 3), coupled with the time needed to form functioning osteoclasts from precursor populations (around 5 days), is completely consistent with the onset of diaphyseal endocortical resorption following muscle paralysis (which occurs during a window between day 6 and day 13 post-paralysis). Surprisingly, however, our primary cell culture experiment indicated that the marrow was not predisposed to generate greater numbers of normal osteoclasts, but rather to generate many more giant osteoclasts. Giant osteoclasts are primarily associated with inflammatory pathologies and are capable of resorbing large volumes of bone mineral [4,5]. Interestingly, it was recently reported that upregulation of TNF in the absence of CD44 results in generation of highly resorbing giant osteoclasts [8]. While downregulation of CD44 in our study did not reach statistical significance, the level of downregulation may have created a sufficiently permissive environment for the profoundly elevated TNF to enable the observed generation of giant osteoclasts. Alternatively, as DC-STAMP has been shown to regulate

cytokine levels in an inflammatory environment [9], the upregulation of multiple osteoclast fusion genes could potentially enhance giant osteoclast formation. As such, the gene alterations ultimately responsible for a permissive giant osteoclast environment remain undefined. In conclusion, these data have identified osteoclast fusion as a potential mechanism mediating diaphyseal endocortical bone resorption following muscle paralysis and identifies a narrow temporal window for optimal intervention in this pathology.

### Acknowledgements

This work was supported by a F31 Fellowship from NIA (AG037287, BJA), NIH AR060304 (TSG), and the Sigvard T. Hansen, Jr. Endowed Chair.

### References

1. Ausk BJ, Huber P, Srinivasan S, Bain S, Kwon YG, McNamara EA, Poliachik SL, Sybrowsky CL, and Gross TS. (2013). Metaphyseal and Diaphyseal Bone Loss in the Tibia Following Transient Muscle Paralysis are Spatiotemporally Distinct Resorption Events. *Bone*, 57(2): 413-422.
2. Marchand-Libouban H, Le Drevo MA, and Chappard D. 2013. Disuse induced by Botulinum toxin affects the bone marrow expression profile of bone genes leading to a rapid bone loss. *J Musculoskelet Neuronal Interact* 13(1): 27-36.
3. Aliprantis AO, Stolina M, Kostenuik PJ, Poliachik SL, Warner SE, Bain SD, and Gross TS. Transient muscle paralysis degrades bone via rapid osteoclastogenesis. *FASEB J* 26(3): 1110-8.
4. Kuratani T, Nagata K, Kukita T, Hotokebuchi T, Nakasima A, and Iijima T. 1998. Induction of abundant osteoclast-like multinucleated giant cells in adjuvant arthritic rats with accompanying disordered high bone turnover. *Histol Histopathol* 13(3): 751-9.
5. da Costa CE, Annels NE, Faaij CM, Forsyth RG, Hogendoorn PC, and Egeler RM. 2005. Presence of osteoclast-like multinucleated giant cells in the bone and nonostotic lesions of Langerhans cell histiocytosis. *J Exp Med* 201(5): 687-93.

# Chemical and Mechanical Nerve Impairment Inhibit Joint Specification and Bone Formation in the Regenerating Zebrafish Fin

Amanda C. Roof, MD, Anthony M. Recidoro, Brandon J. Ausk, PhD, Sundar Srinivasan, PhD, Ted S. Gross, PhD, Edith M. Gardiner, PhD, Steven D. Bain, PhD, Christopher H. Allan, MD, and Ronald Y. Kwon, PhD

We previously showed that intramuscular injection of Botulinum toxin, an inhibitor of synaptic release in cholinergic nerves, induces muscle paralysis and impairs bone outgrowth in the regenerating zebrafish tail fin. In this study, we utilized a model of focal denervation to delineate the role of neuronal, muscle, and mechanical regulation in this process. Our studies suggest that nerve transection is associated with impaired outgrowth in the absence of locomotor defects, highlighting a role of nerve-bone crosstalk in this physiology.

## Introduction

Intramuscular administration of Botulinum toxin (BTx) has been associated with impaired osteogenesis in diverse conditions of bone formation (e.g., development, growth, and healing), yet the mechanisms of neuromuscular-bone crosstalk underlying these deficits have yet to be identified. Motivated by the emerging utility of zebrafish (*Danio rerio*) as a rapid, genetically tractable, and optically transparent model for human pathologies, as well as the potential to interrogate neuromuscular-mediated bone disorders in a simple model organism that bridges *in vitro* and more complex *in vivo* model

systems, we recently developed a BTx model of muscle paralysis in adult zebrafish, and examined its effects on intramembranous ossification during tail fin regeneration. Previously, we showed that BTx administration at the base of the zebrafish tail fin remotely inhibits bone regrowth following amputation, potentially through disruption of intra- and/or inter-ray nerves [1]. In this study, we investigated whether disrupting neural communication by mechanically ablating fin nerves could recapitulate deficits in bone outgrowth observed following BTx. In addition, given evidence that BTx impairs joint morphogenesis during mammalian

skeletal development [2], we sought to determine whether BTx impairs joint specification during fin regeneration.

## Methods

Adult wild-type zebrafish were subjected to 50% tail fin amputation as previously described [1]. To mechanically ablate inter- and intra-ray nerves, a 0.5mm hole was resected from a single bone ray proximal to the amputation plane (Figure 1A). This transected ~2 bone segments and the majority of intra- and inter-ray nerves associated with the damaged ray while leaving the innervation of non-neighboring rays intact. Percentage regrowth in the transected ray and degree of calcein labeling was assessed at 7 and 14 days post amputation (dpa), with calcein and alizarin red respectively. To determine effects of BTx on joint specification, amputated zebrafish were administered Botulinum toxin type B at the base of the tail (as previously described in [3]), and images of regenerated bone rays were analyzed for number of joints and length of bony segments between joints.

## Results

Following transection of inter- and intra-ray nerves, we observed deficits on distal bone formation in regard to both longitudinal growth and mineralizing activity. At 7dpa, we observed a significant reduction in the length of the bone regenerate in transected rays compared to immediately neighboring dorsal/ventral rays (reduction of  $67.5 \pm 9.3\%$ ,  $p=0.03$ ,  $n=5$ ) (Figure 1A). No such reduction was observed in untransected control rays ( $104.0 \pm 3.7\%$ ,

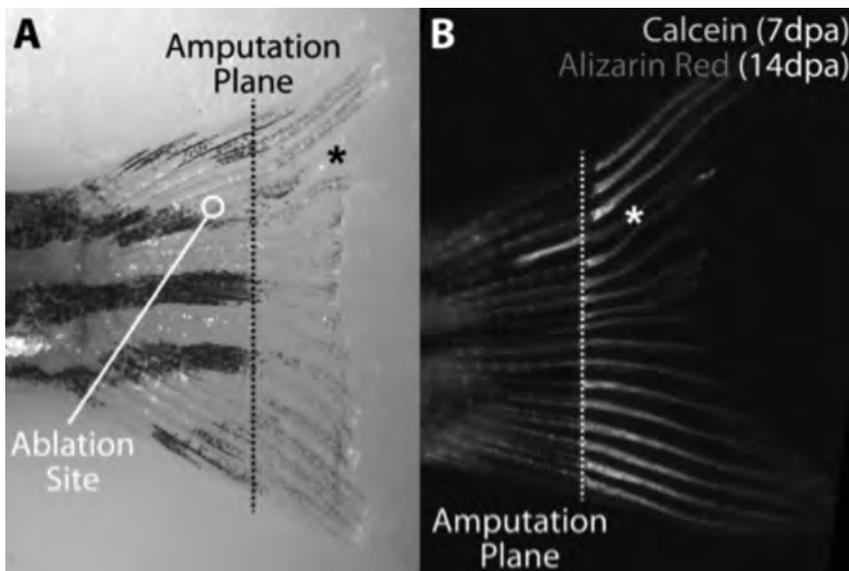


Figure 1: Focal inhibition of bone regrowth and mineralization in the regenerating zebrafish fin following mechanical nerve ablation. (A) Fin regrowth 7dpa. Bone growth in the damaged ray (\*) is visibly shorter than in the neighboring rays. (B) Double fluorochrome labeling 7dpa (calcein) and 14dpa (alizarin red). Calcein labeling is markedly reduced in regenerated portion of the damaged ray (\*). Note also the increased labeling at the site of injury.

$p=0.34$ ,  $n=5$ ). Calcein labeling was also reduced within the regenerate in 67% (6/9) of the damaged rays observed (Figure 1B). We also observed high calcein labeling at the site of nerve ablation (Figure 1B). In fish subjected to BTx, impaired fish exhibited decreased bone regrowth that was associated with a reduced number of segments per bone ray (saline:  $8.4\pm 0.27$  segments, BTx:  $6.0\pm 0.50$  segments,  $p=0.003$ ,  $n=5$ /group) and a significant decrease in the average length per bone segment (saline:  $230.7\pm 5.1$  microns, BTx:  $208.7\pm 6.0$  microns,  $p=0.02$ ).

### Discussion

We previously demonstrated that intramuscular injection of BTx at the base of the tail fin substantially impaired bone outgrowth and mineralizing activity in the regenerating fin [1]. Interestingly, in those studies the effects of BTx on inhibiting mineralization in the regenerate appeared to be spatially restricted within individual rays, suggesting a potential role for fin ray nerves in mediating the effects of neural disruption. In this study, we subjected fish to mechanical intra- and inter-ray nerve ablation and found that nerve transection severely impeded bone outgrowth in the affected ray but not in the immediately adjacent rays. The remote and spatially confined effect of nerve ablation on bone growth suggests that this response is not entirely attributable to soluble factors released at the site of ablation. Expanding on our prior BTx studies [1] we also found that BTx decreased the number of segments per bone ray and decreased the average length per bony segment, suggesting a role for nerves in regulating joint specification in newly regenerating bone. Collectively, these studies are consistent with a role of nerves in regulating osteoblast activity in the regenerating zebrafish fin. Given the sophisticated tools in zebrafish for dissecting neural pathways, as well their amenability to genetic, imaging, and high-throughput approaches, zebrafish may provide an ideal model for identifying novel mechanisms underlying neural control of bone growth and development.

### Significance

These studies demonstrate a critical and multifaceted role for nerves in regulating bone regeneration in

the zebrafish fin. Given the growing evidence that fin regeneration shares common molecular signatures with bone regeneration and healing in mammals, the regenerating zebrafish fin may provide a unique opportunity to explore basic mechanisms of neuroskeletal signaling in a highly tractable experimental system.

### References

1. Recidoro AM, AC Roof, BJ Ausk, S Srinivasan, EM Gardiner, TS Gross, SD Bain, CH Allan, RY Kwon, 2013. *J Bone Min Res* 28(S1):FR0187
2. Kim HM, LM Galatz, N Patel, R Das, S Thomopoulos, 2009. *J Bone and Joint Surg AM* 91(4):879-891.

# Ankle Arthroplasty with Subtalar Fusion or Tibiotocalcaneal Fusion for Patients with Concomitant Tibiotalar and Subtalar Arthritis

Daniel Thuillier, MD, Bruce J. Sangeorzan, MD, Marisa Benich, MS,  
and Sigvard T. Hansen, Jr., MD

Uncertainty exists about the proper treatment of patients who have tibiotalar arthritis and concomitant subtalar arthritis. For the subtalar joint, no effective replacement options and fusion remains the only reliable surgical procedure for pain relief in patients with end-stage subtalar arthritis. For the tibiotalar joint however, both arthroplasty and arthrodesis have shown to be effective at relieving pain. This leaves two treatment options for patients with both tibiotalar and subtalar arthritis; subtalar fusion with either tibiotalar arthroplasty or arthrodesis of both joints (Tibiotocalcaneal - TTC). At present, there are no studies in the literature effectively comparing the clinical outcomes between these two treatment options to help guide clinical decision-making.

The purpose of this retrospective research study was to compare the clinical outcomes of patients who had a subtalar fusion and a tibiotalar replacement to patients who had fusion of both joints. This was done by looking at patient-reported outcomes as well as activity as recorded through a step count monitor. The results demonstrate that patients who had a tibiotalar replacement with a subtalar fusion had statistically improved outcome scores and higher activity compared to patients who had fusion of both joints. This information may aid patients and physicians in choosing treatment options for patients with both tibiotalar and subtalar arthritis.

## Introduction

Idiopathic osteoarthritis of the tibiotalar joint is much less common than either the hip or knee. Arthritis of the tibiotalar or subtalar joint, usually can be traced to previous trauma or instability. This inciting event or chronic condition, can sometimes effect both the tibiotalar and the subtalar joint. Additionally, it has been shown that stiffness in either joint leads to increased stresses on the other joint which can also result in degenerative arthritis.

For many years the only effective treatment option for pain relief of patients with tibiotalar arthritis in who

failed conservative management was fusion. Recently tibiotalar replacements have become available and have been shown to be equally effective at pain relief. For the subtalar joint unfortunately, replacement is not currently available, and fusion remains the only effective treatment option.

It has been well established in the literature that patients who had an isolated tibiotalar or subtalar fusion have better clinical outcomes than patients who had fusion of both. Much of this is likely attributed to the great deal of stiffness that results from fusing both joints. Thus tibiotalar replacement along with a subtalar

fusion as opposed to arthrodesis of both may lead to improved clinical outcomes by eliminating the pain generator but also maintaining some motion in the hindfoot.

## Methods

- Eight patients who had undergone a TTC fusion for end-stage arthritis of both the tibiotalar and subtalar joints at least 12 months previously were analyzed.
- Subjects wore a StepWatch3™ Activity Monitor for 14 days and completed a Musculoskeletal Functional Assessment (MFA) and Short Form 36 (SF-36).
- These patients were then compared to 11 subjects from a previous study who had a tibiotalar arthroplasty and a subtalar fusion performed during a single anesthesia who had similar measures taken at either 24 or 36 months following surgery.
- These two groups were then compared with outcome measures including step counts, MFA, and SF-36.
- The demographics of these groups including age, sex, BMI, and time from operation were also compared.

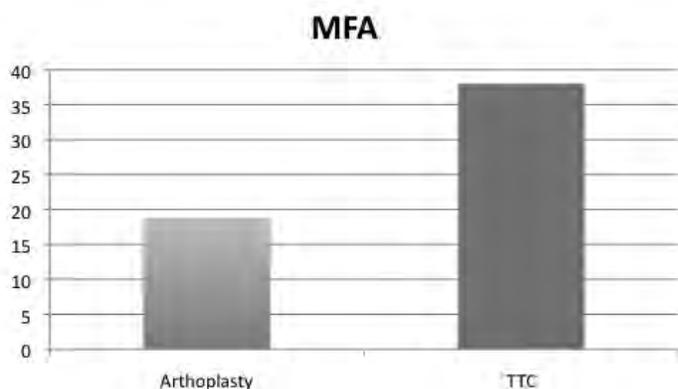


Figure 1: TTC fusion patients had higher MFA scores signifying more dysfunction. (38 vs 18 P=0.01)

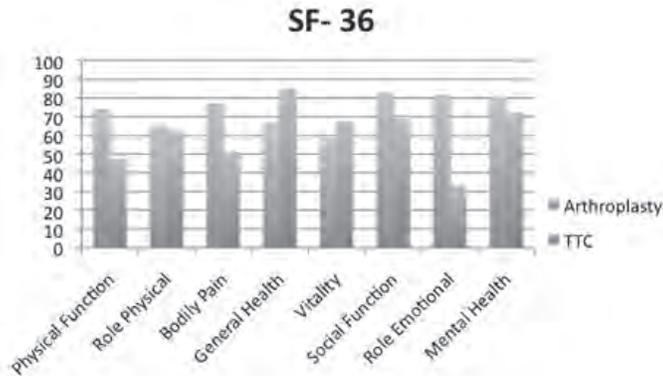


Figure 2: The TTC fusion group had lower scores in the bodily pain (51.25 vs 77.04,  $P=0.02$ ), social function (68.75 vs 82.95,  $P<0.05$ ) and role emotional domains (33.33 vs 81.81,  $P=0.02$ ) of the SF-36. Differences in the physical function (47.50 vs 74.05) and mental health (72.00 vs 80.72) showed a trend towards lower values in the TTC fusion patients ( $P<0.10$ ). Values of the role physical, vitality and general health showed no difference between the groups.

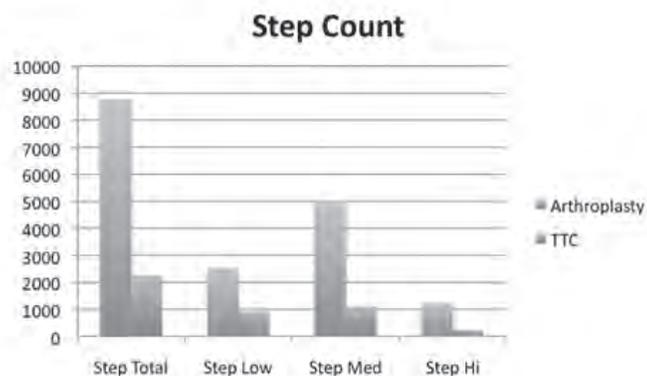


Figure 3: Patients in the TTC group had statistically lower Total number of steps in a day (Step Total), total steps accumulated during the time included for analysis, low activity between 1-15 steps per minute on one leg (Step Low), Total steps accumulated during the time included for analysis, medium activity between 15-40 steps per minute on one leg (Step Med), and Total steps accumulated during the time included for analysis, high activity >40 steps per minute on one leg (Step Hi).

## Results

The 8 TTC patients and 11 arthroplasty patients were not significantly different in regards to sex (4m/4F vs 8M/4F), age (60.1 vs 54 years), BMI (28.22 vs 28.71) or time from surgery (26 vs 33 months). In the arthroplasty group there were 8 patients who received DePuy Agility implants, and three who received Tornier Salto-Talaris implants.

- The patients in the TTC fusion group had significantly worse MFA scores than the arthroplasty group (38 vs 18  $P=0.01$ ) (Figure 1) and rated the importance of their problems related to their disease higher on the Pt rating scale (1.5 vs 2.2  $P<0.01$ ).
- The Tibiotalar Fusion group had lower scores in the bodily

pain (51.25 vs 77.04,  $P=0.02$ ), social function (68.75 vs 82.95  $P<0.05$ ) and role emotional domains (33.33 vs. 81.81  $P=0.02$ ) of the SF-36. (Figure 2)

- The TTC Fusion group also had significantly lower daily average step counts 2266.51 vs 8773.27 ( $P<0.01$ ) (Figure 3) and peak activity index 29.65 vs 75.85 ( $P<0.01$ ).

## Discussion

Both tibiotalar arthrodesis and tibiotalar arthroplasty have been shown to be effective at relieving pain from arthritis of the tibiotalar joint. Arthroplasty may yield slightly better functional results in short-term follow up, but with a slightly higher complication rate. Prospective trials

are continuing to try and establish longer follow up for a better effective comparison.

Previous studies in the literature have demonstrated effective improvement in pain and function after undergoing tibiotalar arthrodesis. Compared to patients who underwent isolated tibiotalar fusion for isolated tibiotalar arthritis, the TTC patients have worse clinical outcomes with increased pain and dysfunction. Since tibiotalar arthroplasty has been demonstrated to be effective at relieving pain in tibiotalar arthritis, along with subtalar fusion it provides another possible treatment option for patients with arthritis that affects both joint. As of yet the clinical outcomes of TTC fusion has not been compared to tibiotalar arthroplasty with concomitant subtalar fusion in the literature.

Though the numbers in this group are small, patients with tibiotalar arthritis and concomitant subtalar arthritis who underwent a tibiotalar arthroplasty and subtalar fusion had significantly improved clinical outcomes and activity levels compared to patients who underwent a tibiotalar arthrodesis. This information may aid patients and physicians in choosing treatment options for patients with both tibiotalar and subtalar arthritis.

## References

- Acosta R, Ushiba J, Cracchiolo A. The results of a primary and staged pantalar arthrodesis and tibiotalar arthrodesis in adult patients. *FAI* 2000 Mar; 21(3):182-94.
- Ajis A, Tan KJ, Myerson MS. Ankle Arthrodesis vs TTC arthrodesis: patient outcomes, satisfaction, and return to activity. *FAI* 2013 May;34(5):655-67.
- Hahn ME, Wright ES, Segal AD, Orendurff MS, Ledoux WR, Sangeorzan BJ.
- Comparative gait analysis of ankle arthrodesis and arthroplasty: initial findings of a prospective study. *FAI* 2012 Apr 33 (4):282-9.
- Russotti GM, Johnson KA, Cass JR. Tibiotalar arthrodesis for arthritis and deformity of the hind part of the foot. *JBJS AM* 1988 Oct; 70(9):1304-7.
- Saltzman et al. Prospective controlled trial of STAR total ankle replacement versus ankle fusion: initial results. *FAI* 2009 Jul 30(7):579-96.

# Prospective Study Investigating the Prevalence and Evolution of Malnourishment in the Acute Orthopaedic Trauma Patient

Benjamin Hamilton, MS, Courtney O'Donnell, MD, Julie Agel, MA,  
Patricia Kramer, PhD, Stephen K. Benirschke, MD,  
M. Bradford Henley, MD, MBA, and Reza Firoozabadi, MD, MA

Malnutrition is a highly prevalent disease in acute hospital settings with a rate of 20 to 50% in developed countries. Patients with poor nutritional status have higher infection rates, impaired wound healing, depression of the immune system, longer lengths of stay, increased recovery time and mortality.<sup>1</sup> Studies of hip fracture patients have demonstrated high rates of malnutrition in this patient group.<sup>2-4</sup> The goal of this investigation was to examine rates of malnutrition, as defined by frequently used nutritional markers, in a population of orthopaedic trauma patients. We hypothesized that rates of malnutrition would increase during hospital stays while nutritional marker levels would decline. A total of 69 patients with varying orthopaedic injuries were evaluated during their acute hospitalization and at their 6-week follow-up. For all nutritional markers, rates of malnutrition increased from admission, to hospital day 3 when nearly all patients had lab values reflecting poor nourishment. These levels then stabilized with a slight drop from day 3 to day 7. A trend towards correction was seen at the 6-week follow-up. This study supports the notion that malnutrition is highly prevalent in acute orthopaedic trauma patients.

## Introduction

Undernutrition has been shown to be associated with poor clinical outcomes in surgical patients.<sup>1</sup> Trauma patients have a 15 to 25% increase in energy requirements, which may grow to 100% if infection is present.<sup>5</sup> Trauma patients may present with inflammatory, hypermetabolic, and/or hypercatabolic conditions, which are increasingly identified as factors predisposing to malnutrition. These patients frequently have reduced oral intake due to nausea and multiple surgeries and are frequently sustained on intravenous fluids alone for much of their hospital stay. Thus, it is not surprising that patients fall far short of the nutritional support needed to meet the increased energy demands of their traumatic conditions. Even patients with low baseline risk of malnutrition, when left unrecognized and unaddressed, may experience a rapid decline in nutritional status.

Within orthopaedics, previous studies of malnutrition in hip fracture patients have shown the incidence of malnutrition to reach rates of up to 78%.<sup>6</sup> Despite this recognition, to our knowledge malnutrition has not been studied specifically in a large group of orthopaedic trauma patients. While there is no gold standard to assess nutritional status in trauma patients, simple hematologic markers have been

used to diagnose malnutrition in hip fracture patients.<sup>2-4</sup> We undertook a prospective study to better determine the evolution of malnutrition in the acute orthopedic trauma patient and to initiate an assessment of its role in postoperative outcomes.

## Materials / Methods

- One hundred one orthopaedic trauma patients admitted to orthopaedics as the primary team from June 2013 through January 2014 were identified at the time of hospital admission, consented, and entered into the prospective database. Subject demographic and clinical data were recorded.
- The markers applied to assess nutritional status included albumin (ALB), prealbumin (PAB), transferrin (TRA), CRP, and vitamin D. Serum laboratory markers were obtained on admission, hospital day 3, hospital day 7 (if available), and at 6 weeks post-surgery for patients who were identified as malnourished at discharge (vit. D taken only on hospital admission and 6 week draws).
- Nutritional status was also determined using the Rainey MacDonald nutritional index (RMNI). The RMNI

was calculated as follows:  $RMNI = (1.2 \times ALB) + (0.013 \times TRA) - 6.43$ . A negative RMNI was previously reported to be significantly associated with longer hospitalization and higher rates of septic complications.<sup>2</sup>

- Values considered representative of suboptimal nutrition were ALB <3.5g/dL, PAB <18mg/dL, RMNI <0 and vitamin D <32ng/mL, while a serum CRP level of >10mg/L was considered indicative of acute-phase response.

## Results

- Of 101 total patients enrolled, 32 patients were excluded because they were discharged and/or did not get appropriate lab results drawn on hospital day 3. As a result, 69 orthopaedic trauma patients were included in the final analysis. Baseline demographic and clinical data are summarized in Table 1.
- Rates of malnourishment as defined by different lab markers at each time point are seen in Table 2. The proportion of subjects malnourished based on ALB, PAB, and RMNI followed similar trends with a significant increase between

N=69	
Sex (M:F)	35:34
Age (range)	51.0±16.8 y (20-85 y)
Body height (cm)	173.3±14.2
Body weight (kg)	86.9±32.5
BMI (kg/m <sup>2</sup> )	28.0±8.9
Mean no. of pre-fracture comorbidities	1.0±1.2
Type of orthopaedic injury, no. cases (%)	
Femur fracture	16 (23.2%)
Tibia fracture	23 (33.3%)
Ankle fracture	10 (14.5%)
Humerus fracture	3 (4.4%)
Forearm fracture	5 (7.3%)
Pelvis fracture	5 (7.3%)
Acetabular fracture	10 (14.5%)
Other	14 (20.3%)
Musculoskeletal injuries requiring >1 surgery, no. cases (%)	18 (26.1%)
Patients receiving nutrition consults (%)	28 (40.6%)
Median length of hospital stay in days (Range)?	6 (2-48)
Infections, no. cases (%)	7 (10.2%)

Table 1: Baseline demographic and clinical data

admit and hospital day 3 with stabilization of rates from day 3 to day 7. Despite a significant decrease from day 7 to 6 week follow-up, 20.0%, 20.0% and 15.2% of patients remained malnourished based on ALB, PAB, and RMNI, respectively.

- Similar trends were seen in percent of patients in acute-phase response, with an increase from admit to HD3 and continual decrease until 6 week follow-up. All patients were in APR (>10mg/dL) at HD3, with 68.4% in severe APR as defined by the upper quartile of our study group's admit CRP levels.
- A large majority (80%) of patients had abnormal Vitamin D levels on admission with some improvement (64.3%) seen at 6 weeks.
- Trends in rates of

malnourishment are also seen in nutritional marker levels at each time point. Levels trended downward during hospital stay reaching their nadir at hospital day 7 [Table 3] and trended toward correction by 6 week follow-up. CRP levels increased from admit to a peak at hospital day 3, with a decline at the 6 week follow-up.

### Discussion

There is no current consensus on a gold standard for diagnosing protein deficient malnutrition. However, we believe that early identification and intervention in malnourished orthopaedic trauma patients may help avoid those complications shown to be associated with malnutrition. This study has shown that serum markers frequently used to assess nutritional status worsen rapidly in the acute orthopaedic trauma patient.

Reproducibility and ease of introduction into clinical practice make biochemical markers an appealing means for detecting patients at risk of malnutrition. Several studies report an association between albumin levels measured on hospital admission and patient outcomes in elderly hip fracture patients.<sup>2-4</sup> Reported prevalence of malnutrition based on albumin measurements in hip fracture patients over age 65 has varied, ranging from 22% reported by Symeonidis et al., to 52% reported by O'Daly et al. This is compared to a prevalence of 79% in patients aged over 65 years and 71% in all patients in this study. Prealbumin is another popular marker for malnutrition owing to its short half-life and sensitivity to changes in nutritional status. In our study, 37.7% of patients were malnourished based on prealbumin on admission. Using a different cutoff, Robinson et al. reported a prevalence of malnutrition of 50% in a population of hospitalized surgical and medical patients.<sup>7</sup> An equivalent figure for this study is 49%. Using the RMNI, 42% of our patients were malnourished on admission.

The increase seen in rate of malnourishment during hospital stay may be a reflection of both undernutrition as well as the known suppressive effect of inflammation on nutritional markers. From admission to day 3, levels of CRP increased while nutritional markers declined. However, from day 3 to 7 CRP levels decreased significantly while nutritional markers continued to decline. We interpreted this continued decline in nutritional markers in the face of a weakening inflammatory response to be a strong indicator of malnourishment. We believe that those patients with both declining nutritional markers and stable or declining CRP levels are at greatest risk of poor clinical outcomes associated with malnutrition.

In conclusion, malnutrition in the acute orthopaedic trauma patient, as defined by frequently used biochemical markers, is a common disease that increases in prevalence throughout their hospitalization. Routine assessment of nutritional status in this population is imperative, given the adverse impact of this condition on patient outcomes. Further studies are necessary to investigate the role of nutritional interventions for orthopaedic trauma patients with regard to improvement in

% Malnourished based on:	Admit	Hospital Day 3	Hospital Day 7	6 Week Follow-up
ALB (<3.5g/dL)	71.0	96.5	96.3	20.0
PAB (<18mg/dL)	37.7	87.9	88.9	20.0
RMNI (<0)	42.0	90.9	80.8	15.2
% In severe acute-phase response (CRP>61.65mg/L)	24.6	68.4	41.7	2.9
% Vitamin D abnormal (<32ng/mL)	80			64.3

Table 2: Malnutrition prevalence at each lab draw.

Marker	Admit	Hospital Day 3	Hospital Day 7	6 Week Follow-up**
Median (range) CRP (mg/L)	33.3 (0.9-168.4)	93.1 (12.5-301.9)	47.5 (9.1-352)	3.7 (0.2-114)
Median (range) ALB (g/dL)	3.2 (1.8-3.9)	2.8 (2.0-3.8)	2.5 (1.8-3.7)	3.9 (1.9-4.6)
Median (range) PAB (mg/dL)	20.0 (3.3-38.1)	12.5 (4.8-19.9)	10.9 (3-23.6)	29.5 (6.9-46)
Median (range) TRA (mg/dL)	208 (75-285)	168 (83-256)	162 (70-235)	239 (75-311)
Median (range) VitD (ng/mL)	20.2 (3.2-66.5)			27.0 (14.1-47.2)

Table 3: Nutritional marker levels at each lab draw\*\*Follow-up labs drawn only in patients identified as malnourished at hospital discharge.

nutritional marker levels and impact on clinical outcome.

## References

1. Norman K, Pichard C, Lochs H, Pirlich M. Prognostic impact of disease-related malnutrition. *Clin Nutr* 2008;27:5-15.
2. Guo JJ, Yang H, Qian H, Huang L, Guo Z, Tang T. The effects of different nutritional measurements on delayed wound healing after hip fracture in the elderly. *J Surg Res* 2010;159:503-508.
3. Symeonidis PD, Clark D. Assessment of malnutrition in hip fracture patients: Effects on surgical delay, hospital stay and mortality. *Acta Orthop. Belg.* 2006;72:420-427.
4. O'Daly BJ, Walsh JC, Quinlan JF, Falk GA, Stapleton R, Quinlan WR, O'Rourke SK. Serum albumin and total lymphocyte count as predictors of outcome in hip fractures. *Clin Nutr* 2010;29:89-93.
5. Mahan KL, Arlin, M. Krause's Food Nutrition & Diet Therapy. 8th Edition ed. Philadelphia: Saunders; 1992.
6. Milte R, Miller M. Dietetic care of hip fracture patients across Australia:

Are we doing enough? *Nutr Diet* 2011; 68: 214-220.

7. Robinson MK, Trujillo EB, et al. Improving nutritional screening of hospitalized patients: the role of prealbumin. *J Parenter Enteral Nutr* 2003;27(6):389-95.

# Regulation of Cruciate Ligament Development and Maintenance by ESET Histone Methyltransferase

Albert O. Gee, MD, Michael J. Chen, BA, Sean Haloman, MD, John W. McCornack, BA, Howard A. Chansky, MD, and Liu Yang, PhD

Injuries to the anterior cruciate ligament (ACL) occur frequently during sports participation and are closely associated with posttraumatic osteoarthritis. At the present time, it is not clear what controls the development and repair of cruciate ligaments, and we know even less about their epigenetic regulation. Therefore, a better understanding of ligament biology will be helpful in the search for newer treatments of injured ACL. ESET (an ERG-interacting protein with a SET domain, also called SETDB1) is an enzyme that methylates histone H3 at lysine 9 and controls access to specific regions within the genome. The ESET gene itself is expressed in various lineages including ligament cells. In this study, we examined the effects of ESET on the development of cruciate ligaments in knockout mice, and found that a lack of ESET protein is detrimental to the formation and maintenance of cruciate ligaments.

## Introduction

Ligaments are a dense fibrous type of connective tissue that connect bones and function to prevent abnormal movements from occurring in the joint, as well as provide stability. These collagen fibers themselves are synthesized and maintained by ligament cells. These cells lie in longitudinal rows and have more of an ovoid appearance with plump nuclei. At the insertion of the ligament into bone, fibrocartilage transitions the ligament to bone and facilitates its attachment.

The bHLH transcription factor scleraxis (Scx) is a distinctive marker of all tendon/ligament cells from the embryonic stage into adulthood

(Schweitzer et al. 2001). Deletion of Scx in mice only disrupts the differentiation of force-transmitting and intermuscular tendons, whereas entheses and ligaments in Scx-null mice are less affected and remain functional (Murchison et al. 2007). This observation suggests that the development of ligament and certain tendon groups are unlikely to be mediated by Scx itself but instead could be controlled by other Scx-related factors or by proteins unrelated to Scx. Since ESET is important to skeletal development and is expressed in ligament cells (Yang et al. 2013), it is possible that additional ligament regulators may include epigenetic

enzymes such as ESET histone methyltransferase.

## Materials / Methods

Mice harboring the floxed ESET allele were mated with Prx1-Cre mice on a C57BL/6 background. Knee joints were collected from mice at different stages of development, fixed in 4% paraformaldehyde and decalcified in 14% EDTA before further embedding treatments. Staining of ligaments was done with 14-18 mm tissue sections using Harris hematoxylin solution and eosin Y-phloxine B (H&E) solution.

## Results

The Prx1-Cre deleter strain of mice was used to achieve conditional ESET knockout that initiates in the forelimb at embryonic day (E) 9.5, followed by one day later in the hindlimb (Logan et al. 2002). In mice that are positive for Prx1-Cre and homozygous for the floxed ESET allele, the bifurcated SET domain (and the intrinsic H3-K9 methyltransferase activity) is eliminated from ESET due to a frame-shift mutation (Figure 1a) that occurs only in mesenchymal cells of the limbs. To examine how ESET knockout from limb mesenchymal cells affects cruciate ligaments in mice, we stained coronal sections of knee joints from 11 month-old wild-type and ESET-deficient mice. As shown in Figure 1b, wild-type animals at this age exhibited normal appearance of cruciate ligaments, whereas conditional knockout of ESET from mesenchymal cells results in total disorganization of cruciate ligaments in all 11 month-old mutant mice.

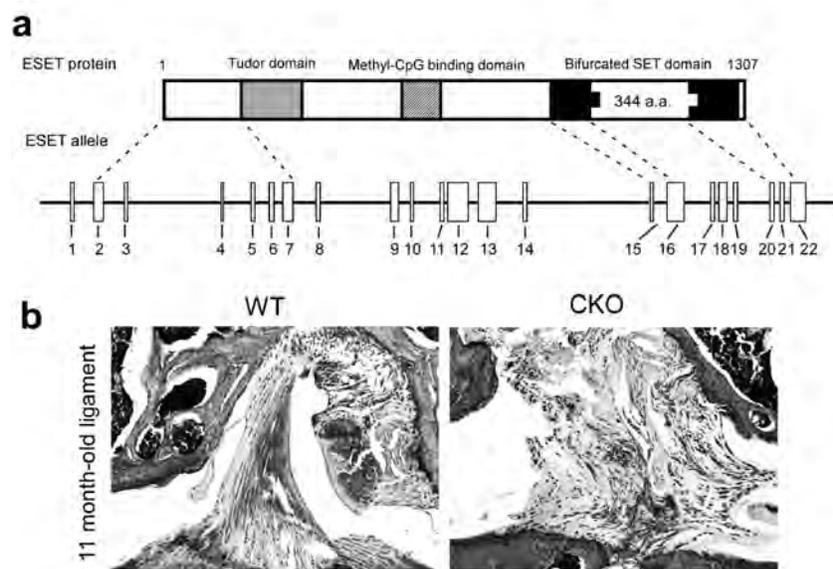


Figure 1: Diagram of ESET protein and cruciate ligament phenotype in ESET-knockout mice. (a), ESET gene and protein structure. (b), sections of cruciate ligaments from 11 month-old wild-type (WT) and mesenchyme-specific knockout (CKO) mice were stained by H&E for comparison of ligament morphology.

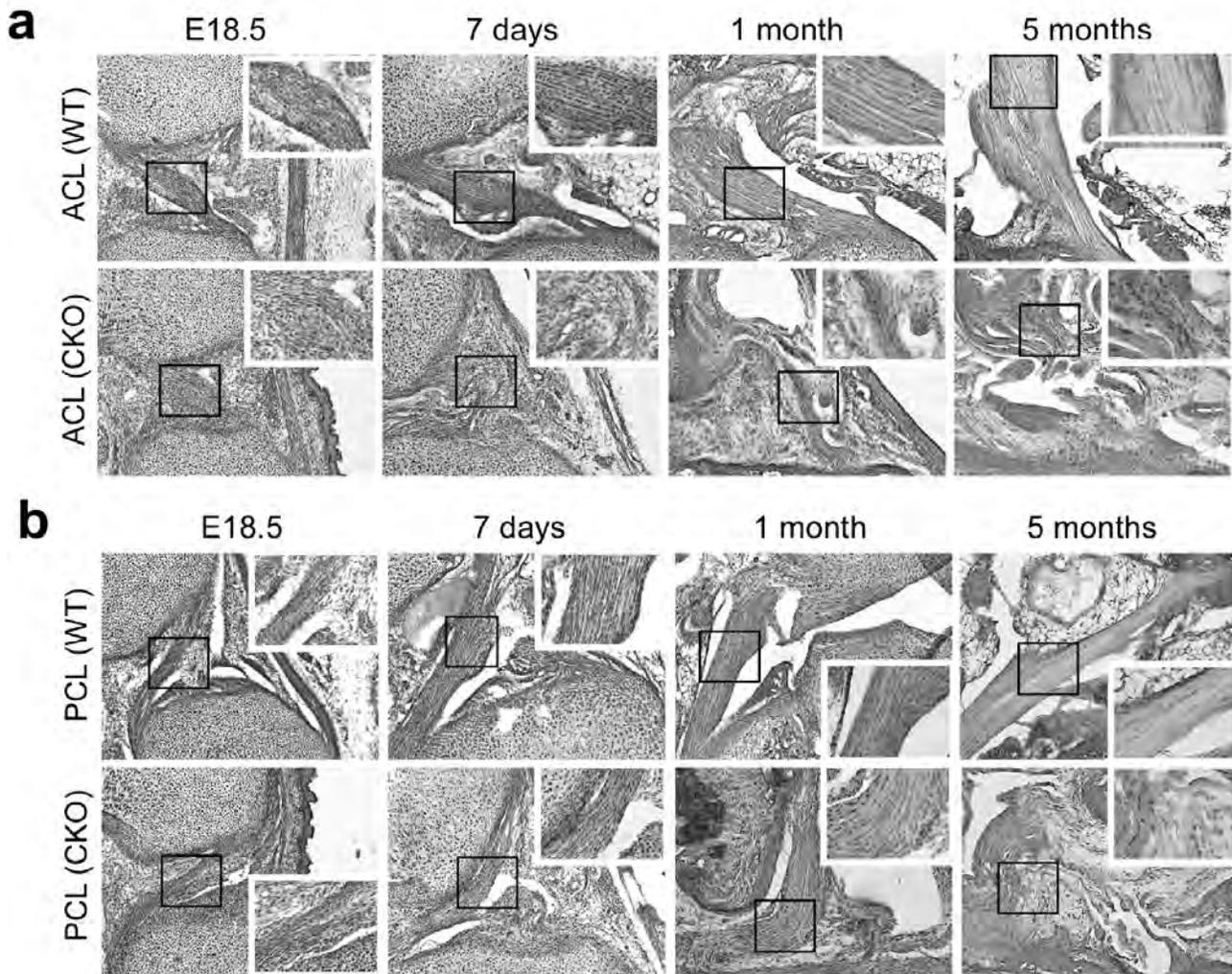


Figure 2: Effects of mesenchyme-specific ESET knockout on cruciate ligaments. (a) ACL and (b) PCL from wild-type (WT) and ESET-null (CKO) littermates at different developmental stages were stained with H&E. Boxed areas of the ligaments are enlarged as inserts for better comparison.

To investigate the developmental stage at which a lack of ESET protein starts to impact cruciate ligaments, we prepared sagittal sections of the knee joints and carried out histological examination of cruciate ligaments in E18.5 embryos and in mice at 7 days, 1 month and 5 months after birth. As shown in Figure 2, while ligament defects at birth were less obvious in ESET-null embryos, the cruciate ligaments during postnatal development exhibited significant differences between wild-type and ESET-null littermates. Histology of the ACL in knockout mice showed disorganization of ligament cells by postnatal day 7, and complete degeneration that was evident 1 month after birth (Figure 2a). The posterior cruciate ligament (PCL) seemed to be less affected by ESET-knockout during early stages of postnatal development,

and appeared normal 7 days after birth. By the age of 5 months, however, the PCLs of knockout mice also showed obvious signs of disorganization and degeneration when compared to wild-type controls (Figure 2b).

Histological defects in ESET-null cruciate ligaments suggest that the biomechanical properties of ACL could be impaired by ESET knockout. To examine the changes in ACL tensile strength, a small number of 3-month-old wild-type and ESET-null animals were sacrificed, their hindlimbs were removed from each animal at the hip joint. Dissection of extraneous tissue exposed the knee joint, and femur-ACL-tibia specimens were created with further careful dissection (Figure 3a). For mechanical testing, both the femur and tibia are fixed to special clamps that are then attached to the load cell (Figure 3b). To obtain force

and displacement data, the ACL was lengthened at a rate of 0.5 mm/second and the load at failure point was recorded for each ACL (Figure 3c). Preliminary experiments based on 6 knees in each group, showed that the testing results are reproducible among the specimens. In 3-month-old female mice, the load at failure for wild-type ACL is  $6.7 \pm 2.3$  N (newton) whereas a force of only  $4.1 \pm 1.8$  N is needed to reach the load at failure for ESET-null ACL.

### Discussion

Cruciate ligaments play a critical role in knee stability during sports participation and other physical activities. Although ACL injuries are a topic that is frequently in the public consciousness due to their occurrence in athletes at all levels of competition, an area of limited investigation to date

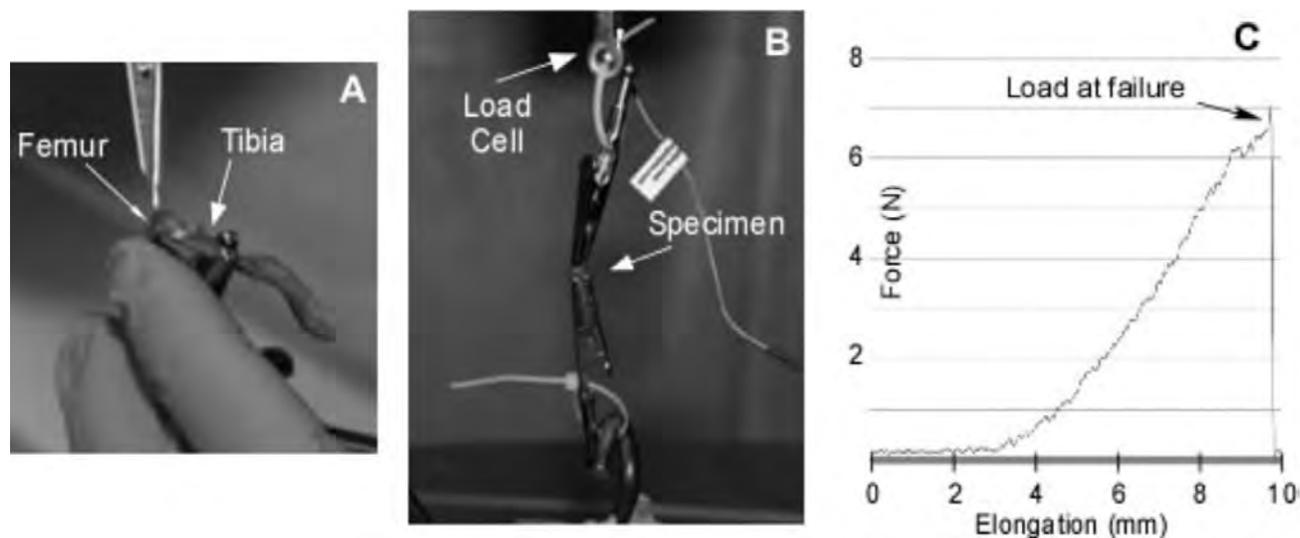


Figure 3: Testing for ACL tensile strength. (a), dissected ACL specimen. (b), specimen loaded onto the tester. (c), force and displacement data from a 3-month old female ACL. Load at failure is indicated by an arrow.

is postnatal development of the cruciate ligaments. At the present time, the regulatory mechanisms responsible for postnatal differentiation and phenotype maintenance of cruciate ligaments remain largely unknown. Understanding the biological processes that control morphogenesis of cruciate ligaments during the embryonic stage and its maturation and maintenance after birth are inherently important questions that need to be answered in skeletal biology.

In this study, we have obtained evidence that mesenchyme-specific knockout of ESET histone methyltransferase causes malformation of the ACL in young mice and accelerates degeneration of the PCL in adult animals. The availability of genetically modified mice with tissue-specific knockout of ESET offers us a unique opportunity to explore how cruciate ligaments are controlled by a specific histone modification enzyme. New insight into the epigenetic regulation of cruciate ligaments by ESET histone methyltransferase not only adds to our fundamental understanding of cruciate ligament development/maintenance, but may also hold clues to ACL injury prevention and potential future treatment modalities that exceed the ones we have available to us today.

## References

1. Schweitzer, R., Chyung, J.H., Murtaugh, L.C., Brent, A.E., Rosen, V., Olson, E.N., Lassar, A., and Tabin, C.J. 2001. Analysis of the tendon cell fate using *Scleraxis*, a specific marker for

tendons and ligaments. *Development* 128(19): 3855-3866.

2. Murchison, N.D., Price, B.A., Conner, D.A., Keene, D.R., Olson, E.N., Tabin, C.J., and Schweitzer, R. 2007. Regulation of tendon differentiation by *scleraxis* distinguishes force-transmitting tendons from muscle-anchoring tendons. *Development* 134(14): 2697-2708.

3. Yang, L., Lawson, K.A., Teteak, C.J., Zou, J., Hacquebord, J., Patterson, D.P., Ghatan, A.C., Mei, Q., Zielinska-Kiatkowska, A., Bain, S.D., Fernandes, R.J., and Chansky, H.A. 2013b. ESET histone methyltransferase is essential to hypertrophic differentiation of growth plate chondrocytes and formation of epiphyseal plates. *Dev Biol* 380(1): 99-110.

4. Logan, M., Martin, J.F., Nagy, A., Lobe, C., Olson, E.N., and Tabin, C.J. 2002. Expression of Cre recombinase in the developing mouse limb bud driven by a *Prxl* enhancer. *Genesis* 33(2): 77-80.

# Posterior Wall Acetabular Fractures and Stability

Clay Spittler, MD, Calvin Schlepp, MD, Benjamin Hamilton, MS, Julie Agel, MA,  
and Reza Firoozabadi, MD, MA

Hip stability after small and intermediate sized posterior wall acetabular fractures is difficult to predict based on radiographic information. The purpose of this project was to determine if the radiographic parameters of femoral head coverage by the intact posterior wall, acetabular version, and location of fracture or a history of dislocation were determinates of hip stability based on intraoperative fluoroscopic exam after a posterior wall acetabular fracture. A retrospective review of clinical and radiographic data from all patients who underwent EUA for PW fracture was performed and data was compared between the stable and unstable groups. Our review identified 138 patients who underwent EUA between 12/1/01-07/01/13. There were 116 stable (84.06%) hips and 22 unstable (15.94%) hips. A history of hip dislocation was not predictive of hip instability after PW fracture. Fractures in the unstable group had a significantly more cranial fracture exit point and were significantly larger according to the measurement techniques of Moed and Keith. None of the other radiographic measurements showed a significant difference between the groups. This study identifies cranial exit point of the fracture as another important radiographic predictor of hip instability after posterior wall acetabular fracture.

## Introduction

Hip stability after small and intermediate sized posterior wall acetabular fractures is difficult to predict based on radiographic information. The gold standard for determination of hip stability following small posterior wall (PW) acetabular fracture is examination under anesthesia (EUA)<sup>1</sup>. Previous attempts to radiographically predict hip stability have focused on measurement of the size of the fracture fragment on axial tomographic images<sup>2-4</sup>. Radiographic measurements have only been marginally successful in accurately predicting instability demonstrated in the operating room during EUA. To our knowledge, other fracture characteristics such as cranial exit point of the fracture have not been identified as predictors of instability. Additionally, patient-specific anatomic variations of the femur and acetabulum may have certain characteristics that contribute to hip stability following PW fracture. This study attempts to identify other radiographic predictors of hip

instability after small PW acetabular fracture.

## Methods

A retrospective review of prospectively collected data was performed using a search of a trauma database to identify all patients who underwent examination under anesthesia to determine hip stability following posterior wall acetabular fracture. EUA was performed with the patient in the supine position with fluoroscopic imaging evaluating the AP and the obturator oblique images while the hip is taken from full extension to 90 degrees of flexion while an axial load was applied along the longitudinal axis of the femur. All patients were categorized as stable or unstable based on the fluoroscopic evaluation of hip concentricity during EUA. Clinical and radiographic data were reviewed and compared between the stable and unstable groups. Variables reviewed included history of hip dislocation, presence of a crossover sign or ischial

spine sign on an adequate AP pelvis X-ray, lateral center edge angle, measurement of fracture fragment size on axial CT scan using previously described methods, measurement of acetabular version on axial CT at both the cranial aspect of the acetabulum as well as at its midpoint<sup>5</sup>, percent of femoral head covered by remaining intact posterior wall, and proximity of the most cranial aspect of the fracture to the acetabular roof.

## Results

Our review identified 138 patients who underwent EUA between 12/1/01-07/01/13. There were 116 stable (84.06%) hips and 22 unstable (15.94%) hips. There were no significant differences in patient age or mechanism of injury between the two groups. Table 1 displays the differences in radiographic parameters between the two groups.

A history of hip dislocation was not predictive of hip instability after PW fracture. Fractures in the unstable

	<b>Dislocations (p=0.49)</b>	<b>Head coverage at fovea (p=0.7)</b>	<b>Cranial exit point of fracture (p=0.004)</b>	<b>Roof edge angle (p=0.85)</b>	<b>Equatorial angle at fracture line (p=0.69)</b>	<b>Center edge angle (p=0.97)</b>	<b>Displaced wall size based on:</b>		
							<b>Moed (p=.02)</b>	<b>Keith (p=.001)</b>	<b>Caulkin (p=.96)</b>
<b>Unstable</b>	15/22 (68%)	33%	5.0mm	5.2°	13.1°	40.3°	26%	27%	25%
<b>Stable</b>	69/116 (59%)	32.7%	9.5mm	4.8°	12.4°	40.4°	21%	17%	25.3%

Table 1: Displays the differences in radiographic parameters between the two groups.

group had a significantly more cranial fracture exit point and were significantly larger according to the measurement techniques of Moed and Keith. None of the other radiographic measurements showed a significant difference between the groups.

5. Werner et al. "Correlation of the cross-over sign of the cross-over sign on conventional pelvic radiographs with computed tomography retroversion measurements. *Skeletal Radiol* (2010) 39:655-660.

## **Discussion**

Hip stability after small posterior wall fracture is difficult to predict, and the gold standard remains exam under anesthesia. Our data suggest that there is no absolute correlation between a history of dislocation and instability after PW fracture, but there is a significantly higher rate of hip instability in fractures with a cranial exit point within 1 cm of the acetabular roof. While not an absolute indicator of instability, this fracture characteristic has not been described previously as a predictor of hip instability. No patient specific anatomic variable were identified as contributing to hip instability after PW fracture. While this information will not eliminate the need for EUA, it will provide clinicians with another tool to help predict instability as well as potentially avoid operating unnecessarily on PW fractures simply because of a history of dislocation. Further investigation into patient anatomic variables may demonstrate a relationship between a patient's native anatomy and risk of instability after PW fracture.

## **References**

1. Grimshaw & Moed "Outcomes of Posterior Wall Fractures of the Acetabulum Treated Nonoperatively After Diagnostic Screening with Dynamic Stress Examination Under Anesthesia" *JBJS Vol 92-A*, no 17, December 2010 pgs. 2792-2800.

2. Keith et al "Stability of Posterior Fracture-Dislocations of the Hip: Quantitative Assessment Using Computed Tomography" *JBJS vol. 70-A* no 5 June 1988 pgs. 711-714.

3. Moed et al "Computed Tomography as a Predictor of Hip Stability Status in Posterior Wall Fractures of the Acetabulum" *J Orthop Trauma vol. 23* no 1 January 2009.

4. Calkins et al "Computed Tomography Evaluation of Stability of Posterior Fracture Dislocation of the Hip" *CORR*, vol. 277 February 1988 pgs. 152-163.

# Risk of Spermatic Cord Injury During Anterior Pelvic Ring and Acetabular Surgery: An Anatomic Study

Reza Firoozabadi, MD, MA, Paul Stafford, MD, and Milton L. Routt, Jr., MD

**Aims:** The primary aim of this study was to identify the distance between the midline and the spermatic cords in adult male cadaveric specimens. The secondary aim was to determine spermatic cord diameters and measure the distance between the spermatic cord and implant during instrumentation of a retrograde superior pubic ramus medullary screw.

**Methods:** Extended Pfannenstiel and Stoppa approaches were performed on 18 embalmed male cadavers bilaterally. Spermatic cord characteristics were recorded and a number of measurements were performed to determine the distance of implants and the midline from the spermatic cord.

**Results:** The average distance between the midline and spermatic cords was 34.2 mm. The average distance between the spermatic cord and implant during placement of retrograde ramus screw was 18.2 mm.

**Discussion:** Due to the proximity of the spermatic cord, the surgeon should either formally expose the cord or limit lateral dissection from the midline during Pfannenstiel and Stoppa exposures. Similarly, the surgeon should use soft-tissue sleeves and oscillating drills to avoid injury to the contralateral spermatic cord during the insertion of retrograde superior pubic ramus medullary screws.

## Introduction

Anterior pelvic ring surgery includes a variety of plating techniques and insertion of retrograde superior pubic ramus screws. Anterior acetabular surgery also includes fixation through an ilioinguinal or Stoppa approach. These exposures risk injury to the spermatic cord and accompanying genital branch of the genitofemoral nerve as they pass anterior to the superior pubic ramus. Additionally, the spermatic cord may also be injured during drilling or placement of a percutaneous retrograde superior ramus screw. The aim of this study was to: 1) measure the distance between the spermatic cord and the midline, 2) measure the distance between the contralateral spermatic cord and the implant during insertion of retrograde superior pubic ramus screws and 3) measure the average spermatic cord diameter and identify potential anomalies.

## Methods

Extended Pfannenstiel and Stoppa approaches were performed bilaterally on 18 embalmed male cadavers. The incision extended from pubic symphysis to the anterior-superior iliac spine. All soft tissue anterior to the rectus abdominus sheath and external oblique muscles was removed. The spermatic cord was identified and assessed. The rectus abdominus muscle was then incised longitudinally through the central raphe and released from its pubic insertion. The deep dissection

proceeded laterally, completing the release of the rectus abdominus muscle and inguinal ligament from the pubic tubercle. With the pubic tubercle exposed, we used a previously described technique to insert a 0.62mm Kirshner wire into the superior pubic ramus. The distance between the Kirshner wire and the contralateral spermatic cord was measured. This technique was duplicated for the contralateral ramus. A student-T test

was utilized to compare the differences between normal and aberrant cords.

## Results

The average of the specimens was 80 years. Eleven of the thirty-six dissections had abnormalities including cord lipomas and inguinal hernias (Figure 1). The average cord diameter was 18.6 mm. The average cord diameter in those with abnormalities was 24.9 mm. The average cord

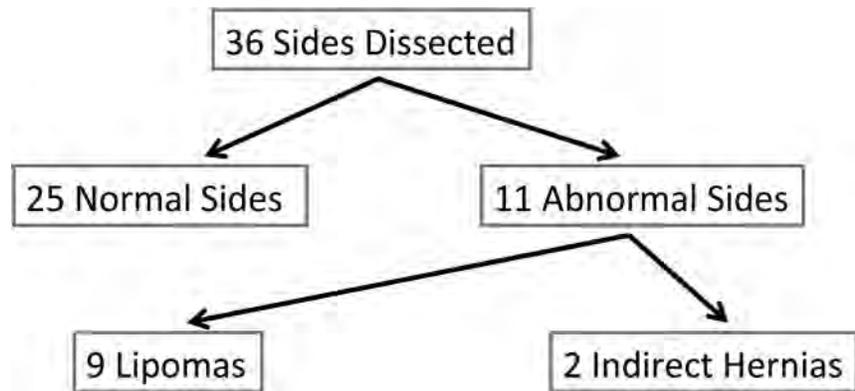


Figure 1: Eleven of the thirty-six dissections had abnormalities including cord lipomas and inguinal hernias

## Cord Diameters

	Average (mm)	Range (mm)	
All Cords	18.6	11-28	
Abnormal Cords	24.9	15-28	$p < 0.01$
Normal Cords	16	11-22	

Figure 2: Cord Diameters.

### Distance between midline and spermatic cord

	Average (mm)	Range (mm)	
All Cords	34.2	22-45	p=0.51
Abnormal Cords	32.7	22-40	
Normal Cords	34.6	25-45	

Figure 3: Distance between midline and spermatic cord.

### Distance between k-wire and spermatic cord

	Average (mm)	Range (mm)	
All Cords	18.2	11-30	p=0.49
Abnormal Cords	17.1	11-25	
Normal Cords	18.4	11-30	

Figure 4: Distance between k-wire and spermatic cord.

diameter in those without abnormalities was 16 mm (Figure 2). The average distance between the midline and spermatic cords was 34.2 mm (Figure 3). During the simulated insertion of a retrograde superior pubic ramus screw, the average distance between the Kirshner wire and contralateral spermatic cord was 18.2 mm (Figure 4).

#### Discussion

The orthopaedic surgeon must be aware of possible inguinal abnormalities and the relative location of the spermatic cord during anterior pelvic ring surgery. The spermatic cord was as close as 22 mm to the midline and as close as 11 mm to the Kirshner wire. To avoid inadvertent spermatic cord injury, the surgeon should reference these minimum distances rather than the averages. Due to the proximity of the spermatic cord, the surgeon should minimize superficial dissection away from the midline during Pfannenstiel and Stoppa approaches. Similarly, during insertion of percutaneous retrograde superior ramus screws, the surgeon should use soft-tissue sleeves and an oscillating drill to avoid injury to the nearby spermatic cord.

#### References

1. Barei DP, Bellabarba C, Mills WJ, et al. Percutaneous management of unstable pelvic ring disruptions. *Injury*. 2001;32 Suppl 1:SA33-44.

2. Roult ML Jr., Simonian PT, Grujic L. The retrograde medullary superior pubic ramus screw for the treatment of anterior pelvic ring disruptions: a new technique. *J Orthop Trauma*. 1995;9:35-44.

3. Andersen RC, O'Toole RV, Nascone JW, et al. Modified stoppa approach for acetabular fractures with anterior and posterior column displacement: quantification of radiographic reduction and analysis of interobserver variability. *J Orthop Trauma*. 2010;24:271-278.

4. Easton L. Hermann Johannes Pfannenstiel (1862-1909). *Br J Obstet Gynaecol*. 1984;91:538-541.

5. Irwin T, McCoubrey A. Adult groin hernias. *Surgery (Oxford)* 2012;30:290-295.

# Nanoengineered 3-Dimensional Tendon Tissue

Albert O. Gee, MD, Philip Tatman<sup>1</sup>, Sang-Jun Kim MD, PhD<sup>2</sup>, and Deok-Ho Kim, PhD<sup>1</sup>

## Introduction

Tendons are responsible for transmitting muscle derived forces to bone and are subjected to significant mechanical loading. The extracellular matrix (ECM) and cellular architecture of tendons are arranged in the direction of force transmission and this organization imparts critical anisotropy to the tissue. In part, this load-bearing role can make tendons susceptible to damage from acute injury, overuse phenomenon, and/or degeneration from aging. However, like other dense connective tissues of the body, tendons have poor intrinsic healing capability after injury. Therefore, stem cell-based therapies and tissue engineering hold much promise for alternative treatment approaches. To this end, we are proposing a nanotopography-based tissue engineering strategy which recapitulates the micro-architecture of the native ECM as a means to control tendon tissue organization and regeneration.

## Fabrication and Seeding of Nanopatterned Cell Culture Substrate

Nanopatterned cell culture substrates which direct cell alignment were fabricated. This was achieved through the use of forced lithography<sup>1-3</sup>. Briefly, a small amount of photo-curable polymer was placed onto a glass slide upon which a 2-inch square laser-etched silicon wafer master pattern with pre-defined groove dimensions is placed on top, and then subjected to ultra violet light (Figure 1).

Once fabricated, we successfully cultured tendon cells harvested and expanded from Sprague-Dawley rat Achilles tendons on 800nm groove pattern made of poly(lactic-

co-glycolic acid) (PLGA) in cell culture. Nanopatterned slides were seeded and cultured for 2 weeks. Immunohistochemical staining was performed to evaluate the presence of tenocyte markers and production of a tendon matrix and regenerative markers. We stained for collagen type 1, Scleraxis (a helix-loop-helix transcription factor common to developing and mature tenocytes), and Oct4 (a cellular protein utilized to dedifferentiate mature cells into pluripotent stem cells and as such is a molecular marker for tendon progenitor cells) (Figure 2). This has been replicated with human tendon cells harvested and expanded from hamstring tendons (data not shown). As shown in Figure 2A, cellular alignment along the direction of the scaffold was achieved.

## Fabrication of Nipaam-Grafted Thermo-responsive Nanopatterned Cell Culture Substrates

Furthering our nanopattern substrate technology, we fabricated a thermally responsive cell-culture substrate through the incorporation of N-isopropyl acrylamide (NIPAAm) and poly-glycidyl methacrylate (GMA) into our lithography technique. The GMA features an epoxide group which provides a binding site to which additional chemical moieties can be attached. The GMA is mixed with the chosen polymer and fabrication of our nanopattern is performed as described above. When this substrate is exposed to NIPAAm, it becomes covalently bonded to the epoxide group of GMA (Figure 3).

NIPAAm becomes hydrophobic at temperatures above 32°C, allowing

it to adhere to cell membranes and proteins and thus anchoring cells. However, below 32 degrees, the NIPAAm becomes more hydrophilic. Water disrupts the attraction between NIPAAm and the overlying monolayer of attached cells. This allows for the release of the cellular monolayer as a sheet without disrupting the cell-cell adhesions and the cellular alignment of the monolayer (Figure 4).

## Generation of Anisotropic 3D Tissue Constructs by Cell Sheet Stacking

Layer-by-layer control of tissue structure by stacking individual aligned cell sheets using thermoresponsive nanostructured cell culture substrate was successfully achieved. When cell sheets are released from the substrate, there is a tendency for the monolayer to curl and become damaged (Figure 4). To address this, a gelatin hydrogel transfer system was developed and utilized to release cell sheets in a controlled manner (Figure 5A). When cell sheet release is desired, a gelatin solution is applied on top of the monolayer. At 37°C, the gelatin remains soft while the NIPAAm continues to anchor the cells. When placed at room-temperature (below 32°C) the gelatin forms a hard layer which anchors the cells at the same time cells release from the NIPAAm scaffold. Once detached from the substrate, cell sheets can be stacked within the gelatin layer. In order to stack multiple sheets, the culture temperature is increased until the gelatin dissolves. This process can be repeated until desired tissue thickness is achieved. To date, several layers of human tenocyte cell sheets have been stacked in orthogonal orientation and visualized under light-microscopy (Figure 5B).

## Conclusion

Successful creation and alignment was achieved using a nanopatterned scaffold and tendon cells from both rat and human sources in vitro. Multi-layered 3D tendon tissue constructs were also achieved using a thermoresponsive polymer scaffold which allowed for release of individual

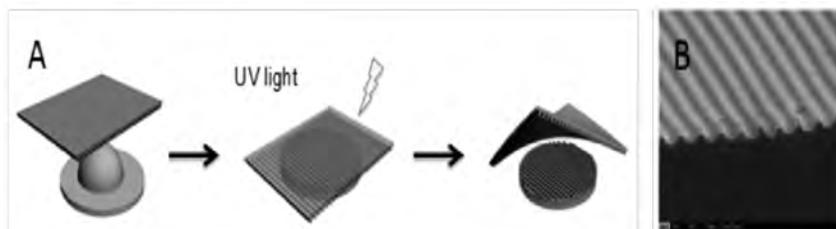


Figure 1: A) Forced lithography overview. B) SEM image of the resulting nanopatterned scaffold.

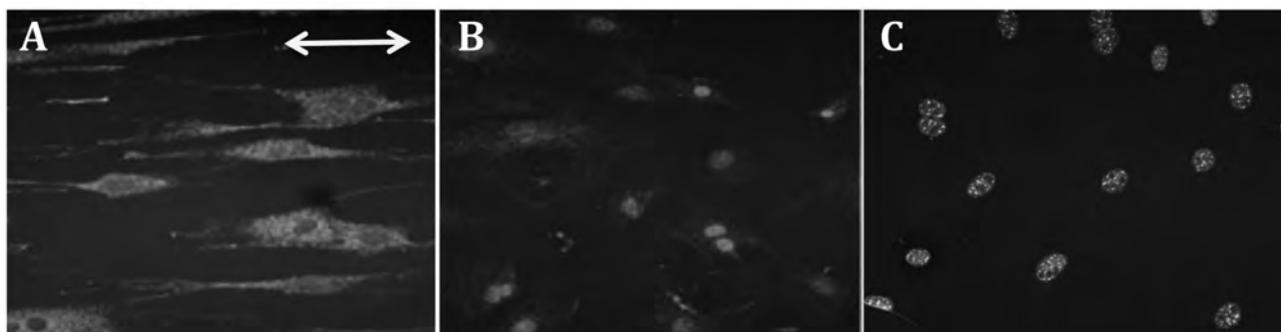


Figure 2: Immunofluorescent staining of rat tenocytes seeded on PLGA 800 nm groove width substrates at 8 days in culture. A) Collagen 1, DAPI and arrow representing groove direction of the underlying scaffold; B) Scleraxis and DAPI; C) Oct4 and DAPI.

cell monolayer sheets and subsequent stacking of these cell sheets.

### Future Studies

Further analysis of these 3D tendon cell constructs will be required and be performed beginning with scanning electron microscopy and optical microscope images illustrating cell attachment, growth and alignment. Alignment of cells will be assessed after detachment from thermoresponsive nanopatterns and after stacking of 3D cell sheets using confocal microscopy. Quantitative analysis to determine the effect of nanopatterns on tenocyte function and differentiation will be carried out using qRT-PCR and immunoblot assay for Scleraxis, Tenascin C, and COL1A1 molecular tendon cell markers.

In vivo studies will be performed to implant and evaluate these 3D tendon tissue constructs in a mouse model of tendon injury<sup>4,5</sup>. Multi-layered tendon tissue constructs will test the hypothesis that nanopatterned 3D tendon constructs can integrate with host tissue and restore function in a mouse model of patellar tendon injury. Analysis will include biomechanical assessment by uniaxial mechanical testing of the patellar tendon at various times after implantation and compared with controls. The patellar tendons from each group will undergo standard histological, biochemical and immunohistochemical analysis to determine the extent of matrix deposition with time and to assess the construct integration and proliferation (staining for col I, scleraxis, decorin, biglycan). In addition, matrix organization will be analyzed using polarized light microscopy as described previously which allows quantification of the collagen fiber alignment and generates histograms of collagen fiber

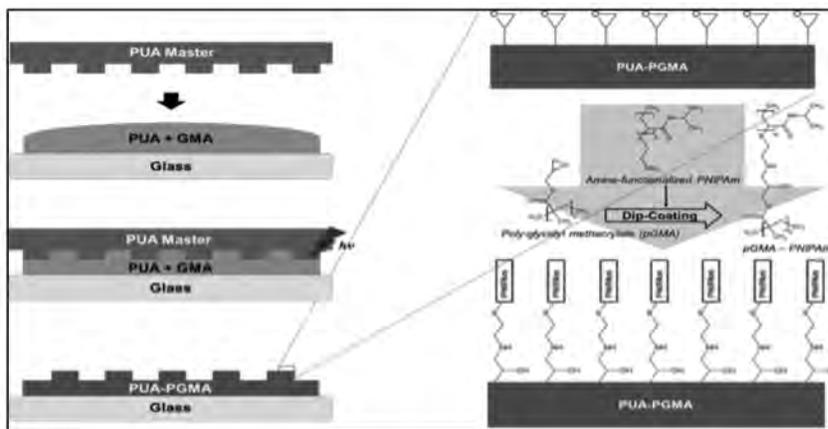


Figure 3: Overview of the modified forced lithography process to create a thermo responsive scaffold using NIPAAm.

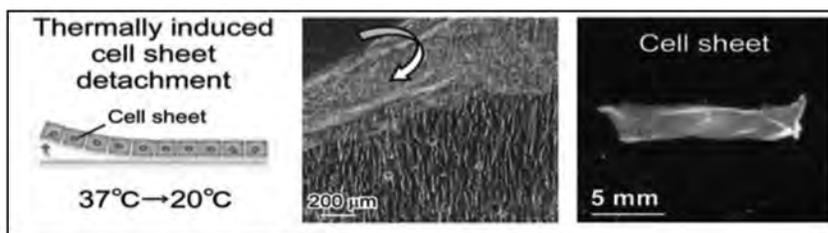


Figure 4: Overview of thermoresponsive polymer substrate and cell sheet detachment with temperature change. Center image shows detachment of cell sheet on light microscopy. Right image shows a detached cell sheet which has rolled upon itself.

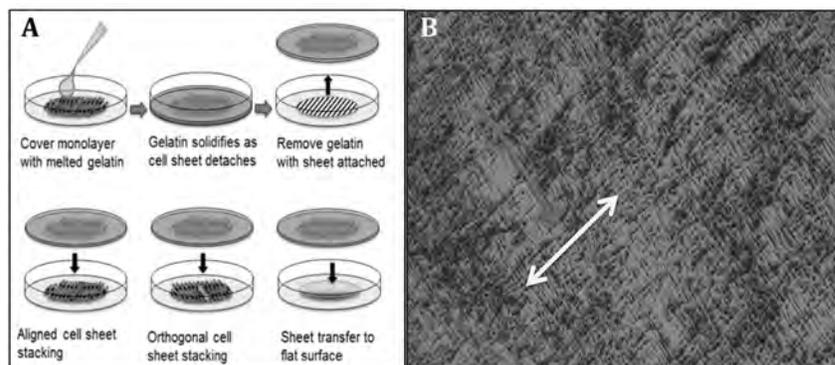


Figure 5: A) Overview of gelatin hydrogel transfer method allowing stacking of cell sheets. B) Light microscope image of 2 human tendon cell sheets stacked orthogonal to each other (arrows show cell alignment direction; 4x magnification).

angular deviations from the prevailing alignment direction.

#### Literature Cited

1. Kim DH, Lipke EA, Kim P, et al. Nanoscale cues regulate the structure and function of macroscopic cardiac tissue constructs. *Proceedings of the National Academy of Sciences*. 2010;107(2):565–570. doi:10.1073/pnas.0906504107.
2. Suh KY, Park MC, Kim P. Capillary force lithography: a versatile tool for structured biomaterials interface towards cell and tissue engineering. *Advanced Functional Materials*. 2009.
3. Kim P, Kim DH, Kim B, Choi SK, Lee SH. Fabrication of nanostructures of polyethylene glycol for applications to protein adsorption and cell adhesion. 2005.
4. Lin TW, Cardenas L, Glaser DL, Soslowsky LJ. Tendon healing in interleukin-4 and interleukin-6 knockout mice. *Journal of Biomechanics*. 2006;39(1):61–69. doi:10.1016/j.jbiomech.2004.11.009.
5. Lin TW, Cardenas L, Soslowsky LJ. Tendon properties in interleukin-4 and interleukin-6 knockout mice. *Journal of Biomechanics*. 2005.

<sup>1</sup>Department of Bioengineering  
University of Washington  
Seattle, Washington

<sup>2</sup>Department of Physical and  
Rehabilitation Medicine  
Samsung Medical Center  
Seoul, Korea

# ESET Histone Methyltransferase is Essential for Fracture Healing in a Mouse Tibia Fracture Model

Jacques Hacquebord, MD, Sean Haloman, MD, Andrew Ghatan, MD, Ning Li, BS,  
Howard A. Chansky, MD, and Liu Yang, PhD

We recently found that ESET histone methyltransferase plays a critical role in the differentiation of chondrocytes and osteoblasts through analyzing mice with a specific deletion of the ESET gene. While the biologic principles of bone fracture repair have been intensively studied by many groups, major questions still remain regarding a complex network of factors that control fracture healing. Using a murine tibia fracture model, here we show that ESET knockout mice have a grossly deficient healing response to tibia fracture when compared to wild-type animals. In the coming months, we plan to further characterize differences between wild-type and ESET knockout mice in their response to tibia fracture through histology examination, immuno-histostaining and micro-CT analysis to better understand the underlying molecular mechanisms.

## Introduction

ESET histone methyltransferase is widely expressed in a variety of cells and tissues, suggesting that the ESET protein may have multiple cellular functions (1). The studies of ESET *in vivo* are made possible since we were able to generate tissue-specific ESET knockout mice that are viable into adulthood. After phenotype characterization of these knockout mice, we have found that ESET is critical for normal skeletal development, maintenance of joint function, and epiphyseal plate formation (2-4). Since bone fracture repair (fracture healing)

is an intricate process that shares many similarities with normal skeletal development, we hypothesized that ESET is also involved in fracture healing. Using a tibia fracture model in mice as a tool, we investigated how ESET knockout influences bone healing response in adult animals.

## Methods

All experiments were reviewed and approved by the Institutional Animal Care and Use Committee at the VA Puget Sound Health Care System. Conditional ESET knockout mice were generated by mating ESET(exons

15&16)<sup>Flox/WT</sup> with ESET(exons 15&16)<sup>Flox/WT</sup>; Prx1-Cre mice. Once the mice became skeletally mature (> two month-old), an established murine tibia fracture was introduced to the animals through the creation of a uni-cortical defect on the medial aspect of the proximal tibia (5). In these experiments, a 1.0 mm drill hole was created in the tibiae of wild-type mice, whereas a 0.6 mm drill hole was created in the tibiae of ESET knockout mice due to the grossly abnormal and significantly smaller skeletons found in the mutant mice. Incisions were closed with suture and mice were able to return to unrestricted activity in their cages. Animals were sacrificed at post-operative days 8 and 50, respectively, for histology staining by hematoxylin-eosin and micro CT analysis to evaluate healing of the cortical defect and surrounding bone.

## Results

H&E staining of the surgical sites at post-operative day 8 is displayed in Figure 1 which exhibits clear signs of corticotomy on the proximal tibia. Repair of the uni-cortical defect progressed normally in wild-type animals at the fracture site, as demonstrated by formation of a fracture callus that is rich in woven bone. In ESET knockout mice, however, no obvious signs of a fracture callus could be observed at the surgical site and the fracture gap was completely filled with undifferentiated cells with a total lack of woven bone. Though not presented in this report, preliminary micro CT analysis of the surgical sites at post-operative day 50 show a well healed tibia in wild-type animals. In contrast, fracture healing

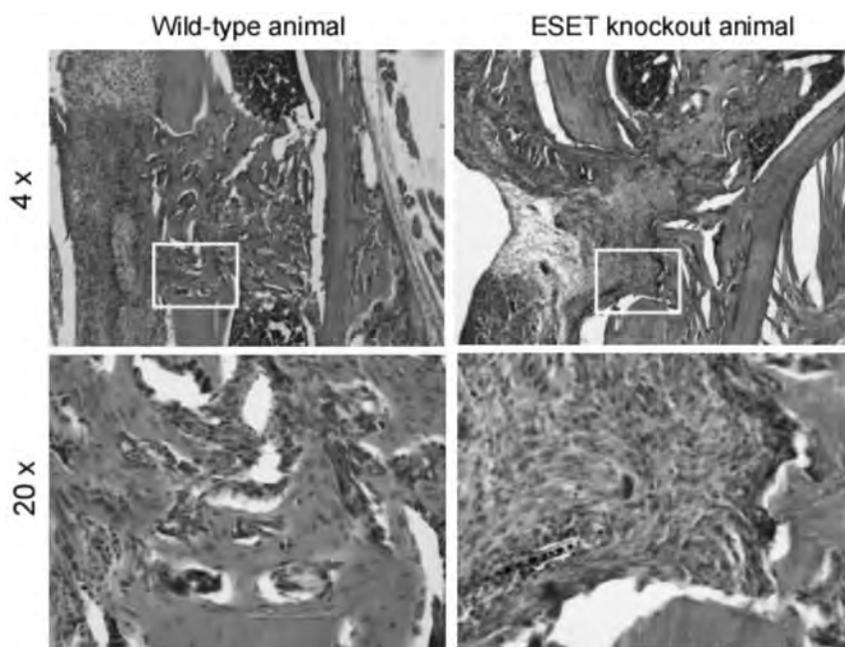


Figure 1: H&E staining of tibia fracture sites at post-operative day 8. Surgical sites on the tibia of wild-type mice (left panels) and ESET knockout mice (right panels) were shown. Lower panels represent selected areas with higher magnification.

is significantly impaired in the absence of ESET protein expression since micro CT scan at post-operative day 50 revealed minimal calcification of the fracture gap in ESET-null animals.

### Discussion

In normal fracture healing, three major phases of recovery facilitate the proliferation and protection of the areas surrounding fractures. In the reactive phase, the blood vessels constrict, stopping any further bleeding and the extravascular blood cells form a blood clot known as a hematoma. In the reparative phase, cells of the periosteum replicate and transform into chondroblasts and osteoblasts to produce a new mass of heterogeneous tissue known as the fracture callus. In the remodeling phase, the hyaline cartilage and woven bone within the fracture callus is replaced by lamellar bone in a manner similar to endochondral ossification, restoring most of the bone's original strength. Since there are clear differences in the formation of fracture callus between wild-type and ESET knockout mice, it appears that periosteal cells lacking ESET protein are defective in their ability to differentiate into chondroblasts and osteoblasts. Without these specialized cells, the reparative phase of fracture healing cannot proceed properly, and bridging of the fracture gap will be difficult. Since ESET is a histone modification enzyme that regulates cellular processes through epigenetic mechanisms, in future experiments we plan to investigate how ESET controls genes that are known to play pivotal roles in fracture healing.

### Acknowledgement

This work is supported in part by a Resident Trauma Research grant from AO North America.

### References

1. Blackburn, M. L., Chansky, H. A., Zielinska-Kwiatkowska, A., Matsui, Y. & Yang, L. Genomic structure and expression of the mouse ESET gene encoding an ERG-associated histone methyltransferase with a SET domain. *Biochim. Biophys. Acta* 1629, 8–14 (2003).
2. Yang, L. et al. ESET histone methyltransferase is essential to hypertrophic differentiation of growth plate chondrocytes and formation

of epiphyseal plates. *Dev. Biol.* 380, 99–110 (2013).

3. Lawson, K. A. et al. Mesenchyme-specific knockout of ESET histone methyltransferase causes ectopic hypertrophy and terminal differentiation of articular chondrocytes. *J. Biol. Chem.* 288, 32119–32125 (2013).

4. Lawson, K. A. et al. ESET histone methyltransferase regulates osteoblastic differentiation of mesenchymal stem cells during postnatal bone development. *FEBS Lett.* 587, 3961–3967 (2013).

5. Prasad, J., Wiater, B. P., Nork, S. E., Bain, S. D. & Gross, T. S. Characterizing gait induced normal strains in a murine tibia cortical bone defect model. *J. Biomech.* 43, 2765–2770 (2010).

# 2005 and 2013 Health Survey of SRS Member Surgeons Focusing on Thyroid Cancer and Cataract Prevalence – Occupational Radiation Risk?

Theodore A. Wagner, MD, Christie L. Benevich, BA, Maria A. Vanushkina, Marc A. Asher, Sue Min Lai, Courtney O'Donnell, MD, Darin J. Davidson, MD, MHSc, and Mark Weidenbaum

We attempted to correlate cancer and cataract prevalence, radiation exposure and shielding habits in SRS members. A total of 733 unique responses were collected via surveys administered in 2005 and 2013. Overall 13% of surgeons reported malignancies and 30% reported cataracts (61 answered “yes” of 206 responses; 527 did not respond to the question). Shielding equipment was grossly underutilized. We recommend implementation of mandatory surveillance of occupation-related health risks for Scoliosis Research Society (SRS) members in the future.

## Introduction

Professional organizations, such as SRS, are minimally involved in surveillance or prevention of occupation-related health risks. In 2005, the diagnosis of three colleagues with thyroid cancer prompted a survey evaluation of these risks for spine deformity surgeons. Several studies have documented correlation between cumulative radiation doses and increased cancer and cataract rates. The survey was re-written with this in mind and repeated in 2013. We hypothesized that cancer and cataract prevalence relates to the cumulative radiation dose generated by C-arms and plain x-rays in operating rooms or treatment areas.

## Methods

To expand the 2005 data set, a second survey of SRS members was conducted via Survey Monkey with support from the SRS Instrumentation Committee. The 2013 questions requested additional information on cataracts and medically related radiation exposure and family history. The information from both surveys were combined and evaluated. Entries for surgeons who participated in both surveys were combined to avoid duplication. Surgeon cancer rates were compared with the age and gender adjusted general population statistics from the National Cancer Institute's Surveillance, Epidemiology, and End Results Program data. The cataract rates were compared to the Center for Disease Control's Behavioral Risk Factor Surveillance System Vision

Module data.

## Results

42% (429/1012) of the SRS member surgeons responded to the survey in 2013 compared to the 81% (528/650) response rate in 2005 for a total of 733 unique entries. Overall, 13.1% (n=96) of surgeons reported a malignancy. Of the 2013 group, 29.6% (n=61) reported suffering from cataracts. The use of protective equipment was low, with 47.3% (n=347) reporting regular use of lead neck shields and 5.6% (n=41) reporting regular use of lead eye protection.

## Conclusion

Dr. Sue Lai has cautioned that the survey data needs careful correlation

with a population (not exposed to workspace radiation) that would be age adjusted, geographically sampled, and gender sorted.

This cohort survey of the SRS spine deformity surgeons reveals a real risk of increased cancer and cataract rates. Because the effect of radiation is cumulative, appropriate radiation protection should be emphasized for the youngest orthopaedic residents and maintained throughout their careers. To encourage safety precautions the authors suggest purchasing comfortable, custom fitted leaded goggles, vest, and aprons (skirts) that are engraved with the owners' names. This work is ongoing.

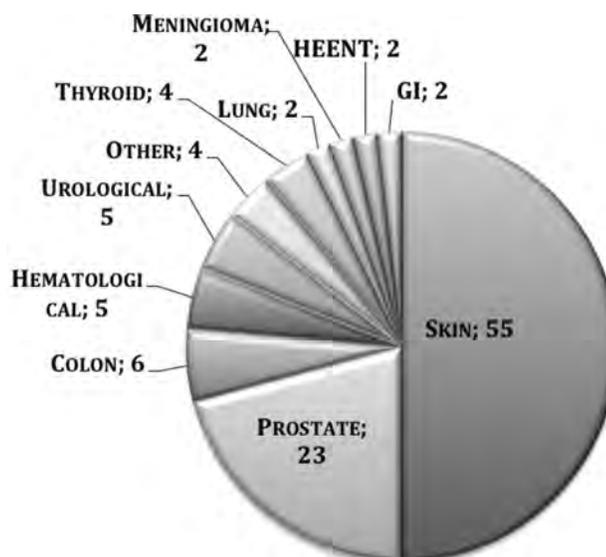


Figure 1: Preliminary survey results of SRS fellows cancer incidence.

# Normal and Misaligned Talonavicular Fusion Alters Cadaveric Foot Pressure and Kinematics

Elizabeth P. Wahl, BA, William R. Ledoux, PhD, Eric C. Whittaker, MS,  
Brian K. Cook, BS, and Bruce J. Sangeorzan, MD

A cadaveric simulation of talonavicular fusion, and the affects of misalignment, was conducted using the robotic gait simulator. Fusion, and the associated varus and valgus misalignments, was achieved with an external fixation system. Motion was severely reduced at the talonavicular joint, but remained the same at the talocalcaneal and calcaneocuboid joints, indicating that fusion of the talonavicular joint was not equivalent to a triple joint fusion. Misalignments resulted in lateral (for varus) or medial (for valgus) shifting of the center of pressure, but there were no differences in joint kinematics.

## Introduction

While destructive joint disease of the ankle can be treated with arthroplasty (joint replacement) or arthrodesis (joint fusion) after non-surgical treatments have failed, a diseased talonavicular (TN) joint requires fusion due to the small surface area and complex anatomy of the joint. Historically, fusion of the triple joint complex, i.e., the talocalcaneal (TC), calcaneocuboid (CC) and TN joints, was employed as treatment for congenital deformities and arthritis [1]; however, more recent *in vivo* studies have employed isolated TN fusion as an alternative to a triple fusion [2], which has the potential advantages of reduced invasiveness, and spared motion. Previous *in vitro* studies have

reported that fusion of the TN joint decreases motion at the other joints of the triple joint complex to five degrees or fewer in all three cardinal planes [3]. However, these cadaveric studies did not dynamically simulate stance phase nor did they look at the impact on joints other than the triple joint complex. The effects of TN fusion, especially misaligned TN fusion, have not been fully explored. The objective of this study was to assess the dynamic kinetic and kinematic outcomes of a neutral TN fusion as well as the outcomes of varus and valgus misaligned TN fusions.

## Methods

In this IRB-approved study, ten fresh-frozen cadaveric lower limb

specimens (63y ± 23y; 5F, 5M) were prepared by dissecting the nine extrinsic tendons and collecting radiographs to ensure no pathological abnormalities. Fusion was simulated with the Stryker Hoffman II Compact external fixation system (Kalamazoo, MI). Four total pins were drilled bicortically into the medial and lateral navicular and talus neck/body, with care taken not to impinge the natural joint motion. Clamps were attached to each pin, and rods connected the two medial pins and two lateral pins. An additional rod with two clamps connected the medial and lateral rods for increased rigidity (Figure 1). The foot was mounted onto the robotic gait simulator (RGS) [4] and tested under four conditions:

Joint	Plane	UN range of motion (Degrees [SE])	UN to FN change (Degrees [SE])	FN to FV change (Degrees [SE])	FN to FG change (Degrees [SE])
Nav_Tal	Frontal	10.9 [1.5]	-8.7 [1.4]*	0.1 [0.3]	-0.2 [0.3]
	Transverse	12.0 [1.6]	-9.2 [1.5]*	0.2 [0.3]	0.1 [0.2]
	Sagittal	8.4 [1.6]	-6.2 [1.5]*	0.6 [0.5]	-0.2 [0.1]
Calc_Tal	Frontal	6.3 [0.8]	-1.5 [0.9]	-0.1 [0.3]	0.7 [0.5]
	Transverse	7.9 [1.6]	-3.2 [1.4]	0.2 [0.4]	0.4 [0.6]
	Sagittal	6.1 [2.1]	-2.4 [1.7]	0.2 [0.6]	0.3 [0.8]
Cub_Calc	Frontal	6.4 [1.2]	-0.8 [0.5]	0.1 [0.5]	0.4 [0.4]
	Transverse	9.9 [1.4]	-1.0 [0.9]	1.2 [1.6]	-0.3 [1.0]
	Sagittal	9.9 [2.2]	-0.9 [0.8]	0.3 [1.3]	-0.2 [1.0]

Nav\_Tal = talonavicular joint, Calc\_Tal = talocalcaneal joint, Cub\_Calc = calcaneocuboid joint; \*p < 0.005

Table 1: Unfused range of motion and change in range of motion of the triple joint complex in all three cardinal planes.

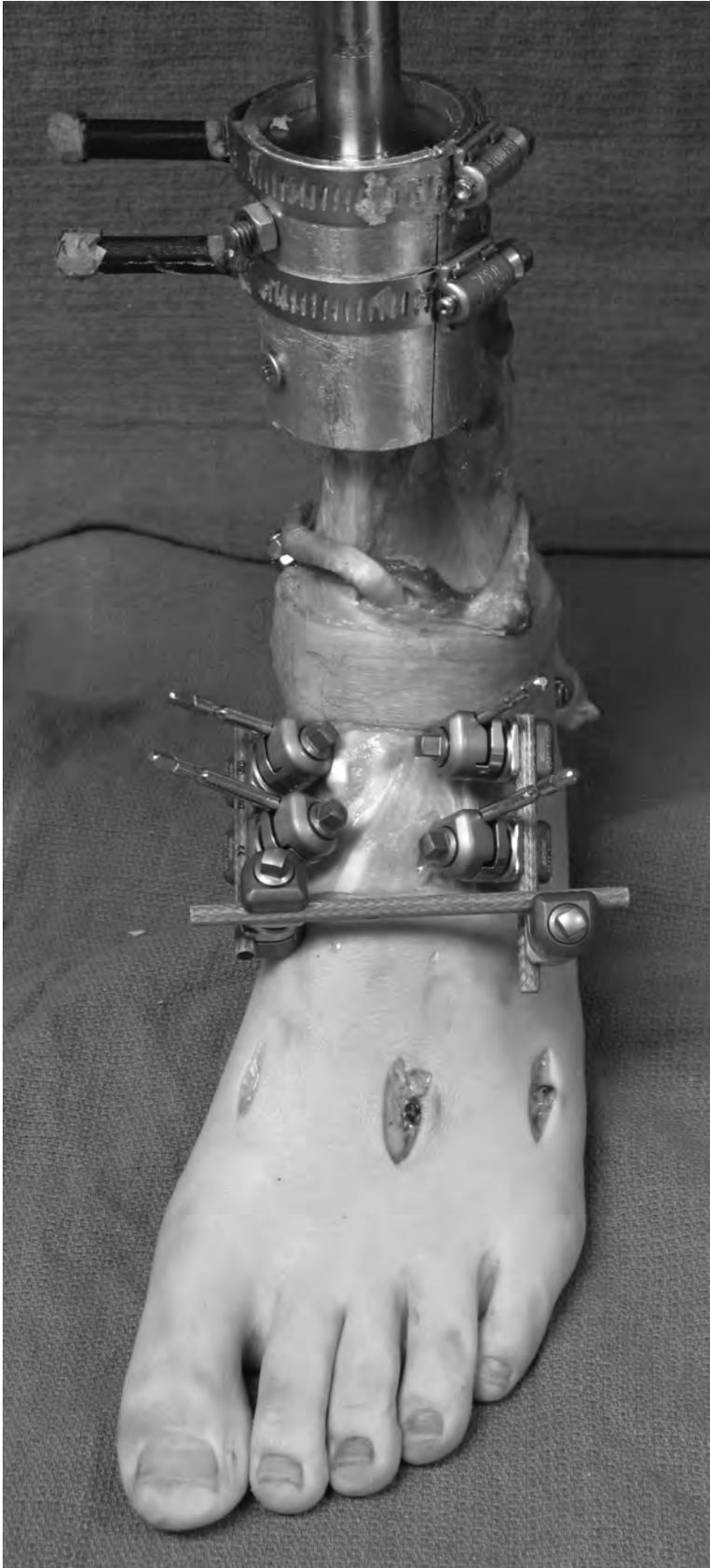


Figure 1: Stryker pins in the medial and lateral talus and navicular with Stryker external fixation hardware attached, including six clamps and three rods. The clamps were tightened to simulate fusion.

unfused (UN), fused in neutral position (FN), fused with varus misalignment (FV) (greatest achievable adduction, inversion and plantar flexion), and fused with valgus misalignment (FG) (greatest achievable abduction, eversion and dorsiflexion). Misaligned fusions were achieved by holding the foot in the desired position while locking down all six clamps. The stance phase of gait was simulated in 4.09 s at 25% of the specimen's body weight. An eight-camera Vicon system tracked the range of motion of ten bones using a ten-segment foot model [5], and a novel pliance pressure mat measured the peak plantar pressure. Linear mixed effects models were used to determine if biomechanical variable differed due to the fusion (i.e., UN to FN) and the misalignments (i.e., FN to FV and FN to FG) with a significance level of  $p = 0.05$ .

### Results

Of the 10 feet tested, two were excluded because pins holding the fusion loosened during testing. In the remaining eight feet, TN fusion was simulated successfully as indicated by a significant reduction and near elimination of motion in all three cardinal planes (Table 1). There were no significant range of motion changes in the remaining triple joint complex for either the fusion or the misalignment conditions (Table 1). From the plantar pressure data, the only change from UN to FN was a 30 kPa decrease in pressure under the first metatarsal head (MH1, Figure 2). From FN to the FV misalignment, there was an 81 kPa decrease in hallux pressure. Several changes were seen from FN to the FG misalignment, including an increase in MH1 and hallux pressure, and a decrease in lateral midfoot and third metatarsal head (MH3) pressure. Additional biomechanical variables, including medial/lateral center of pressure deviation, bone position at 0% stance, and other distal foot joint kinematics were calculated; statistical analysis is ongoing.

### Discussion

Isolated TN fusion may better preserve normal foot biomechanics over fusion of the entire triple joint complex [2], but its effects on the entire foot, especially when misaligned, are not fully understood. While Wulker et al. [3] reported a decrease in motion at

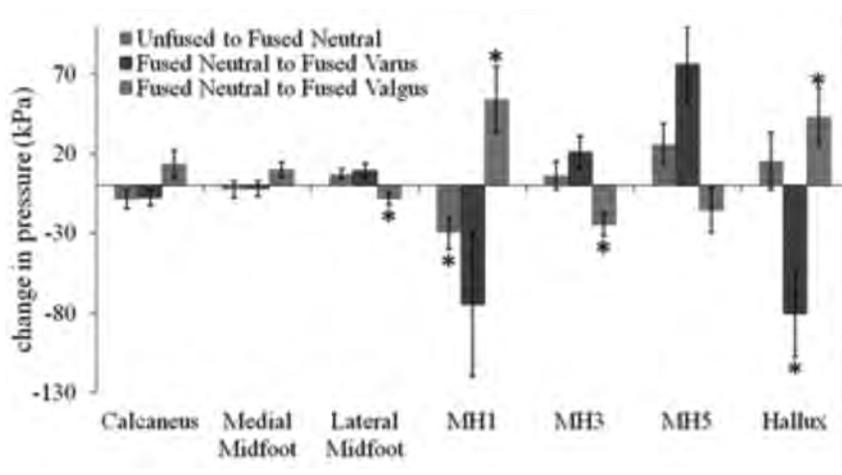


Figure 2: Changes in pressure for primary foot regions; \*p < .05

the CC and TC joints after TN fusion, our study showed no significant change in motion at these joints for the neutral fusion or the misaligned fusions. A long-term *in vivo* study of isolated TN fusion [6] reported postoperative arthritis at the CC and tibiotalar joints, perhaps as a result of altered motion at these adjacent joints when the TN is fused. The lack of change in the triple joint complex motion in this study indicates that perhaps the ankle joint and/or the other foot joints (still undergoing statistical analysis) may show alterations that explain these effects. The significant decrease in first metatarsal pressure for the neutral fusion did not accompany significantly increased lateral foot pressure, despite an obvious trend. The valgus misalignment had a more drastic effect than the varus misalignment, shifting the pressure medially under the foot similar to pressure trends in a pes planus deformity. Although the pressure shift was not significant in the varus misalignment, the trends show an increase in lateral plantar pressure similar to a pes cavus deformity. In general, feet were more compliant when positioning the TN joint in the valgus misalignment, which may indicate a stronger likelihood for surgical misalignment in this direction. The presence of plantar pressure changes without triple joint kinematic changes suggests that either pressure is sensitive to very small kinematic alterations, and/or kinematic changes are occurring elsewhere in the foot. Limitations include the small number of specimens, and having only the two extreme misalignments, rather than incremental misalignment steps, which was a restriction of the external fixation

hardware.

### Conclusion

This study emphasizes the importance of good surgical technique when performing a TN fusion, and with completed analysis, will provide valuable evidence of the possible causes of arthritis and/or injury after a TN fusion.

### Acknowledgements

This work was funded by UW School of Medicine Medical School Research Training Program (MSRTP) and VA RR&D Grant A9243C. Data analysis was conducted by Jane Shofer.

### References

1. Ryerson E, *Clin Orthop Relat Res.*, 466(1):5-14, 2008
2. Thordarson D, et al., *J Am Acad Orthop Surg*, 12(5): 322-22, 2004
3. Wulker N, et al., *Foot Ankle Int.*, 21(11): 921-7, 2002
4. Aubin P, et al., *IEEE Trans Robot*, 28:246-55, 2012
5. Whittaker E, et al., *Gait Posture*, 33(4): 645-50, 2011
6. Chen C, et al., *Foot Ankle Int*, 22(8): 633-6, 2001

# Effectiveness of the “Spine At Risk” Safety Program

Walter F. Krengel III, MD, Courtney O’Donnell, MD, Nicole Burkette-Ikebata, MPH,  
Emma Satchell, BA, Viviana Bompadre, PhD, and Klane K. White, MD, MSc

## Purpose

Patients with unrecognized cervical or thoracolumbar spinal instability or severe stenosis (e.g. skeletal dysplasia) are at risk for spinal cord injury during anesthesia. We developed the “Spine At Risk” (SAR) safety program, in which patients with qualifying diagnosis of potential critical spine instability or stenosis are identified by electronic medical record (EMR) prior to any anesthetic. Evaluation and completion of a spine precaution form by neurosurgical or orthopedic staff is required (Figure 1). We aim to describe the process and its results two years after implementation.

## Methods

Diagnoses with a SAR designation were identified by members of the spine team at our institution. Patients with these designated diagnoses, by ICD-9 coding were automatically flagged by the EMR as SAR. Each patient identified as SAR then had a review by a member of the spine team,

with recommendations made prior to undergoing general anesthetic for any procedure. In this study, a chart review of patients potentially affected by SAR from April 2011 to June 2012 was performed. Informal cost evaluation was also performed.

## Results

920 patients carried a diagnosis qualifying them for a SAR alert. 315 had a precaution form completed. Of these, 190 (60%) needed “no special precautions” and 125 (40%) had at least one precaution checked (general, cervical, thoracolumbar or post op). 84 (27%) suggested spinal cord monitoring be utilized; 142 (45%) suggested cervical spine precautions; 98 (30%) suggested thoracolumbar precautions; and 145 (46%) required special post operative evaluation. No patient had spinal cord injury in the period of study. 35% of precautions forms were filled out separately from any billable consultation by orthopaedics or neurosurgery staff. Estimates for the program including

evaluation, time, inconvenience for families and pro fees are \$9M over 10 years. This cost is similar to a lifetime cost of a single cervical spine injury (\$3.5M to \$9M).

## Conclusion

The SAR program is effective in identifying surgical patients who require extra attention to prevent spinal cord injury. Clinical and cost-benefit analyses are being performed. Despite automated EMR identification, large amounts of uncompensated work, particularly by neurosurgical and orthopedic staff is required.

## Significance

The estimated cost of a single avoidable spine injury is similar to the cost of SAR over 10 years. Practical concerns when implementing safety programs need further considerations.

The image shows a screenshot of a web-based form titled "Spinal Cord at Risk Spine Team Recommendations". The form is intended to be completed by the Spine Risk Team. It is divided into several sections:

- Primary Service for Precautions:** Includes checkboxes for "Neurosurgeon" (checked) and "Orthopedic".
- Patient's Clinical Description:** A large empty text box.
- Pre & Intraoperative Recommendations:**
  - General Recommendations:** Includes checkboxes for "No special precautions needed - standard positioning and care", "Spinal cord monitoring for anesthetized procedures greater than 45 minutes", and "Avoid multiple position involving transfers under single anesthetic if possible".
  - Cervical Spine Precautions:** Includes checkboxes for "Cervical collar on when in hospital wherever possible", "Fiberoptic intubation", "Avoid neck flexion and forward translation", "Avoid neck extension and posterior translation", "Avoid neck rotation", "Sandbags on side of head", and "Elevate chest/theta on pad to avoid flexion/extension translation of skull".
  - Thoracic and Lumbar Spine Precautions:** Includes checkboxes for "Avoid thoracic/lumbar extension", "Avoid thoracic/lumbar flexion", and "Avoid thoracic/lumbar rotation".
- Post Operative Recommendations:** Includes checkboxes for "No spinal or epidural anesthetic given until 8 hours postop and documented normal neurological exam", "Anesthetic plan allows for rapid emergence to allow neurological exam in recovery room within 1 hour", and "Nursing orders in PADU to provide for awakening to level of consciousness that allows good neurological exam by surgical team before extubation".

Figure 1: Spine at Risk Precaution Form

# Safety and Efficacy of Reconstruction of the Unstable Sternoclavicular Joint: A Case Series of 12 Patients

Andrew J. Pastor, MD, Yaw D. Boachie-Adjei, MD, and Winston J. Warne, MD

## Introduction

Injuries to the sternoclavicular joint are very uncommonly seen in the majority of orthopaedic practices. The incidence of injuries to the sternoclavicular joint ranges between 0.5 and 3% of injuries to the shoulder complex<sup>1,2</sup>. Pathology of the SC joint can range from degenerative changes to ligament sprains to frank dislocations and medial clavicle fracture/dislocations. In this paper, we will focus on injuries leading to instability.

The sternoclavicular joint is the only true articulation between the axial skeleton and upper extremity. It is a diarthrodial joint with very little bony congruity. With less than half of the medial clavicle articulating with the sternum, the SC joint has the least amount of bony stability of any major joint in the body<sup>3</sup>. The integrity of the joint is almost solely reliant on its surrounding ligaments; the intra-articular disk ligament, the costoclavicular ligament, the capsular ligament, and the interclavicular ligament<sup>3</sup>. Despite its lack of bony stability, the strong ligamentous structures make the SC joint one of the least dislocated joints in the body.

Instability of the sternoclavicular joint is secondary to insufficiency of the ligamentous structures surrounding the joint, especially the capsular ligament, which is the most important ligament in preventing upward displacement of the medial clavicle<sup>4</sup> and anterior/posterior translation<sup>5</sup>. Injury can result from either direct or indirect force, with indirect

being the most common, leading to anterior or posterior dislocation of the medial clavicle or a fracture/dislocation through the medial clavicle physis. The most common mechanism of injury is from motor vehicle accidents followed by participation in sports<sup>6-8</sup>.

The symptoms of anterior instability include pain and late degenerative changes, where the sequelae of posterior injuries can include pain in addition to neurovascular complications. Historically, a majority of these injuries have been treated nonoperatively, due to the risk of surgical complications, which range from loss of reduction to fatalities secondary to migrating pins<sup>6,10-14</sup>. Soft tissues techniques have been developed that offer the ability to stabilize the sternoclavicular joint without the risk of catastrophic complications. Secondary to a high rate of unsatisfactory outcomes with nonoperative treatment in our patients, we have been offering surgical reconstruction of these injuries in patients who fail nonoperative treatment, using a previously described technique<sup>15</sup> that reduces the risk of injury to the posterior neurovascular structures.

The purpose of this study to is illustrate that operative treatment of sternoclavicular joint injuries can result in greatly improved clinical function with a low complication rate.

## Methods

We conducted a retrospective review of patients that were surgically treated

for sternoclavicular joint instability by the senior surgeon, Winston J. Warne, MD. Our goals were to evaluate the outcome and complication rate in this patient population. Inclusion criteria included all patients who underwent a primary reconstruction of the sternoclavicular joint with semitendinosus allograft or an open reduction and internal fixation of a medial clavicle physeal fracture/dislocation by the senior author. The analysis excluded patients who were lost to follow-up before clinical follow-up a minimum of 2 years from surgery.

A total of 12 patients met the inclusion criteria. All patients underwent a course of nonoperative treatment prior to being considered for surgical reconstruction, except for the fracture / dislocation patient. Demographic data collected for each patient included age, sex, and indications for surgery. The primary clinical outcome measures were the change from preoperative to postoperative Single Assessment Numeric Evaluation (SANE) rating and Simple Shoulder Test (SST) score. The secondary outcome measure was the complication rate.

## Surgical Technique

The surgical technique depended on the type of pathology encountered. The majority of cases required an anterior reconstruction. Additional patients required an anterior and posterior reconstruction with a semitendinosus allograft or a medial clavicle fracture/dislocation open reduction and internal fixation with nonabsorbable suture



Figure 1: Pre- and Postoperative SANE Scores.

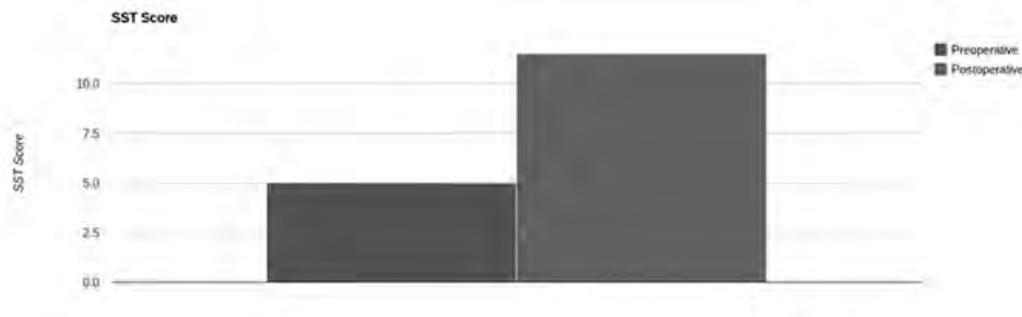


Figure 2: Pre- and Postoperative SST Scores.

through bone tunnels.

The senior author's preferred technique has been written about previously<sup>15</sup>. In an effort to increase safety, the senior author developed a method to reconstruct posterior or anterior SC dislocations using a posterior cruciate ligament drill guide. This technique provides controlled drilling of the sternum and medial clavicle, and therefore reduces the risk of iatrogenic injury to the anatomic structures that are found in the upper mediastinum. This technique has been used in a series of patients with anterior or posterior SC instability and does not increase the operative time nor does it require additional training.

### Outcome Measures

Each patient completed the SANE and SST questionnaires in the preoperative period and at the time of final followup.

### I/MPI

We utilized the I/MPI (improvement/maximal possible improvement), described in a previous manuscript from this institution<sup>16</sup>, which is shown below, to assess the clinical outcomes.

$$\frac{(\text{score at the time of follow-up} - \text{score before surgery})}{(\text{perfect score} - \text{score before surgery})}$$

For purposes of this analysis, we defined the minimal clinically important difference (MCID) as an improvement of 30% of the total improvement possible<sup>17</sup>.

### Statistical Analysis

Statistical analysis was carried out using the statistical language R using the software RStudio (Boston,

MA). The means, medians, and standard deviations were calculated and tabulated. The Welch Two sample t-test, a statistical hypothesis test, was used to assess if the difference in the pre- and postoperative outcome measures were statistically significant.

### Results

12 patients were included in this study. The study included 7 men and 5 women with an average age of 37 years (range 17-62) at the time of surgery. The average followup was 36 months (range 26-52). The indications for surgery included anterior instability (9), posterior instability (2), and medial clavicle physeal fracture/dislocation (1).

The average preoperative SANE and SST scores were 43 and 5, respectively. All 12 patients showed an improvement in their SANE scores at last followup from a mean of 43 preoperatively to 91 postoperatively ( $p=5e-6$ ), which is illustrated in Figure 1.

The same improvement was seen with regards to the SST scores. The average improvement was from 5.0 to 11.5 ( $p=4.5e-5$ ). The SST scores are illustrated in Figure 2.

The mean I/MPI for the SANE and SST scores were noted to be 80% and 94%, respectively, which is illustrated in Figure 3.

There were no major or minor complications recorded.

### Discussion

The treatment of sternoclavicular joint instability remains a controversial subject in orthopaedics. A major cause of this controversy is the relative infrequency in which these injuries are seen leading to an unfamiliarity for most practicing orthopaedic surgeons. In Kocher and Feagin's study<sup>2</sup> of 3451 alpine skiing injuries, injuries to the sternoclavicular accounted for only

0.5% of all injuries to the shoulder complex. Cave and colleagues<sup>1</sup>, showed a higher percentage of 3% of all shoulder injuries in their series of 1603 injuries to the shoulder girdle. Within these, anterior dislocations are far more common than posterior dislocations. In Nestle and Linscheid's<sup>6</sup> series of 60 patients with sternoclavicular joint dislocations, 57 were noted to be anterior and only 3 posterior.

We believe that the unfamiliarity with this area and the risk of major complications with historical surgical techniques have led surgeons to treat many injuries that may be better suited with operative stabilization with nonoperative means, leading to a less than optimal outcome. We know from experience, that nonoperative treatment of unstable SC joints often leads to continued pain, dysfunction, and degenerative changes in the joint. Unfortunately, no long term followup study on the outcomes of nonoperative treatment of unstable sternoclavicular joints has been performed. The historical techniques mentioned include Kirschner wire and Steinmann pin fixation that have led to devastating complications including migration of pins into the heart, pulmonary artery, subclavian artery, and the aorta<sup>12,18,19-25</sup>, and numerous deaths<sup>6,10-14</sup>.

We have opted to reconstruct the SC joint with a semitendinosus tendon in a figure of 8 pattern using the technique described above. Spencer and Kuhn<sup>5</sup> showed in their biomechanical analysis, that this configuration was superior to subclavius reconstruction and an intramedullary ligament reconstruction, which they attributed to the fact that the figure of 8 reconstructs both the anterior and posterior joint capsules.

Due to the relative dearth of sternoclavicular joint injuries, reported series were very small. In a systematic



Figure 3: SANE and SST I/MPI.

review by Thut et al<sup>26</sup>, the largest series was that of 12 patients<sup>27,28</sup>. In 2013, Bak et al from Denmark reported on 27 patients that underwent a minimally open SC joint reconstruction using tendon autograft with at least 2 years followup. Average WOSI scores improved from a median of 44% preoperatively to 75% postoperatively<sup>29</sup> Singer et al reported on their series of 6 patients in Austria who underwent a SC joint reconstruction with gracilis or semitendinosus autograft. All patients returned to full activity without limitation, including competitive contact sports, at a mean followup of 22 months<sup>30</sup> In our series, all patients showed a statistically significant improvement in both SANE and SST scores at the final evaluation of 3 years. What we found to be most significant, was the SST I/MPI score of 94%, which is well over the minimal important clinical difference of 30%. With operative stabilization, these patients were able to return to near perfect self-assessed comfort, motion, and function. Consistent with the position of the American Academy of Orthopaedic Surgeons' (AAOS) Guideline and Evidence Report on "The Treatment of Glenohumeral Joint Osteoarthritis,"<sup>31</sup> we based our study on patient-oriented outcomes rather than on what the AAOS report refers to as "surrogate outcome measures", such as physical signs or radiographic results "used as substitutes for a clinically meaningful end point that measures directly how a patient feels, functions or survives."

The complication rate of soft tissue reconstruction falls far below the reported complications with hardware fixation. In the systematic review by Thut<sup>26</sup>, the only reported complications with soft tissue procedures included two patients with transient scar sensitivity and 2 revisions on one patient. No

neurovascular complications were noted. In the recent study of 27 patients by Bak<sup>29</sup>, the only complications included donor site morbidity and some discomfort at followup. No surgical complications were noted in a study of 6 patients by Guan et al<sup>32</sup> treated with a SCJ reconstruction with a soft tissue graft. We noted no major or minor complications in our study utilizing the previously described technique. With this technique, the drilling of bone tunnels through the medial clavicle and manubrium are controlled with the PCL guide, greatly minimizing the possibility of damage to mediastinal structures.

There are several limitations to this study. Firstly, the retrospective nature of this study is a known limitation. Secondly, the small sample size may limit our ability to extrapolate our results to a larger population. However, as stated earlier, these injuries are rare and documentation of the operative outcomes as rarer still.

### Conclusion

SC joint instability is rarely encountered by orthopaedic surgeons, and the proximity to "tiger country" is somewhat daunting. The senior author's experience and surgical technique has made safe operative management practical and reproducible. We have documented significant improvement in both SST and SANE scores in our series of postoperative patients with 2 year follow up. Treatment of unstable sternoclavicular joints and medial clavicular fracture/dislocations with operative reconstruction yields reliably excellent clinical outcomes with a low complication rate.

Level of Evidence: IV

### References

1. Cave EF. Fractures and Other Injuries. Chicago: Year Book, 1958

2. Kocher MS, Feagin JA Jr. Shoulder injuries during alpine skiing. *Am J Sports Med.* 1996; 24:665-669.

3. Rockwood C.A.; and Matsen F.A.III (eds) *The Shoulder* 4th Edition. W. B. Saunders Philadelphia 2009.

4. Bearn JG. Direct observations on the function of the capsule of the sternoclavicular joint in clavicular support. *J Anat* 101:159-170. 1967

5. Spencer EE, Kuh JE, Huston IL, et al: Ligamentous restraints to anterior and posterior translation of the sternoclavicular joint. *J Shoulder and Elbow Surgery* 11: 43-47, 2002

6. Nettles JL, Lincheid R. Sternoclavicular joint dislocations. *J Trauma* 8: 158-164, 1868

7. Waskowitz WJ: Disruption of the sternoclavicular joint: An analysis and review. *Am J Orthop* 3: 176-179, 1961

8. Omer GE. Osteotomy of the clavicle in surgical reduction of sternoclavicular joint dislocation. *J Trauma* 7:584-590, 1967.

9. Salvatore JE. Sternoclavicular joint dislocation. *Clin Orthop Relat Res* 58: 51.54, 1968.

10. Clark RL, Milgram JW, Yawn DH. Fatal aortic perforation and cardiac tamponade due to a Kirchner wire migration from the right sternoclavicular joint. *South Med J* 67:316-318, 1974.

11. D Gerlach, SR Wemhöner, S Ogbuihi: [On two cases of fatal heart tamponade due to migration of fracture nails from the sternoclavicular joint. *Z Rechtsmed.* 93:53-60 1984

12. JW Leonard, RW Gifford: Migration of a Kirchner wire from the clavicle into pulmonary artery. *Am J Cardiol.* 16:598-600 1965

13. KM Richman, RD Boutin, LM Vaughan, et al.: Tophaceous pseudogout of the sternoclavicular joint. *AJR Am J Roentgenol.* 172:1587-1589 1999

14. FM Smolle-Juettner, PH Hofer, H

- Pinter, et al.: Intracardiac malpositioning of a sternoclavicular fixation wire. *J Orthop Trauma*. 6:102-105 1992
15. Winston J. Warme, MD and Anastasios Papadonikolakis, MD The Use of a PCL Drill Guide to Increase Safety in the Reconstruction of Unstable Sternoclavicular Joints *Tech Should Surg* 2012;13: 142–144
  16. Gilmer BB, Comstock BA, Jette JL, Warme WJ, Jackins SE, Matsen FA. The prognosis for improvement in comfort and function after the ream-and-run arthroplasty for glenohumeral arthritis: an analysis of 176 consecutive cases. *J Bone Joint Surg Am*. 2012 Jul 18;94(14):e102. doi: 10.2106/JBJS.K.00486.
  17. Dworkin RH, Turk DC, McDermott MP, Peirce-Sandner S, Burke LB, Cowan P, Farrar JT, Hertz S, Raja SN, Rappaport BA, Rauschkolb C, Sampaio C. Interpreting the clinical importance of group differences in chronic pain clinical trials: IMMPACT recommendations. *Pain*. 2009;146:238-44.
  18. JE Brown: Anterior sternoclavicular dislocation—a method of repair. *Am J Orthop*.31:184-189 1961
  19. JW Pate, J Wilhite: Migration of a foreign body from the sternoclavicular joint to the heart: A case report. *Am Surg*. 35:448-449 1969
  20. I Nordback, H Markkula: Migration of Kirschner pin from clavicle into ascending aorta. *Acta Chir Scand*. 151:177-179 1985 3890437
  21. V Jelesijevic, D Knoll, F Klinke, et al.: Penetrating injuries of the heart and intrapericardial blood vessels caused by migration of a Kirschner pin after osteosynthesis. *Acta Chir Iugosl*. 29:274 1982 6762027
  22. HP Liu, CH Chang, PJ Lin, et al.: Migration of Kirschner wire for the right sternoclavicular joint into the main pulmonary artery: A case report. *Chang Gung Med J*. 15:49-53 1992.
  23. Rubenstein ZR, Moray B, Itzchak Y, et al: Percutaneous removal of intravascular foreign bodies. *Cardiovasc Intervent Radiol* 1982; 5: 64-68.
  24. Schechter DC, Gilbert L: Injuries of the heart and great vessels due to pins and needles. *Thorax* 1969; 24: 246-253
  25. Sethi GK, Scott SM: Subclavian artery laceration due to migration of a Hagie pin. *Surgery* 1976; 80: 644-646
  26. Thut D, Hergan D, Dukas A, Day M, Sherman OH. Sternoclavicular joint reconstruction--a systematic review. *Bull NYU Hosp Jt Dis*. 2011;69(2):128-35.
  27. Ferrandez L, Yubero J, Usabiaga J, et al. Sternoclavicular dislocation. Treatment and complications. *Ital J Orthop Traumatol*. 1988 Sep;14(3):349-55.
  28. Rockwood CA, Groh GI, Wirth MA, et al. Resection arthroplasty of the sternoclavicular joint. *J Bone Joint Surg Am*. 1997 Mar;79(3):387-93.
  29. Bak K, Fogh K. Reconstruction of the chronic anterior unstable sternoclavicular joint using a tendon autograft: medium-term to long-term ,follow-up results. *J Shoulder Elbow Surg*. 2013 Jul 10.
  30. Singer G, Ferlic P, Kraus T, Eberl R. Reconstruction of the sternoclavicular joint in active patients with the figure-of-eight technique using hamstrings. *J Shoulder Elbow Surg*. 2013 Jan;22(1):64-9.
  31. Izquierdo R, Voloshin I, Edwards S, Freehill MQ, Stanwood W, Wiater JM, Watters WC 3rd, Goldberg MJ, Keith M, Turkelson CM, Wies JL, Anderson S, Boyer K, Raymond L, Sluka P. American Academy of Orthopedic Surgeons. Treatment of glenohumeral osteoarthritis. *J Am Acad Orthop Surg*. 2010;18:375-82.
  32. Guan JJ, Wolf BR. Reconstruction for anterior sternoclavicular joint dislocation and instability. *J Shoulder Elbow Surg*. 2013 Jun;22(6):775-81.

# Case Report: Acute Total Hip Arthroplasty as Treatment for Intertrochanteric Hip Fracture in the Setting of End-Stage Arthritis

Conor P. Kleweno, MD

**G**eriatric intertrochanteric hip fracture in the setting of end-stage arthritis is a rare occurrence. Acute total hip arthroplasty with a diaphyseal press-fit stem is an option with advantages of early mobilization with minimal pain, full weight bearing and treatment of both conditions. This strategy might be preferential in select geriatric patients with an intertrochanteric hip fracture and severe pre-existing arthritis.

## Background

Geriatric hip fractures are common and the incidence is increasing (1). Intertrochanteric fractures are a frequent pattern and standard treatment remains sliding hip screw and side plate or cephalomedullary nail. Acute arthroplasty is not generally utilized given that, unlike displaced femoral neck fractures, the blood supply to the femoral neck and head remain intact. In addition, part or all of the hip abductors are involved in the fracture and a more complex revision-style femoral component would be required. Previous studies have not demonstrated a superiority of acute arthroplasty compared with open reduction and internal fixation for standard intertrochanteric hip fractures in the geriatric population (2-8). However, the treatment of these fractures in the setting of severe arthritis presents a more rare clinical problem.

## Case Description

The patient is a 79 year-old female who had a mechanical ground level fall, slipping on icy cement, and sustained a left three-part intertrochanteric hip fracture (OTA type 31-A2). At baseline she was a community ambulator with cane assistance due to pain in her left hip. Of note she had an ipsilateral acetabular fracture 10 years prior treated non-operatively that had a history of severe arthritis (post-traumatic versus primary osteoarthritis), which has been getting substantially

worse and limiting her activities of daily living. She was hoping to undergo elective hip replacement in the near future although this had been delayed due to personal reasons. She was seen and evaluated at an outside hospital and transferred to Harborview Medical Center due to complexity of injury.

## Physical Findings of Left Lower Extremity

The patient had intact skin on the lateral hip and diffuse tenderness to palpation. No tenderness to palpation throughout the knee, ankles, toes. Her neurologic exam of her left lower extremity revealed 4/5 strength in hip flexion, knee extension, ankle dorsiflexion, ankle plantar flexion, great toe extension and flexion (all limited by pain). Sensation was intact in superficial peroneal, deep peroneal, sural, saphenous, and tibial nerve distributions. The dorsalis pedis and posterior tibial pulses were palpable.



Figure 1a (top) and 1b (bottom): AP pelvis and AP hip demonstrating left intertrochanteric hip fracture and pre-existing severe arthritis.

## Imaging

Figures 1a and 1b demonstrate a displaced three-part intertrochanteric left hip fracture (OTA type 31-A2). Although difficult to visualize, there was a fracture of the posterior medial cortex. There is obvious pre-existing severe arthritis with obliteration of the joint space, subchondral sclerosis, and multiple subchondral cysts. Of note, the patient had had an acetabular fracture 10 years prior treated non-operatively and led to a dysmorphic acetabulum.

## Results

The patient was counseled regarding the nature of her injury and that standard treatment for this was open reduction and internal fixation with cephalomedullary nail or sliding hip screw with side plate. Given her severe arthritis she was offered the alternative treatment of acute total hip arthroplasty. After discussion of the risks and benefits of each option, she elected to proceed with acute hip arthroplasty.

## Surgical Technique

A press-fit acetabular component and fully-coated modular revision press-fit stem were pre-operatively templated. A standard posterior approach to the hip was utilized. The intertrochanteric fracture was exposed and the femoral neck cut was made sparing the fractured fragment of cranial greater trochanter. In addition, we noted the fracture of the posteromedial aspect of the proximal femur. The acetabulum was reamed in the standard fashion up to 53mm with good evidence on inspection of bleeding bone throughout the acetabulum and press-fit a size 54mm acetabular component, verifying our cup position. Two screws were placed up into the intact ilium for additional stability and rotational control. Of note, the acetabular component needed to be placed more cranial than normal due to the abnormal acetabulum from previous acetabular fracture.



Figure 2: Immediate post-operative AP pelvis.

The femur was prepared in the standard fashion, reaming up to a size 21mm diameter. A fully-coated stem of diameter 21mm was placed, verifying on x-ray this was centered in the AP and lateral views. We then reamed proximally and tested the proximal stem and determined the degree of anteversion necessary for appropriate hip stability. Once we were satisfied with our trial, we then placed the final components; the head size was 36mm. The final construct was stable on provocative maneuvers of the hip, except at the very extremes of the hip flexion, internal rotation and adduction. We then verified on x-rays that our components were in

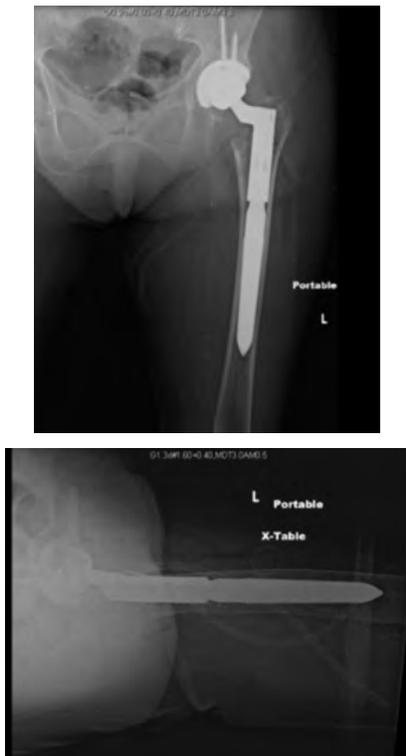


Figure 3: Immediate post-operative AP and lateral hip.

satisfactory alignment and that there was no distal fracture created during placement of the stem.

At this point, we turned our attention to the greater trochanteric fracture. We reduced this fragment with two pointed reduction clamps. Then, using drill holes, we passed four #1 Ticron™ sutures through the fracture greater trochanter and then tied this down to both the intact femur and our capsule.

A standard layered closure over hemovac drain was performed. Post-operatively she was made weight bearing as tolerated with posterior hip precautions. Immediate post-operative films are shown (Figure 2 and 3).

### Outcome

By post-operative day two, the patient reported less pain in her hip than pre-injury. She was discharged to a skilled nursing recovery from the hospital. At 3-month follow-up the patient was able to walk 200 feet with cane assistance and had no pain in her hip. Radiographs (Figure 4) show maintained position of implant with no evidence of subsidence or loosening.

### Discussion

This case is an example of an intertrochanteric hip fracture in a geriatric patient with severe pre-existing arthritis treated with acute hip arthroplasty. Although it is frequently the treatment of femoral neck fractures in this age group, acute hip replacement for intertrochanteric hip fractures is

rarely indicated and open reduction, internal fixation remains standard of care. However, as the geriatric population continues to increase, the situation as described above might become more common. For select geriatric patients with intertrochanteric hip fracture and severe pre-existing hip arthritis, treatment with acute hip arthroplasty should be considered.

### References

1. Kaplan K et al. Surgical Management of Hip Fractures: An Evidence-based Review of the Literature. II: Intertrochanteric Fractures. *J Am Acad Orthop Surg* 2008;16:665-673
2. Kim SY, Kim YG, Hwang JK: Cementless calcar-replacement hemiarthroplasty compared with intramedullary fixation of unstable intertrochanteric fractures: A prospective, randomized study. *J Bone Joint Surg Am* 2005;87:2186-2192.
3. Stappaerts KH, Deldycke J, Broos PL, Staes FF, Rommens PM, Claes P: Treatment of unstable peritrochanteric fractures in elderly patients with a compression hip screw or with the Vandeputte (VDP) endoprosthesis: A prospective randomized study. *J Orthop Trauma* 1995;9:292-297.
4. Haentjens P, Casteleyn PP, De Boeck H, Handelberg F, Opdecam P: Treatment of unstable intertrochanteric and subtrochanteric fractures in elderly patients: Primary bipolar arthroplasty compared with internal fixation. *J Bone Joint Surg Am* 1989;71:1214-1225.
5. Chan KC, Gill GS: Cemented hemiarthroplasties for elderly patients with intertrochanteric fractures. *Clin Orthop Relat Res* 2000;371:206-215.
6. Rodop O, Kiral A, Kaplan H, Akmaz I: Primary bipolar hemiprosthesis for unstable intertrochanteric fractures. *Int Orthop* 2002;26:233-237.
7. Harwin SF, Stern RE, Kulick RG: Primary Bateman-Leinbach bipolar prosthetic replacement of the hip in the treatment of unstable intertrochanteric fractures in the elderly. *Orthopedics* 1990;13:1131-1136.
8. Berend KR, Hanna J, Smith TM, Mallory TH, Lombardi AV: Acute hip arthroplasty for the treatment of intertrochanteric fractures in the elderly. *J Surg Orthop Adv* 2005;14:185-189.



Figure 4: AP hip 3 months post-operative.

# Harborview Medical Center Orthopaedics

## Departmental Changes

“Nothing endures but change.”  
--Heraclitus

It would be difficult to look back on the past academic year without focusing on the considerable faculty-related changes that have occurred within Harborview Orthopaedics.

We are privileged to have had several new faculty join us for the 2013-14 academic year. Conor Kleweno, MD has completed an orthopaedic trauma fellowship at the University of Maryland's world-renowned R Adams Cowley Shock-Trauma Center after having done his orthopaedic surgery residency within the Harvard Combined Orthopaedic Residency Program. Tania Ferguson, MD came to us from her position as attending surgeon at the University of California, Davis, and Keith Mayo, MD has re-entered the world of academic surgery by moving his practice a few miles north to Harborview from Tacoma, to assume a leadership position in the Hansjörg Wyss Hip Institute. All three are part of the orthopaedic trauma and pelvis/acetabular teams.

Unfortunately, last May we parted ways with another valuable colleague, Jim Krieg, MD. Dr. Krieg accepted a leadership position in orthopaedic trauma at Jefferson University's Rothman Institute, where he has already been thriving. Dr. Krieg's clinical expertise and teaching have been sorely missed, and we wish him all the best in his new career path.

These faculty changes been accompanied by modifications in the structure and personnel of Harborview Orthopaedics' leadership. At the beginning of the academic year, Bruce Sangeorzan, MD chose to step down after approximately 20 successful years as Chief of Orthopaedics at Harborview Medical Center, an unprecedented record of longevity and productivity that is unlikely to be matched. Both the institution and the faculty owe Dr. Sangeorzan an enormous debt of gratitude for his stewardship of Harborview Orthopaedics during an era that witnessed a sea-change in the delivery of orthopaedic trauma care, in Harborview's impact on elective



orthopaedic subspecialty care within our community, and in how training programs in general are conducted.

Dr. Chapman was gracious enough to temporarily take on the challenge of shouldering Dr. Sangeorzan's previous responsibilities, which he was willing to do in addition to his already substantial commitments as Department Chair. He was particularly instrumental in implementing the various faculty changes described above. He has since chosen to lessen his administrative burden and focus on his clinical practice. We remain eminently thankful to Dr. Chapman for his leadership during this transition process.

With the increasing size and complexity of our clinical service, we have created several leadership positions to assist the Chief of Service in overseeing the administration of Harborview Orthopaedics. Sean Nork, MD, has been appointed the Trauma Section Chief, in recognition of his invaluable leadership talents and clinical contributions to our largest and most complex sub-specialty service. We are also fortunate that Lisa Taitsman, MD has accepted the position of Orthopaedic Trauma Clinic Director. In an environment of increasing challenges and regulation in both the inpatient and outpatient clinical realms, not the least of which has involved our recent implementation of the EPIC medical records system, we are grateful for the energy and organizational expertise

that Dr. Taitsman has provided in helping us navigate through this period of uncertainty.

As always, with change comes opportunity, and we look forward to the further evolution of our clinical, education and research enterprise.

## Medical Center

The medical center remains focused on various metrics that are being used to gauge quality of care, and which are becoming increasingly important to the financial viability of the institution. Also, in partnership with our colleagues in other departments and with the medical center's administrators, a renewed commitment to improve cost-effectiveness continues to identify and rectify areas of inefficiency, with the ultimate goal of providing improved and more cost-effective care to our patients.

## Clinical Care

The four subspecialty divisions that comprise Harborview Orthopaedics remained stable overall relative to the previous year. The Trauma Division continues to influence how orthopaedic trauma is approached world-wide, maintaining Harborview's widely regarded status as one of the world's best trauma centers, and has seen the highest growth of all divisions compared to last year. The adult Foot and Ankle Division provides care for musculoskeletal disorders of the foot and ankle and podiatric services for

diabetic foot care and limbs at risk. The Orthopaedic component of the Hand Surgery Division collaborates closely with the Plastic Surgery and General Surgery Departments to provide complex reconstructive treatment of elective as well as traumatic conditions. The Spine Division, which collaborates closely with the Department of Neurological Surgery and the Department of Rehabilitation Medicine, treats the entire spectrum of spine injuries among all patient demographics and continues to be a key resource in the Pacific Northwest.

### **Research**

In addition to approximately 70 retrospective research studies, there are currently a dozen prospective studies in progress within the Orthopaedics Department at Harborview Medical Center. Harborview continues to participate in the Major Extremity Trauma Research Consortium (METRC), a combined civilian and military clinical trial network funded by the Department of Defense, which focuses on severe extremity injury, infection, limb impairment and loss. The prospective studies also include a NIH funded multicenter clinical trial comparing ankle fusion to ankle replacement, which is being done in conjunction with the Puget Sound VA Hospital.

### **Teaching**

Harborview remains the busiest of our growing list of teaching hospitals in the Orthopaedic Department at the University of Washington. Fully 14 orthopaedic residents and more than 10 fellows are distributed among the 4 subspecialty divisions at any given time, in addition to residents and fellows from other departments who rotate through the Spine and Hand Surgery divisions. Teaching opportunities abound, as our trainees are able to choose from approximately a dozen different didactic conferences per week, in addition to the high volume of hands-on teaching that occurs in the operating rooms, inpatient wards and outpatient clinics.

Our faculty remain instrumental in Continuing Medical Education projects world-wide and Harborview continues to host visitors from all over the globe. In the past academic year 60 visitors have come to observe our approach to the treatment of orthopaedic conditions, including neurosurgical colleagues with

an interest in spine. Surgeons world-wide want to know how orthopaedic conditions are being treated at Harborview Medical Center.

Carlo Bellabarba, MD  
Professor  
Harborview Medical Center

# Seattle Children's Hospital Orthopaedics

## Clinical Programs

All Pediatric Orthopedic faculty at Seattle Children's Hospital (SCH) care for both sub-specialty and pediatric trauma conditions. Clinical programs are managed by Continuous Process Improvement (CPI) and a musculoskeletal value stream strategy. Value stream programs include pediatric spine, pediatric upper extremity, pediatric sports, skeletal dysplasia, pediatric tumor, pediatric trauma and pediatric foot. Dedicated value stream work began in 2007 with a focus on maximizing patient access, which improved from 35 days to 6 days, with an increase in clinic visits from 15 to 40,000 per year and the creation of new pediatric specialties (spine, sports, hand, and skeletal dysplasia). Orthopaedic value stream work and "clinical pathways" at Seattle Children's have been recognized nationally at the Pediatric Orthopedic Society of North America (POSNA) and by other pediatric orthopaedic programs such as the du Pont/Nemours Pediatric Orthopedic program.

The SCH Pediatric Orthopedics department has been a leader in providing expanded access at all sites of practice that include Laurelhurst, Bellevue, Mill Creek, and Federal Way. New out-patient facilities are planned in Mill Creek and Federal Way within 3 years. Sports coverage continues to be provided by the SCH Orthopedic Sports Medicine athletic trainers for 10 Seattle public high schools in addition to Inglemoor, Bellevue Christian, Mercer Island, Bainbridge, Foster, Issaquah, Holy Names, Woodinville, and Marysville Pilchuck. Dr. Cammy Mowery continues to provide care and supervision for the Orthopedic Outreach program, which accounts for approximately 1,500 visits per year; and Dr. Nathan Frost (Madigan) has been added as a part-time on-call trauma provider, and Dr. Mark Dales supervises a new weekly fracture clinic. Plans for new pediatric orthopedic faculty are being completed for pediatric foot/deformity and pediatric sports. Future

recruitments are planned for pediatric spine, pediatric trauma, and pediatric hip.

## Education

SCH Pediatric Orthopedics department provides training and education in Pediatric Orthopedics for the University of Washington Department of Orthopedics and Sports Medicine, Madigan Army Medical Center, and Kingsbrook Jewish Hospital of Long Island. Currently four R3 UW orthopedic residents, one R1 UW resident, and two visiting R3/R4 residents from Madigan and Kingsbrook represent the full-time house staff at SCH. Other residents and fellows attending SCH part-time include orthopedic oncology, spine



and hand fellows from the University of Washington. Education is well-defined by the pediatric orthopedic resident curriculum and the ACGME milestone curriculum; and teaching conferences occur 5 days per week with 8 hours of teaching conferences per week. The Pediatric Orthopedic Fellowship program enjoys a new ACGME accreditation and broad clinical exposure to strong pediatric sub-specialties. M&M conferences, directed by Dr. Michael Goldberg, have been expanded to review orthopedic "process" improvements and the goal of the program remains improving safety and quality of care, with an emphasis on resident education and a review of the respective published literature.

## International Education

The Pediatric Orthopedic department has enjoyed an active program for international visiting pediatric orthopedic

surgeons or "visiting scholars" That program, directed by Melanie Miller, has sponsored 15 visitors in 2013, 6 in 2014 (May), and 6 different traveling fellows groups (ASEAN, AOA/JOA, SIGN/Nicaragua, BC Children's Hospital, and APPOS). These visitors typically visited for 1-4 weeks and represented 18 countries.

## Research and Clinical Pathways

Viviana Bompadre has been promoted to Director of Research for the Department of Pediatric Orthopedics. The department continues extensive research efforts, with both clinical research programs and "clinical pathways" established for supracondylar forearm fractures and femur fractures, and scoliosis. Those pathways have implemented AAOS guidelines and now routinely collect outcomes metrics for review. Dr. Michael Goldberg has pioneered this work, which includes both resident and faculty attestations for treated patients. The department has also participated in several national prospective protocols for scoliosis (Dr. Krengel), club foot bracing (Dr. Mosca), and an international Biomechanical study in the evaluation and treatment of Mucopolysaccharidoses (Dr. White). Other projects include several studies in spine patients (Dr. Krengel), intraoperative navigation for orthopedic oncology (Dr. Conrad), the re-evaluation of the incidence of pediatric trauma via the pediatric trauma registry (Dr. Dales/Dr. Lindberg), the multiple concussion studies in high school athletes (Dr. Jinguji), and the effectiveness of post-operative physical therapy (Dr. Schmale). The first clinical pathway data regarding the treatment of the supracondylar elbow fractures was presented by Dr. Steinman at this year's POSNA annual meeting.

Ernest U. Conrad III, MD  
Director of Pediatric Orthopedics  
Seattle Children's Hospital

# University of Washington Medical Center Orthopaedics

## State of the Union: University of Washington Medical Center and Northwest Hospital

The University remains a busy center for tertiary and quaternary orthopaedic care. We have robust programs in spine, upper extremity, sports, tumor and adult reconstruction. In each of these programs the focus is on complex cases that are best handled in an academic center. In fact, our orthopaedic case mix index, a national measure of complexity of care, has continued to increase. We have one of the highest measures of complexity in the University Health Systems Consortium, a group consisting of the nation's premier academic medical centers. Despite this high case mix index our infection and mortality rates remain lower than expected.

This has been a year of constant change. Most significantly, Dr. Michael Lee will be leaving to take a position as Chief of Spine Surgery at the University of Chicago. We all, and particularly his patients, will miss Mike but this represents a wonderful opportunity for him and his family. We will keep Dr. Lee on our mailing list and expect him to return frequently to update us on his career and lecture the residents.



Michael J. Lee, MD



Carol C. Teitz, MD

Another prominent faculty member, John Sack, MD is leaving by virtue of a well-earned retirement. Our hand team recently hosted a spectacular retirement party for John. Peter Stern, MD was the special guest lecturer and the heavy turnout gave many surgeons in our community a chance to pay homage to Dr. Sack and recognize his three decades of contributions to Seattle medicine. Last but certainly not least, Carol Teitz has also announced that she is retiring from clinical care. Dr. Teitz was a pioneering member of our Sports Medicine program and she is a knowledgeable historian of the program. Carol also was responsible for the development of the musculoskeletal curriculum for the School of Medicine. In addition to her clinical work, we will miss her frank insightful comments at our faculty meetings. She will fortunately remain the Associate Dean for Admissions for the UW School of Medicine.

This year of change also involved several faculty that required time off for medical leave, if there was any bright side to these issues, it was the remarkable efforts that were made by their partners to 'hold down the fort' and provide continuity of care for our patients. This laudable behavior is entirely consistent with UW Medicine's "Patients are First" initiative.

We have also gained faculty over the past year. Bruce Twaddle, BHB, FRACS is the Orthopaedic Chief of

our sports program in the new sports medicine clinic at Husky Stadium. He has become very busy with his elective sports practice while continuing to take care of the multiligament injuries at Harborview. On the hand service, Amanda Petersen PA-C moved here from Texas to work with Dr. Jerry Huang. Amanda has quickly become a valued member of the department and the Hand Service. At Northwest Hospital, Navin Fernando, MD is our newest member of the Joint Service. Dr. Fernando has impressed us with his work ethic and skills. In addition he brings institutional knowledge from the Rothman Institute, a high volume total joint center where Navin did his



Bruce C. Twaddle, BHB, FRACS



Peter R. Cavanagh, PhD, DSc

fellowship. Navin's wife Laura Montour, MD is also a physician and is practicing in the UW Neighborhood Clinic System. Finally, we have two new surgeons that will soon join us. We are very excited to have Jason Hsu joining the Shoulder and Elbow Service and Adam Sassoon joining our Total Joint Service. Both Dr. Hsu and Dr. Sassoon are currently fellows at Washington University St. Louis and will be starting in early fall of this year. Jason will be based at the UWMC and Adam at Northwest Hospital.

There are a wide variety of research interests at the University of Washington Medical Center and these are strongly reflected in the publication of this year's research report. Ron Y. Kwon, PhD., the newest member of our Musculoskeletal Systems Biology Lab, secured NIH funding this year for his proposal titled "Muscle Atrophy and Bone Anabolism". Ron studies zebra fish as a model for musculoskeletal development and disease and his work has clearly attracted the interest of our residents as several are working with him and presenting their work at conferences and in journals. The change on the clinical side is mirrored in our research enterprise. Peter Cavanagh, PhD, DSc, holder of the Endowed Chair in Women's Sports Medicine and Lifetime Fitness, has announced that he will also be slowing down and relinquishing his

title of Vice Chair of Research. Our research enterprise will continue to be in good hands under the leadership of Ted Gross, PhD at Harborview, Liu Yang, PhD at the VA, and David Eyre, PhD at UWMC. We also have a burgeoning outcomes research program that is led by Julie Agel, MA at Harborview and Amy Cizik, MPH at UWMC. Finally, Viviana Bompadre, PhD anchors our research group at Seattle Children's Hospital. We have never had greater resident-scientist interaction and collaboration; this has been a boon to our residency and is one of several features that distinguishes the University of Washington from other training programs around the country.

Howard A. Chansky, MD  
Professor and Acting Chair

# VA Puget Sound Orthopaedics

## State of the Union: The Puget Sound Veteran's Administration Medical Center

The Puget Sound Veteran's Administration Medical Center (VA) remains an active and busy orthopaedic surgery practice. We remain a general tertiary care orthopaedic center and we see patients from the entire northwest United States. We see a wide variety of cases, which range from the routine to the complex problems. Despite changes in VA national and local policy, we remain one of the busiest VA orthopaedic programs in the country.

Our University of Washington residents continue to rate the VA rotation as one of their favorites. While closely supervised, they are given graduated responsibility throughout their training at the VA. Our goal at the VA is to train residents that are dedicated to caring for patients with a fairly wide range of challenging orthopaedic problems, and thereby, giving them a strong general orthopaedic surgery foundation to work from.

This year we saw a change in leadership at the VA, with our long-time Chief of Service, Howard Chansky, MD, leaving the position to transition into his new role as the Acting Chairman of the Department of Orthopaedics and Sports Medicine at the University of Washington. In his place, I have

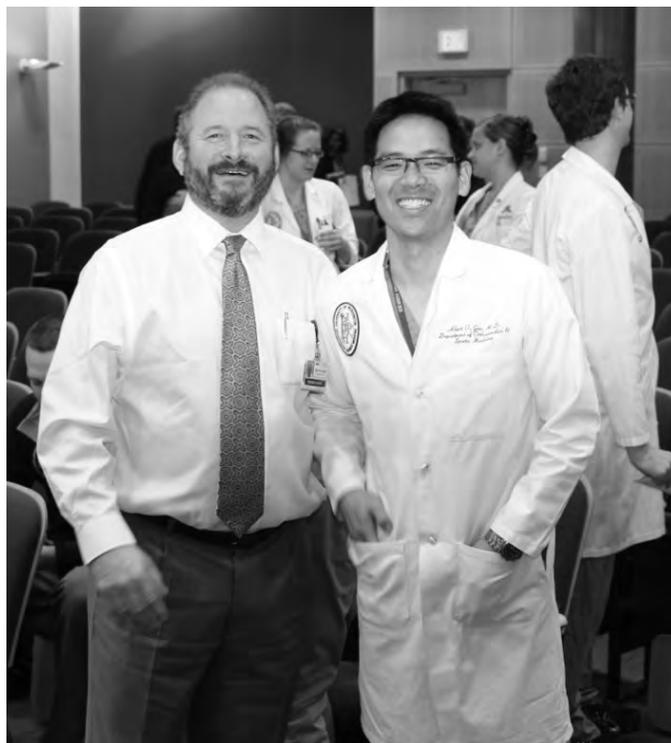
Drs. Howard Chansky and Albert Gee

been serving as the Acting Chief of the Orthopaedic service and doing my best to fill very large shoes.

In a bit of sad news, we bid farewell to Dr. Ted Greenlee this year who retired from clinical practice after a lifetime of service to the VA and its veterans as

well as a long and celebrated practice at the University of Washington. Ted was always willing to help out in any way possible, a great counselor and a good friend and colleague to us all at the VA and we will miss seeing him there. As a celebration of his service, the corner of the surgeons lounge at the VA—where you would often find Ted sitting in his usual spot on one of the two weathered couches from which he would be advising residents, conversing with colleagues and telling old war stories of the good ol' days of orthopaedic surgery—has now been named Greenlee's Corner and a plaque dedicated to him is on display there.

To help fill the void left by Dr. Greenlee and the transition of Dr. Chansky to Acting Chairman, the division has added Dr. Jerry Huang in a part-time role at the VA. He now provides regular hand and upper extremity expertise and care to our Veterans. The other Dr. Huang, Fred Huang, MD who we all know as a former UW orthopaedic resident, continues to be of great service, providing sports and general orthopaedic care on a monthly part-time basis as well. Dr. Bruce Sangeorzan continues to be a stalwart in



VA Puget Sound Health Care System



Dr. Ted Greenlee, pictured here early in his orthopaedic career.

our division, providing ongoing foot and ankle specialty services to the Veterans at the Puget Sound VA. Additionally, we are pleased to announce that Joshua Shatsky, MD, will be joining the orthopaedic staff in the fall. He is a recent graduate of both the Harborview Trauma and Spine Fellowships here at the University of Washington and will be providing subspecialty as well as general orthopaedic services. I am very grateful to all for their contributions and the high quality orthopaedic care they provide to our veterans.

We have the great fortune of having some of the best physician extenders and clinical support staff on our orthopaedic team. Steve Casowitz, PA-C and Dustin Higbee, PA-C are the backbone of our surgical service and Amy Katzenmeyer, ARNP has been a great addition to our service; working in the clinic and helping to manage outpatient musculoskeletal problems. Monette Manio, RN and Katherine German, RN manage all of our surgical scheduling and with a large population of very ill patients of limited means for travel, this can be extremely challenging. They have perhaps the most difficult jobs in the entire VA! Annette Testa, LPN, assists in our outpatient clinics and is an accomplished casting technician and crucial team member.

Cindy Lostoski provides our administrative support and has many roles in assisting patients as well as

the physicians. Assisting Cindy on the administrative side is Lyra Bryant, who has helped Cindy shoulder a very large volume of duties for our busy service.

In the operating room, the orthopaedic service could not function without Anne Dinsmore, RN. Anne is the head orthopaedic nurse and does a wonderful job managing all of the logistics of performing orthopaedic surgery. She navigates the elaborate system of rules governing equipment procurement, setting up for cases and sterile processing of specialized instruments and implants. Our trusted scrub technicians and friends, Leo Cruz, Adrian Sisson and Amy Arce round out our surgical service.

There is an active orthopaedic research program at the VA with extramurally funded programs for Drs. Chansky and Liu Yang in sarcoma and cartilage biology. Dr. Yang and his research team have recently received national recognition for their work on the molecular biology of ESET histone methyltransferase and its effect on bone, cartilage and ligament development at the ORS Meeting in New Orleans. Dr. Sangeorzan continues his dual role as a Foot and Ankle surgeon and the Director of the VA Center for Excellence for Limb Loss Prevention and Prosthetic Engineering. The Center of Excellence research faculty include William Ledoux, PhD and Joseph laquinto, PhD who continue their work on foot and ankle biomechanics. In

addition, several new investigators have joined the biomechanics research team, Patrick Aubin, PhD and Eric Rombokas, PhD. Both are recent graduates of the University of Washington and have interests in robotics, rehabilitation and human performance.

The Medical Center continues to expand in size to address the growing number of veterans that it serves. In addition to the new research building, work has begun on the addition of above and below ground parking facilities. All of this should improve access to and the quality of the medical care for our Veterans and their families.

As you can see, the Puget Sound VA Medical Center remains a very vital part of the medical care provided in the Northwest region of the United States. We are a proud and strong division with a busy clinical practice that strives for excellence in patient care, education and musculoskeletal research with the mission of improving the lives of those who have served our country.

Albert O. Gee, MD  
Acting Chief  
Division of Orthopaedic Surgery  
VA Puget Sound Health Care  
System

## Graduating Residents

---



**Sid Baucom, MD**

Following graduation Sid and his family will be moving to Nashville, Tennessee to begin a Hand and Upper Extremity Fellowship at Vanderbilt University. They plan to return to the Mountain West to begin practice.



**Jacques Hacquebord, MD**

Upon completion of residency, Jacques will pursue a Hand/Micro Fellowship with Dr. Neil Ford Jones at UC Irvine. Following fellowship, Jacques plans to follow Siri, his significant other, to the ends of the earth, i.e. New York City.



**Nathan Coleman, MD**

Following residency, Nathan will complete a sports fellowship at Hospital for Special Surgery in New York City. Nathan and his wife Mabel plan to return to the Mid-Atlantic region.



**Nicholas Iannuzzi, MD**

Following residency, Nick will complete a hand surgery fellowship at the Curtis National Hand Center in Baltimore, MD. He is looking to return to the Northwest to practice hand and general orthopaedic surgery.

## Graduating Residents

---



**Paul Kim, MD**

Following residency, Paul will complete a fellowship in Foot and Ankle Orthopaedics at Hospital for Special Surgery in New York. He and his wife, Linda, and their pug, Lulu, plan to return to Northern California to settle down afterwards to be near their family and friends.



**Nicholas Wegner, MD**

After residency, Nick will move with his family to Salt Lake City to complete a fellowship in Foot and Ankle Surgery at the University of Utah. Upon completion, he plans to practice in either California or the Midwest.



**Ted Sousa, MD**

Following residency, Ted will complete a fellowship in Pediatric Orthopedics at Children's Hospital Los Angeles. He and his wife, Janelle, will then move to Melbourne Australia for an international orthopaedic fellowship.



**David Zeltser, MD**

Following residency, Dave will complete a fellowship in hand surgery at Columbia University in New York City. He plans to pursue career opportunities on the west coast.

## Incoming Residents

---



**Kariline Bringe, MD**

Kariline is from Viroqua, Wisconsin. She attended college at Washington University in St. Louis and medical school at the Mayo Clinic. For orthopaedics, she is interested in “everything.” In her free time, she enjoys traveling, sushi, and musical theatre.



**David Ibrahim, MD**

David Ibrahim is from Tarzana, California. He attended the University of Southern California for both his bachelors and his medical degrees. In orthopaedics, he is interested in trauma, bone healing, sports medicine, joints, and anatomy. Away from orthopaedics, he likes weightlifting, football, movies, traveling, and cycling.



**Romie Gibly, MD**

Romie Gibly joins us from Portland, Oregon. He attended Haverford College in Ardmore, PA and Northwestern University Feinberg School of Medicine in Chicago. He notes his areas of interest as trauma, upper extremity, general orthopaedics, biomaterials and bioengineering. In his spare time, Romie enjoys good food, craft beer, rock climbing, trail running, and building things.



**Colin Kennedy, MD**

A local guy, Colin is from Gig Harbor and attended college at Washington State University in Pullman and medical school at Oregon Health & Science University. He hopes to pursue his interest in hand, trauma, and joints during his time with us in orthopaedics. Away from work, he likes any activity on the water as well as snowboarding, hiking, and basketball.

## Incoming Residents

---



**Lauren Meyer, MD**

From Renton, Washington, Lauren attended Pacific Lutheran University in Tacoma and the University of Washington for medical school. She is interested in sports, pediatrics, and trauma. Away from orthopaedics, she likes anything active and outdoors as well as watching the Seahawks and Sounders.



**Adam Sangeorzan, MD**

Adam Sangeorzan is from Bellevue, Washington. He graduated with his bachelors from the University of Washington and got his medical degree from Northwestern University Feinberg School of Medicine in Chicago. At this time, he is interested in anatomy, trauma, and musculoskeletal oncology. He enjoys running, reading, basketball, and rooting for the Seahawks and Huskies.



**Stuart Michnick, MD**

Stuart Michnick is from Dallas, Texas where he attended the University of Texas and Baylor College of Medicine. In orthopaedics, his primary interests are shoulder and elbow, sports medicine, trauma, and education. He enjoys baseball, tennis, hiking, camping, kayaking, and movies.



**Alan Swenson, MD**

Alan joins us from Anchorage, Alaska. His undergraduate education is from Brigham Young University in Hawaii. His medical education is from the University of Washington School of Medicine. At this time, he is undecided on where he wishes to direct his efforts in orthopaedics. When he has free time, he enjoys the culinary arts, carpentry, motorcycles, surfing, and family time.

# ACEs and Fellows

---



**Sonya Agnew, MD**  
Hand



**Thomas Fishler, MD**  
Trauma



**James Learned, MD**  
Trauma



**Max Berdichevsky, MD**  
Spine



**Jonah Hebert-Davies, MD**  
Trauma



**Milton Little, MD**  
Trauma



**Yaw Boachie-Adjei, MD**  
Shoulder & Elbow



**Daniel Hoopes, MD**  
Foot & Ankle



**Karin Ljungquist, MD**  
Hand



**Maryse Bouchard, MD**  
Pediatrics



**Matthew Iorio, MD**  
Hand



**Joan D. Miles, MD**  
Oncology

# ACEs and Fellows

---



**Vincent Ng, MD**  
Oncology



**Joshua B. Shatsky, MD**  
Trauma



**Andrew Pastor, MD**  
Shoulder & Elbow



**Clay Spitler, MD**  
Trauma



**Viral Patel, MD**  
Spine



**Daniel Thuiller, MD**  
Foot & Ankle



**James Saucedo, MD**  
Hand



**Joan Williams, MD**  
Foot & Ankle

# Research Grants

---

## National Institutes of Health

Aging-Related Degradation in Bone  
Mechanotransduction  
Sundar Srinivasan, PhD  
Ted S. Gross, PhD

Brief Rest Intervals Amplify the Response of Bone  
Mechanical Loading  
Ted S. Gross, PhD  
Steven D. Bain, PhD  
Sundar Srinivasan, PhD

Collagen Assembly in Tissue-Engineered Cartilage  
Russell J. Fernandes, PhD  
Jiann-Jiu Wu, PhD

Collagen Cross-Linking in Skeletal Aging and  
Diseases  
David R. Eyre, PhD  
Jiann-Jiu Wu, PhD

Collagen Diversity and Pathobiology in Skeletal  
Tissues  
David R. Eyre, PhD  
Jiann-Jiu Wu, PhD

Comparing Ankle Arthrodesis to Ankle Arthroplasty  
Bruce J. Sangeorzan, MD

Muscle Atrophy and Bone Anabolism  
Ted S. Gross, PhD  
Steven D. Bain, PhD  
Ronald Y. Kwon, PhD  
Edith M. Gardiner, PhD

Neuronal Modulation of Focal Bone Homeostasis  
Ted S. Gross, PhD  
Steven D. Bain, PhD  
Edith M. Gardiner, PhD  
Ronald Y. Kwon, PhD

## National Space Biomedical Research Institute

Monitoring Bone Health by Daily Load Stimulus  
Measurement During Lunar Missions  
Peter R. Cavanagh, PhD, DSc

## Veterans Affairs Rehabilitation Research and Development Service

Dynamic Foot Bone Motion: Evaluation of  
Reconstructive Procedures  
Bruce J. Sangeorzan, MD

EWS-Fli1 Fusion Protein and Ewing's Sarcoma  
Howard A. Chansky, MD

Foot Bone Motion in End Stage Ankle Arthritis Patients  
Bruce J. Sangeorzan, MD

VA Center of Excellence in Amputation Prevention  
and Prosthetic Engineering  
Bruce J. Sangeorzan, MD

## A.O. Foundation

Quality of Fracture Reduction and Its Influence on  
Functional Outcome in Patients With Pilon Fractures  
Sean E. Nork, MD

5.0 vs. Standard Locking Screws in Fracture of Distal  
Femur Treated with Locked Plate Fixation  
David P. Barei, MD

## A.O. North America

Effect of Riluzole in Patients with Cervical Spondylotic  
Myelopathy Undergoing Surgical Treatment  
Jens R. Chapman, MD

AO North America Orthopaedic Trauma Fellowship  
David P. Barei, MD

AO Spine North America Fellowship  
Carlo Bellabarba, MD

The Role of ESET Histone Methyltransferase  
in Fracture Healing  
Howard A. Chansky, MD

## A.O. Spine International

AO Spine Injury Case Collection  
Carlo Bellabarba, MD

Development of an ICF Core Sets for Spinal Trauma  
Carlo Bellabarba, MD

## American Society for Surgery of the Hand

The Use of Vibration Anesthesia  
Jerry I. Huang, MD  
Jason H. Ko, MD

## Arthrex, Inc.

UW Hand Fellowship Education Grant  
Jerry I. Huang, MD

Biomechanical Evaluation of a Novel Distal  
Biceps Reconstruction with a Cortical Button  
Utilizing Only Anterior Cortical Bone Tunnels  
Jerry I. Huang, MD

## Baylor College of Medicine

Pathogenesis of Novel Forms of Osteogenesis  
Imperfecta  
David R. Eyre, PhD

## Boston Medical Center

Intramedullary Nails versus Plate Fixation  
Re-Evaluation Study in Proximal Tibia Fractures a  
Multi-Center Randomized Trial Comparing Nails and  
Plate Fixation  
Robert P. Dunbar, MD

# Research Grants

---

## **DePuy Spine, Inc.**

DePuy Synthes Grand Rounds  
Richard Bransford, MD

## **DePuy Synthes Trauma Grant**

Biomechanical Assessment of the Dorsal Spanning Plate in Distal Radius Fracture Fixation: Implications for Immediate Weightbearing  
Jerry I. Huang, MD

## **Johns Hopkins University**

The Major Extremity Trauma Research Consortium  
Reza Firoozabadi, M.D.

## **National Science Foundation Extreme Science and Engineering Development Environment (XSEDE)**

Agent-Based Models of Bone Mechanotransduction  
Sundar Srinivasan, PhD

## **OMeGA Medical Grants Association, LLC**

Electronic Milestone Tracking & Resident Competency System  
Douglas P. Hanel, MD

OMeGA Shoulder and Elbow Fellowship Program Grant  
Winston J. Warme, MD

OMeGA Spine Fellowship  
Carlo Bellabarba, MD

OMeGA Trauma Fellowship  
David P. Barei, MD

## **Orthopaedic Research and Education Foundation**

OREF Residency Enhancement Grant  
Douglas P. Hanel, MD

OREF Spine Fellowship  
Carlo Bellabarba, MD

OREF Trauma Fellowship Grant  
David P. Barei, MD

## **Orthopaedic Trauma Association**

A Multi-Center Prospective Cohort Study of Sacral Fractures Using Patient Based and Objective Outcomes  
Jens R. Chapman, MD

COTA Trauma Fellowship  
David P. Barei, MD

## **Royalty Research Fund**

Osteoactive Compound Screening in the Regenerating Zebrafish Fin  
Ronald Y. Kwon, PhD

## **Seattle Children's Hospital**

Do Patient Safety Checklists Improve Patient Safety?  
Suzanne E. Steinman, MD  
Mark C. Dales, MD

## **Synthes USA**

PRODISC-C Versus Anterior Cervical Discectomy and Fusion (ACDF)  
Jens R. Chapman, MD

Spine End-Results Research Fund  
Jens R. Chapman, MD

Synthes Request for Basic AO Course R2s  
Douglas P. Hanel, MD

## **The Boeing Company**

Randomized Clinical Trial of Open versus Endoscopic Carpal Tunnel Release and Hand Therapy Comparing Patient Satisfaction. Functional Outcome and Cost Effectiveness  
Jerry I. Huang, MD

## **US Army Research Office**

Exogenous Blastema Delivery to Injured Human Digits  
Christopher H. Allan, MD

## **UW Department of Bioengineering**

Remote Monitoring of Knee Function after Total Joint Replacement (Coulter Grant)  
Peter R. Cavanagh, PhD, DSc  
Paul A. Manner, MD

## **US Department of Defense**

Engineered Osteoclasts for the Treatment and Prevention of Heterotopic Ossification  
Bruce J. Sangeorzan, MD  
Steven D. Bain, PhD

# Department Publications 2013-2014

A list of publications authored by our faculty from January 2013 through June 2014. Our faculty members names are in **bold type**.

1. Alton TB, **Gee AO**. Classifications in brief: Letournel classification for acetabular fractures. Clin Orthop Relat Res. 2014 Jan;472(1):35-8.
2. Alton TB, Patel AM, **Lee MJ, Chapman JR**. Pediatric cervical spondylolysis and American football. Spine J. 2013 Oct 18.
3. Arnold PM, Fehlings MG, Kopjar B, Yoon ST, Massicotte EM, Vaccaro AR, Brodke DS, Shaffrey CI, Smith JS, Woodard EJ, Banco RJ, **Chapman JR**, Janssen ME, Bono CM, Sasso RC, Dekutoski MB, Gokaslan ZL. Mild diabetes is not a contraindication for surgical decompression in cervical spondylotic myelopathy: results of the AOSpine North America multicenter prospective study (CSM). Spine J. 2014 Jan;14(1):65-72.
4. Ausk BJ, Huber P, **Srinivasan S, Bain SD, Kwon RY**, McNamara EA, Poliachik SL, Sybrowsky CL, **Gross TS**. Metaphyseal and diaphyseal bone loss in the tibia following transient muscle paralysis are spatiotemporally distinct resorption events. Bone. 2013 Dec;57(2):413-22.
5. Barnes AM, Duncan G, Weis M, Paton W, Cabral WA, Mertz EL, Makareeva E, Gambello MJ, Lacbawan FL, Leikin S, Fertala A, **Eyre DR**, Bale SJ, Marini JC. Kuskokwim syndrome, a recessive congenital contracture disorder, extends the phenotype of FKBP10 mutations. Hum Mutat. 2013 Sep;34(9):1279-88.
6. **Beingessner DM**, Scolaro JA, Orec RJ, **Nork SE, Barei DP**. Open reduction and intramedullary stabilisation of subtrochanteric femur fractures: A retrospective study of 56 cases. Injury. 2013 Dec;44(12):1910-5.
7. **Bellabarba C**. Expert's comment concerning Grand Rounds case entitled "Lead toxicity and management of gunshot wounds in the lumbar spine" (by B. Rentfrow, R. Vaidya, C. Elia, A. Sethi doi:10.1007/s00586-013-2805-6). Eur Spine J. 2013 Nov;22(11):2358-9.
8. **Benirschke SK**, Kramer PA. Open reduction and internal fixation of the tibial plafond. Atlas of essential orthopaedic procedures: AAOS; 2013. p. 437-42.
9. **Benirschke SK**, Meinberg EG, Anderson SA, Jones CB, Cole PA. Fractures and dislocations of the midfoot: Lisfranc and Chopart injuries. Instr Course Lect. 2013;62:79-91.
10. Biau DJ, Weiss KR, Bhumbra RS, **Davidson D**, Brown C, Wunder JS, Ferguson PC. Using the CUSUM test to control the proportion of inadequate open biopsies of musculoskeletal tumors. Clin Orthop Relat Res. 2013 Mar;471(3):905-14.
11. Bompadre V, Satchell E, Burton M, Gilbert K, **Conrad E**, Herring S, Jinguji T. The Effect of the Washington State Concussion Law on Documenting Concussion in Seattle Public High Schools. J of Athletic Trainers. 2013.
12. Bugbee WD, Khanna G, Cavallo M, McCauley JC, Gortz S, **Brage ME**. Bipolar Fresh Osteochondral Allografting of the Tibiotalar Joint. The Journal of Bone & Joint Surgery. 2013;95(5):426-32.
13. Callegari A, Coons ML, Ricks JL, Yang HL, **Gross TS**, Huber P, Rosenfeld ME, Scatena M. Bone marrow- or vessel wall-derived osteoprotegerin is sufficient to reduce atherosclerotic lesion size and vascular calcification. Arterioscler Thromb Vasc Biol. 2013 Nov;33(11):2491-500.
14. **Carofino BC, Leopold SS**. Classifications in brief: the Neer classification for proximal humerus fractures. Clin Orthop Relat Res. 2013 Jan;471(1):39-43.
15. **Chapman J**. Spine Wars: The Lessons of YODA. Evid Based Spine Care J. 2013 Oct;4(2):67.
16. **Chapman J**. Measuring success in spine care. Evid Based Spine Care J. 2013 Apr;4(1):1.
17. **Chapman J**. Treating spinal storage diseases with macro data? Evid Based Spine Care J. 2014 Apr;5(1):1.
18. **Chapman J**, Smith JS, Kopjar B, Vaccaro AR, Arnold P, Shaffrey CI, Fehlings MG. The AOSpine North America Geriatric Odontoid Fracture Mortality Study: A Retrospective Review of Mortality Outcomes for Operative versus Non-Operative Treatment in 322 Patients with Long-Term Follow-Up. Spine (Phila Pa 1976). 2013 Jan 24.
19. **Chapman J**, Smith JS, Kopjar B, Vaccaro AR, Arnold P, Shaffrey CI, Fehlings MG. The AOSpine North America Geriatric Odontoid Fracture Mortality Study: a retrospective review of mortality outcomes for operative versus nonoperative treatment of 322 patients with long-term follow-up. Spine (Phila Pa 1976). 2013 Jun 1;38(13):1098-104.
20. Chen MR, Moore TA, Cooperman DR, **Lee MJ**. Anatomic variability of 120 L5 spondylolytic defects. Global Spine J. 2013 Dec;3(4):243-8.
21. Chrea B, Malempati H, Campbell JR, Khan S, Ching RP, **Lee MJ**. Enhancing Pedicle Screw Fixation in the Lumbar Spine Utilizing Allograft Bone Plug Interference Fixation. J Spinal Disord Tech. 2013 Nov 6.
22. Coleman NW, Fleckman P, **Huang JI**. Fungal Nail Infections. J Hand Surg Am. 2014 May;39(5):985-8.
23. Dailey EA, Cizik A, Kasten J, **Chapman JR, Lee MJ**. Risk factors for readmission of orthopaedic surgical patients. J Bone Joint Surg Am. 2013 Jun 5;95(11):1012-9.

24. Eary JF, **Conrad EU**, O'Sullivan J, Hawkins DS, Schuetze SM, O'Sullivan F. Sarcoma mid-therapy [F-18]fluorodeoxyglucose positron emission tomography (FDG PET) and patient outcome. *J Bone Joint Surg Am*. 2014 Jan 15;96(2):152-8.
25. Eastman JG, **Firoozabadi R**, **Benirschke SK**, **Barei DP**, **Dunbar RP**. Entrapped Posteromedial Structures in Pilon Fractures. *J Orthop Trauma*. 2013 Dec 13.
26. **Eyre DR**, Weis MA. Bone Collagen: New Clues to Its Mineralization Mechanism from Recessive Osteogenesis Imperfecta. *Calcif Tissue Int*. 2013 Mar 19.
27. **Firoozabadi R**, Kramer PA, **Benirschke SK**. Technical Trick: Kirschner wire (K-wire) bending. *J Orthop Trauma*. 2013 Mar 19.
28. **Firoozabadi R**, Kramer PA, **Benirschke SK**. Plantar Medial Wounds Associated With Calcaneal Fractures. *Foot Ankle Int*. 2013 Mar 11.
29. **Firoozabadi R**, Kramer PA, **Benirschke SK**. Kirschner wire bending. *J Orthop Trauma*. 2013 Nov;27(11):e260-3.
30. Florczyk SJ, Leung M, Li Z, **Huang JI**, Hopper RA, Zhang M. Evaluation of three-dimensional porous chitosan-alginate scaffolds in rat calvarial defects for bone regeneration applications. *J Biomed Mater Res A*. 2013 Oct;101(10):2974-83.
31. Gebhart S, Alton TB, Bompadre V, **Krengel WF**. Do anchor density or pedicle screw density correlate with short-term outcome measures in adolescent idiopathic scoliosis surgery? *Spine (Phila Pa 1976)*. 2014 Jan 15;39(2):E104-10.
32. **Gee AO**, Angeline ME, Dines JS, Dines DM. Shoulder instability after total shoulder arthroplasty: a case of arthroscopic repair. *Hss J*. 2014 Feb;10(1):88-91.
33. **Gee AO**, Kinsella S, Huffman GR, Sennett BJ, Tjoumakaris FP. Anterior cruciate ligament reconstruction in patients aged > 40 years: a case-control study. *Phys Sportsmed*. 2013 Feb;41(1):30-4.
34. Ghatan AC, **Hanel DP**. Madelung deformity. *J Am Acad Orthop Surg*. 2013 Jun;21(6):372-82.
35. **Goldberg MJ**, Jevsevar D, Bozic KJ. Displaced clavicle fractures in adolescents: facts, controversies, and current trends. *J Am Acad Orthop Surg*. 2013 Apr;21(4):199-200.
36. Grafe I, Yang T, Alexander S, Homan E, Lietman C, Jiang M, Bertin T, Munivez E, Chen Y, Dawson B, Ishikawa Y, Weis M, Sampath T, Ambrose C, **Eyre D**, Bächinger H, Lee B. Excessive transforming growth factor-B signaling is a common mechanism in osteogenesis imperfecta. *Nat Medicine*. 2014.
37. Group WaRISTWS (**Huang JI**). Reflections 1 year into the 21-Center National Institutes of Health-funded WRIST study: a primer on conducting a multicenter clinical trial. *J Hand Surg Am*. 2013;38(6):1194-201.
38. Gruenwald K, Castagnola P, Besio R, Dimori M, Chen Y, Akel NS, Swain FL, Skinner RA, **Eyre DR**, Gaddy D, Suva LJ, Morello R. Sc65 is a novel endoplasmic reticulum protein that regulates bone mass homeostasis. *J Bone Miner Res*. 2014 Mar;29(3):666-75.
39. Gundle KR, Cizik AM, Punt SE, **Conrad EU, 3rd**, **Davidson DJ**. Validation of the SF-6D Health State Utilities Measure in Lower Extremity Sarcoma. *Sarcoma*. 2014;2014:450902.
40. Gupta A, Barei D, Khwaja A, **Beingessner D**. Single-staged Treatment Using a Standardized Protocol Results in Functional Motion in the Majority of Patients With a Terrible Triad Elbow Injury. *Clin Orthop Relat Res*. 2014 Jan 29.
41. Hacquebord J, Cizik AM, Malempati SH, Konodi MA, **Bransford RJ**, **Bellabarba C**, **Chapman J**, **Lee MJ**. Medicaid Status is Associated With Higher Complication Rates After Spine Surgery. *Spine (Phila Pa 1976)*. 2013 Apr 15.
42. Hagen J, **Chansky H**, **Nork SE**, **Taitzman LA**. Salvage of an infected periprosthetic failed fracture fixation in a nonagenarian. *Geriatr Orthop Surg Rehabil*. 2013 Jun;4(2):39-42.
43. **Henley MB**. ICD 10: "what orthopedic surgeons should know, how it will affect them and the cost of implementation?". *Sports Med Arthrosc*. 2013 Sep;21(3):142-7.
44. Homan EP, Lietman C, Grafe I, Lennington J, Morello R, Napierala D, Jiang MM, Munivez EM, Dawson B, Bertin TK, Chen Y, Lua R, Lichtarge O, Hicks J, Weis MA, **Eyre D**, Lee BH. Differential effects of collagen prolyl 3-hydroxylation on skeletal tissues. *PLoS Genet*. 2014 Jan;10(1):e1004121.
45. Hrabe NW, Heini P, Bordia RK, Korner C, **Fernandes RJ**. Maintenance of a bone collagen phenotype by osteoblast-like cells in 3D periodic porous titanium (Ti-6Al-4 V) structures fabricated by selective electron beam melting. *Connect Tissue Res*. 2013;54(6):351-60.
46. Hsu JW, Kollitz KM, Jegapragasan M, **Huang JI**. Radiographic Evaluation of the Modified Brunelli Technique Versus a Scapholunotriquetral Transosseous Tenodesis Technique for Scapholunate Dissociation. *J Hand Surg Am*. 2014 Apr 25.
47. Hudson DM, **Eyre DR**. Collagen prolyl 3-hydroxylation: a major role for a minor post-translational modification? *Connect Tissue Res*. 2013;54(4-5):245-51.
48. Hudson DM, Werther R, Weis M, **Wu JJ**, **Eyre DR**. Evolutionary Origins of C-Terminal (GPP)n 3-Hydroxyproline Formation in Vertebrate Tendon Collagen. *PLoS One*. 2014;9(4):e93467.
49. Iaquinto JM, Tsai R, Haynor DR, Fassbind MJ, **Sangeorzan BJ**, Ledoux WR. Marker-based validation of a biplane fluoroscopy system for quantifying foot kinematics. *Med Eng Phys*. 2014 Mar;36(3):391-6.
50. Jacobsen CM, Barber LA, Ayturk UM, Roberts HJ, Deal LE, Schwartz MA, Weis M, **Eyre D**, Zurakowski D, Robling AG, Warman ML. Targeting the LRP5 Pathway Improves Bone Properties in a Mouse Model of Osteogenesis Imperfecta. *J Bone Miner Res*. 2014 Feb 12.
51. Jevsevar DS, Brown GA, Jones DL, Matzkin EG, **Manner PA**, Moar P, Schousboe JT, Stovitz S, Sanders JO, Bozic KJ, **Goldberg MJ**, Martin WR, 3rd, Cummins DS, Donnelly P, Woznica A, Gross L. The American Academy of Orthopaedic Surgeons evidence-based guideline on: treatment of osteoarthritis of the knee, 2nd edition. *J Bone Joint Surg Am*. 2013 Oct 16;95(20):1885-6.

52. Juneja SC, Vonica A, Zeiss C, Lezon-Geyda K, Yatsula B, Sell DR, Monnier VM, Lin S, Ardito T, **Eyre D**, Reynolds D, Yao Z, Awad HA, Yu H, Wilson M, Honnons S, Boyce BF, Xing L, Zhang Y, Perkins AS. Deletion of Mecom in mouse results in early-onset spinal deformity and osteopenia. *Bone*. 2014 Mar;60:148-61.
53. Keeney JA, **Leopold SS**. Editor's Spotlight/Take 5: Magnetic resonance imaging of the hip: poor cost utility for treatment of adult patients with hip pain. *Clin Orthop Relat Res*. 2014 Mar;472(3):783-6.
54. **Kennedy SA, Hanel DP**. Complex distal radius fractures. *Orthop Clin North Am*. 2013 Jan;44(1):81-92.
55. Koehler RJ, Amsdell S, Arendt EA, Bisson LJ, Bramen JP, Butler A, Cosgarea AJ, Harner CD, Garrett WE, Olson T, **Warne WJ**, Nicandri GT. The Arthroscopic Surgical Skill Evaluation Tool (ASSET). *Am J Sports Med*. 2013 Apr 2.
56. Koenig L, Schafer M, **Leopold SS**. Editor's spotlight/take 5: How does accounting for worker productivity affect the measured cost-effectiveness of lumbar discectomy? *Clin Orthop Relat Res*. 2014 Apr;472(4):1065-8.
57. Kollitz KM, **Gee AO**. Classifications in Brief: The Herring Lateral Pillar Classification for Legg-Calve-Perthes Disease. *Clin Orthop Relat Res*. 2013 Apr 20.
58. Kollitz KM, Hammert WC, Vedder NB, **Huang JI**. Metacarpal fractures: treatment and complications. *Hand (N Y)*. 2014 Mar;9(1):16-23.
59. Kumar A, Donley B, **Cavanagh PR**. Design of an implant for first metatarsophalangeal hemi-arthroplasty. *Computer methods in biomechanics and biomedical engineering*. 2013 Mar 12.
60. Lachman RS, Burton BK, Clarke LA, Hoffinger S, Ikegawa S, Jin DK, Kano H, Kim OH, Lampe C, Mendelsohn NJ, Shediach R, Tanpaiboon P, **White KK**. Mucopolysaccharidosis IVA (Morquio A syndrome) and VI (Maroteaux-Lamy syndrome): under-recognized and challenging to diagnose. *Skeletal Radiol*. 2014 Mar;43(3):359-69.
61. Langereis EJ, Borgo A, Crushell E, Harmatz PR, van Hasselt PM, Jones SA, Kelly PM, Lampe C, van der Lee JH, Odent T, Sakkars R, Scarpa M, Schaifroth MU, Struijs PA, Valayannopoulos V, **White KK**, Wijburg FA. Treatment of hip dysplasia in patients with mucopolysaccharidosis type I after hematopoietic stem cell transplantation: results of an international consensus procedure. *Orphanet J Rare Dis*. 2013;8:155.
62. Large TM, Alton TB, Patton DJ, **Beingessner D**. Does perioperative systemic infection or fever increase surgical infection risks after internal fixation of femur and tibia fractures in an intensive care polytrauma unit? *J Trauma Acute Care Surg*. 2013 Oct;75(4):664-8.
63. Lawrence BD, Jacobs WB, Norvell DC, Hermsmeyer JT, **Chapman JR**, Brodke DS. Anterior versus posterior approach for treatment of cervical spondylotic myelopathy: a systematic review. *Spine (Phila Pa 1976)*. 2013 Oct 15;38(22 Suppl 1):S173-82.
64. Lawrence BD, Shamji MF, Traynelis VC, Yoon ST, Rhee JM, **Chapman JR**, Brodke DS, Fehlings MG. Surgical management of degenerative cervical myelopathy: a consensus statement. *Spine (Phila Pa 1976)*. 2013 Oct 15;38(22 Suppl 1):S171-2.
65. Lawson KA, Teteak CJ, Gao J, Li N, Hacquebord J, Ghatan A, Zielinska-Kwiatkowska A, Song G, **Chansky HA**, Yang L. ESET histone methyltransferase regulates osteoblastic differentiation of mesenchymal stem cells during postnatal bone development. *FEBS Lett*. 2013 Dec 11;587(24):3961-7.
66. Lawson KA, Teteak CJ, Yang L, **Gee AO, Chansky HA**, Garrity JT, Stoker AM, Cook JL. Analyzing chondrocyte viability: letter to the editor. *Am J Sports Med*. 2013 May;41(5):NP29-30.
67. Lawson KA, Teteak CJ, Zou J, Hacquebord J, Ghatan A, Zielinska-Kwiatkowska A, **Fernandes RJ, Chansky HA**, Yang L. Mesenchyme-specific knockout of ESET histone methyltransferase causes ectopic hypertrophy and terminal differentiation of articular chondrocytes. *J Biol Chem*. 2013 Nov 8;288(45):32119-25.
68. Le Corre S, **Eyre D**, Drummond IA. Modulation of the Secretory Pathway Rescues Zebrafish Polycystic Kidney Disease Pathology. *J Am Soc Nephrol*. 2014 Mar 13.
69. **Lee MJ**. Safety in surgery: the role for registries. *Clin Orthop Relat Res*. 2013 Sep;471(9):2743-5.
70. **Lee MJ**. Quality: a process or an outcome? It's not what you may think. *Clin Orthop Relat Res*. 2013 Apr;471(4):1097-9.
71. **Lee MJ**. Optimizing the safety of surgery, before surgery. *Clin Orthop Relat Res*. 2014 Mar;472(3):809-11.
72. **Lee MJ**. The patient protection and Affordable Care Act: better coverage, worse access. Will it really improve patient safety? *Clin Orthop Relat Res*. 2014 Jan;472(1):32-4.
73. **Lee MJ**. Safety in Surgery and Overall Health: What is the Responsibility of the Patient? *Clin Orthop Relat Res*. 2014 May;472(5):1373-4.
74. **Lee MJ**, Cizik AM, Hamilton D, **Chapman JR**. Predicting surgical site infection after spine surgery: a validated model using a prospective surgical registry. *Spine J*. 2014 Jan 20.
75. **Lee MJ**, Cizik AM, Hamilton D, **Chapman JR**. Predicting medical complications after spine surgery: a validated model using a prospective surgical registry. *Spine J*. 2014 Feb 1;14(2):291-9.
76. **Lee MJ**, Konodi MA, Cizik AM, Weinreich MA, **Bransford RJ, Bellabarba C**, Chapman J. Risk factors for medical complication after cervical spine surgery: a multivariate analysis of 582 patients. *Spine (Phila Pa 1976)*. 2013 Feb 1;38(3):223-8.
77. **Leopold SS**. Editor's Spotlight/Take 5: A Review of Current Fixation Usage and Registry Outcomes in Total Hip Arthroplasty: The Uncemented Paradox [DOI 10.1007/s11999-013-2941-7]. *Clin Orthop Relat Res*. 2013 Apr 30.
78. **Leopold SS**. Editor's Spotlight/Take 5: Orthopaedic Surgeons Frequently Underestimate the Cost of Orthopaedic Implants (DOI 10.1007/s11999-012-2757-x). *Clin Orthop Relat Res*. 2013 Jun;471(6):1741-3.
79. **Leopold SS**. Editorial: duplicate submission and dual publication: what is so wrong with them? *Clin Orthop Relat Res*. 2013 May;471(5):1401-2.

80. **Leopold SS.** Editor's Spotlight/Take 5: Comparative Responsiveness and Minimal Clinically Important Differences for Idiopathic Ulnar Impaction Syndrome (DOI 10.1007/s11999-013-2843-8). *Clin Orthop Relat Res.* 2013 May;471(5):1403-5.
81. **Leopold SS.** Editorial: orthopaedics, advocacy, action. *Clin Orthop Relat Res.* 2013 Apr;471(4):1067-8.
82. **Leopold SS.** Editorial: Research is a team sport: updated authorship guidelines for CORR. *Clin Orthop Relat Res.* 2013 Mar;471(3):701-2.
83. **Leopold SS.** Editor's Spotlight/Take 5: Novel 3-D quantification and classification of cam lesions in patients with femoroacetabular impingement (DOI 10.1007/s11999-012-2693-9). *Clin Orthop Relat Res.* 2013 Feb;471(2):355-7.
84. **Leopold SS.** Editor's Spotlight/Take 5: Prophylactic stabilization for bone metastases, myeloma, or lymphoma: do we need to protect the entire bone? (DOI 10.1007/s11999-012-2656-1). *Clin Orthop Relat Res.* 2013 Mar;471(3):703-5.
85. **Leopold SS.** Editorial: Let's talk about Level IV: The bones of a good retrospective case series. *Clin Orthop Relat Res.* 2013 Feb;471(2):353-4.
86. **Leopold SS.** Editorial: Sharing Some Goals. *Clin Orthop.* 2013;471(2-3).
87. **Leopold SS.** Editor's Spotlight/Take 5: Have Bilateral Total Knee Arthroplasties Become Safer? A Population-Based Trend Analysis. *Clin Orthop.* 2013;471(13-16).
88. **Leopold SS.** Editor's Spotlight/Take 5: Orthopaedic surgeons' knowledge and misconceptions in the identification of intimate partner violence against women. *Clin Orthop.* 2013(471):1069-73.
89. **Leopold SS.** Growth plate alteration precedes cam-type deformity in elite basketball players. *Clin Orthop.* 2013(471):1081-3.
90. **Leopold SS.** Editorial: our enthusiasm for "related research". *Clin Orthop Relat Res.* 2013 Oct;471(10):3069-70.
91. **Leopold SS.** Editorial: Words and meaning in scientific reporting: consecutive, prospective, and significant. *Clin Orthop Relat Res.* 2013 Sep;471(9):2731-2.
92. **Leopold SS.** Editor's Spotlight/Take 5: Conditional survival greater than overall survival at diagnosis for Ewing's and osteosarcoma. *Clin Orthop Relat Res.* 2013 Nov;471(11):3395-7.
93. **Leopold SS.** Editor's Spotlight/Take 5: Nano-ceramic composite scaffolds for bioreactor-based bone engineering. *Clin Orthop Relat Res.* 2013 Aug;471(8):2419-21.
94. **Leopold SS.** Consensus statement from the International Consensus Meeting on Periprosthetic Joint Infection. *Clin Orthop Relat Res.* 2013 Dec;471(12):3731-2.
95. **Leopold SS.** Editor's spotlight/take 5: Growth plate alteration precedes cam-type deformity in elite basketball players. *Clin Orthop.* 2013;471(1081-1083).
96. **Leopold SS.** Editor's Spotlight/Take 5: CT pulmonary angiography after total joint arthroplasty: overdiagnosis and iatrogenic harm? . *Clin Orthop.* 2013;471:2733-6.
97. **Leopold SS.** Editor's spotlight/take 5: Longitudinal urban-rural discrepancies in the US orthopaedic surgeon workforce. 2013;471:3071-3.
98. **Leopold SS.** Editor's Spotlight/Take 5: Death, Taxes, and Trapeziometacarpal Arthrosis. *Clinical Orthopaedics and Related Research-Æ.* 2013;471(12):3734-7.
99. **Leopold SS.** Editorial: We Thank Our Peer Reviewers. *Clin Orthop Relat Res.* 2013;471(12):3733-.
100. **Leopold SS.** Editorial: Clinical Orthopaedics and Related Research: The World's General-Orthopaedic Journal. *Clin Orthop Relat Res.* 2013;471(8):2417-8.
101. **Leopold SS.** Editorial: Paying to Publish - What is Open Access and Why is it Important? *Clin Orthop Relat Res.* 2014 Apr 4.
102. **Leopold SS.** Editorial: Transition from Training to Practice-Is there a Better Way? *Clin Orthop Relat Res.* 2014 May;472(5):1351-2.
103. **Leopold SS.** Editor's Spotlight/Take 5: What are the levels of evidence on which we base decisions for surgical management of lower extremity bone tumors? *Clin Orthop Relat Res.* 2014 Jan;472(1):3-7.
104. **Leopold SS.** Editor's Spotlight/Take 5: Is Changing Hospitals for Revision Total Joint Arthroplasty Associated With More Complications? *Clin Orthop Relat Res.* 2014 Apr 29.
105. **Leopold SS.** Editor's Spotlight/Take 5: Nationwide Inpatient Sample and National Surgical Quality Improvement Program Give Different Results in Hip Fracture Studies. *Clin Orthop Relat Res.* 2014 Apr 8.
106. **Leopold SS.** Editor's Spotlight/Take 5: Mesenchymal Stem Cells in Synovial Fluid Increase After Meniscus Injury. *Clin Orthop Relat Res.* 2014 May;472(5):1353-6.
107. **Leopold SS.** Trust in science. *Clin Orthop Relat Res.* 2014 Apr;472(4):1063-4.
108. **Leopold SS.** Going Far: CORR(R)'s newest affiliated societies. *Clin Orthop Relat Res.* 2014 Mar;472(3):781-2.
109. **Leopold SS.** Editor's spotlight/take 5: How does accounting for worker productivity affect the measured cost-effectiveness of lumbar discectomy? *Clin Orthop.* 2014;472:1065-8.
110. **Leopold SS.** Editor's Spotlight/Take 5: Osteogenic Gene Expression Correlates With Development of Heterotopic Ossification in War Wounds. *Clinical Orthopaedics and Related Research-Æ.* 2014;472(2):393-5.

111. **Leopold SS.** Editorial: Proceedings and Symposia in CORR: What They Are, and Why We Publish Them. *Clin Orthop Relat Res.* 2014;472(1):1-2.
112. **Leopold SS,** Beadling L, Dobbs MB, Gebhardt MC, Lotke PA, **Manner PA,** Rimnac CM, Wongworawat MD. Fairness to all: gender and sex in scientific reporting. *Clin Orthop Relat Res.* 2014 Feb;472(2):391-2.
113. **Leopold SS,** Beadling L, Dobbs MB, Gebhardt MC, Lotke PA, Rimnac CM, Wongworawat MD. Active management of financial conflicts of interest on the Editorial Board of CORR. *Clin Orthop Relat Res.* 2013 Nov;471(11):3393-4.
114. **Leopold SS,** Porcher R. Editorial: reporting statistics in abstracts in clinical orthopaedics and related research ((R)). *Clin Orthop Relat Res.* 2013 Jun;471(6):1739-40.
115. Lichstein P, Gehrke T, Lombardi A, Romano C, Stockley I, Babis G, Bialecki J, Bucsi L, Cai X, Cao L, de Beaubien B, Erhardt J, Goodman S, Jiranek W, Keogh P, Lewallen D, **Manner P,** Marczynski W, Mason JB, Mulhall K, Paprosky W, Patel P, Piccaluga F, Polkowski G, Pulido L, Suarez J, Thorey F, Tikhilov R, Velazquez JD, Winkler H. One-stage versus two-stage exchange. *J Orthop Res.* 2014 Jan;32 Suppl 1:S141-6.
116. Lichstein P, Gehrke T, Lombardi A, Romano C, Stockley I, Babis G, Bialecki J, Bucsi L, Cai X, Cao L, de Beaubien B, Erhardt J, Goodman S, Jiranek W, Keogh P, Lewallen D, **Manner P,** Marczynski W, Mason JB, Mulhall K, Paprosky W, Patel P, Piccaluga F, Polkowski G, Pulido L, Suarez J, Thorey F, Tikhilov R, Velazquez JD, Winkler H. One-stage vs two-stage exchange. *J Arthroplasty.* 2014 Feb;29(2 Suppl):108-11.
117. Luszczyc MJ, Blaisdell GY, Wiater BP, **Bellabarba C,** **Chapman JR,** Agel JA, **Bransford RJ.** Traumatic dural tears: what do we know and are they a problem? *Spine J.* 2014 Jan;14(1):49-56.
118. Maddox JJ, Pruitt DR, Agel J, **Bransford RJ.** Unstaged versus staged posterior-only thoracolumbar fusions in deformity: a retrospective comparison of perioperative complications. *Spine J.* 2013 Oct 29.
119. **Manner P.** A spoonful of sugar: commentary on an article by Annette L. Adams, PhD, MPH, et al.: "surgical outcomes of total knee replacement according to diabetes status and glycemic control, 2001 to 2009". *J Bone Joint Surg Am.* 2013 Mar 20;95(6):e371-2.
120. **Manner P.** CORR Insights(R): outcome of one-stage cementless exchange for acute postoperative periprosthetic hip infection. *Clin Orthop Relat Res.* 2013 Oct;471(10):3223-4.
121. Maroto MD, Scolaro JA, **Henley MB,** **Dunbar RP.** Management and incidence of tibial tubercle fractures in bicondylar fractures of the tibial plateau. *Bone Joint J.* 2013 Dec;95-B(12):1697-702.
122. **Matsen FA, 3rd.** CORR Insights(R): Factors that influence the choice to undergo surgery for shoulder and elbow conditions. *Clin Orthop Relat Res.* 2014 Mar;472(3):892-3.
123. **Matsen FA, 3rd,** Butler-Wu S, **Carofino BC,** Jette JL, Bertelsen A, Bumgarner R. Origin of propionibacterium in surgical wounds and evidence-based approach for culturing propionibacterium from surgical sites. *J Bone Joint Surg Am.* 2013 Dec 4;95(23):e1811-7.
124. **Matsen FA, 3rd,** Gupta A. Axillary view: arthritic glenohumeral anatomy and changes after ream and run. *Clin Orthop Relat Res.* 2014 Mar;472(3):894-902.
125. **Matsen FA, 3rd,** Jette JL, Neradilek MB. Demographics of disclosure of conflicts of interest at the 2011 annual meeting of the American Academy of Orthopaedic Surgeons. *J Bone Joint Surg Am.* 2013 Mar 6;95(5):e29.
126. **Matsen FA, 3rd,** Papadonikolakis A. Published evidence demonstrating the causation of glenohumeral chondrolysis by postoperative infusion of local anesthetic via a pain pump. *J Bone Joint Surg Am.* 2013 Jun 19;95(12):1126-34.
127. **Matsen FA, 3rd,** Stephens L, Jette JL, **Warne WJ,** **Huang JI,** Posner KL. The quality of upper extremity orthopedic care in liability claims filed and claims paid. *J Hand Surg Am.* 2014 Jan;39(1):91-9.
128. **Matsen FA, 3rd,** Stephens L, Jette JL, **Warne WJ,** Posner KL. Lessons regarding the safety of orthopaedic patient care: an analysis of four hundred and sixty-four closed malpractice claims. *J Bone Joint Surg Am.* 2013 Feb 20;95(4):e201-8.
129. McAlinden A, Traeger G, Hansen U, Weis MA, Ravindran S, Wirthlin L, **Eyre DR,** **Fernandes RJ.** Molecular properties and fibril ultrastructure of types II and XI collagens in cartilage of mice expressing exclusively the alpha1 (IIA) collagen isoform. *Matrix Biol.* 2013 Oct 7.
130. McElvany MD, McGoldrick E, **Gee AO,** Neradilek MB, **Matsen FA, 3rd.** Rotator Cuff Repair: Published Evidence on Factors Associated With Repair Integrity and Clinical Outcome. *Am J Sports Med.* 2014 Apr 21.
131. Mendelsohn NJ, Wood T, Olson RA, Temme R, Hale S, Zhang H, Read L, **White KK.** Spondyloepiphyseal dysplasias and bilateral legg-calve-perthes disease: diagnostic considerations for mucopolysaccharidoses. *JIMD Rep.* 2013;11:125-32.
132. Miller AN, **Beingessner DM.** Intra-articular distal humerus fractures. *Orthop Clin North Am.* 2013 Jan;44(1):35-45.
133. **Mosca V.** The Foot. In: Morrissy RT and Weinstein SL e, editor. *Lovell and Winter's Pediatric Orthopedics.* 7th ed ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2013. p. 1425-562.
134. **Mosca V.** Principles and Management of Pediatric Foot and Ankle Deformities and Malformations. Philadelphia, PA: Lippincott Williams & Wilkins; 2014.
135. **Mosca VS.** Management of the Painful Adolescent Flatfoot. *Techniques in Foot & Ankle Surgery.* 2014(13):3-13.
136. Ng VY, **Davidson DJ,** Kim EY, Pollack SM, **Conrad III EU,** Jones RL. The multidisciplinary management of giant cell tumor of bone. *Expert Rev Anticancer Ther.* 2014 Mar 26.
137. Nguyen HM, Ruppender N, Zhang X, Brown LG, **Gross TS,** Morrissey C, Gulati R, Vessella RL, Schimmoller F, Aftab DT, Corey E. Cabozantinib inhibits growth of androgen-sensitive and castration-resistant prostate cancer and affects bone remodeling. *PLoS One.* 2013;8(10):e78881.

138. O'Brien A, Bompadre V, Hale S, **White KK**. Musculoskeletal Function in Patients With Mucopolysaccharidosis Using the Pediatric Outcomes Data Collection Instrument. *J Pediatr Orthop*. 2014 Mar 4.
139. O'Donnell C, Maertens A, Bompadre V, **Wagner TA, Krengel W, 3rd**. "Comparative Radiation Exposure Using Standard Fluoroscopy Versus Cone Beam CT For Posterior Instrumented Fusion In Adolescent Idiopathic Scoliosis". *Spine (Phila Pa 1976)*. 2014 Apr 11.
140. Papadonikolakis A, Neradilek MB, **Matsen FA, 3rd**. Failure of the glenoid component in anatomic total shoulder arthroplasty: a systematic review of the English-language literature between 2006 and 2012. *J Bone Joint Surg Am*. 2013 Dec 18;95(24):2205-12.
141. Parada SA, Krieg JC, **Benirschke SK, Nork SE**. Bicortical fixation of medial malleolar fractures. *American journal of orthopedics*. 2013 Feb;42(2):90-2.
142. Patel AR, Alton TB, **Bransford RJ, Lee MJ, Bellabarba CB, Chapman JR**. Spinal epidural abscesses: risk factors, medical versus surgical management, a retrospective review of 128 cases. *Spine J*. 2014 Feb 1;14(2):326-30.
143. Pet MA, Ko JH, Friedly JL, Mourad PD, **Smith DG**. Does Targeted Nerve Implantation Reduce Neuroma Pain in Amputees? *Clin Orthop Relat Res*. 2014 Apr 11.
144. Pingel J, Lu Y, Starborg T, Fredberg U, Langberg H, Nedergaard A, Weis M, **Eyre D**, Kjaer M, Kadler KE. 3-D ultrastructure and collagen composition of healthy and overloaded human tendon: evidence of tenocyte and matrix buckling. *J Anat*. 2014 May;224(5):548-55.
145. Rethman MP, Watters W, 3rd, Abt E, Anderson PA, Carroll KC, Evans RP, Futrell HC, Garvin K, Glenn SO, **Goldberg MJ**, Hellstein J, Hewlett A, Kolessar D, Moucha C, RJ OD, Osmon DR, J OT, Rinella A, Steinberg MJ, Martin WR, 3rd, Cummins DS, Song S, Sluka P, Boyer K, Woznica A, Ristic H, Hanson NB. The American Academy of Orthopaedic Surgeons and the American Dental Association clinical practice guideline on the prevention of orthopaedic implant infection in patients undergoing dental procedures. *J Bone Joint Surg Am*. 2013 Apr 17;95(8):745-7.
146. Rhee JM, Shamji MF, Erwin WM, **Bransford RJ**, Yoon ST, Smith JS, Kim HJ, Ely CG, Dettori JR, Patel AA, Kalsi-Ryan S. Nonoperative management of cervical myelopathy: a systematic review. *Spine (Phila Pa 1976)*. 2013 Oct 15;38(22 Suppl 1):S55-67.
147. Roberts TT, Prummer CM, Papalioidis DN, Uhl RL, **Wagner TA**. History of the orthopedic screw. *Orthopedics*. 2013 Jan;36(1):12-4.
148. Roof AC, Jinguji TM, **White KK**. Musculoskeletal screening: developmental dysplasia of the hip. *Pediatr Ann*. 2013 Nov;42(11):229-35.
149. Rubin CT, Seeherman H, Qin Y-X, **Gross TS**. The mechanical consequences of load bearing in the equine third metacarpal across speed and gait: the nonuniform distributions of normal strain, shear strain, and strain energy density. *The FASEB Journal*. 2013;27(5):1887-94.
150. **Schmale G**, Mercer L, Bompadre V. Lack of Benefit of Physiotherapy on Function following Supracondylar Humerus Fracture: A Randomized Controlled Trial. *Journal of Bone and Joint Surgery*. 2013(February).
151. **Schmale GA**. Adolescent knee pain management. *Pediatr Ann*. 2013 Mar;42(3):122-7.
152. **Schmale GA**, Kweon C, **Larson RV**, Bompadre V. High Satisfaction Yet Decreased Activity 4 Years After Transphyseal ACL Reconstruction. *Clin Orthop Relat Res*. 2014 Mar 15.
153. Schwarze U, Cundy T, Pyott SM, Christiansen HE, Hegde MR, Bank RA, Pals G, Ankala A, Conneely K, Seaver L, Yandow SM, Raney E, Babovic-Vuksanovic D, Stoler J, Ben-Neriah Z, Segel R, Lieberman S, Siderius L, Al-Aqeel A, Hannibal M, Hudgins L, McPherson E, Clemens M, Sussman MD, Steiner RD, Mahan J, Smith R, Anyane-Yeboah K, Wynn J, Chong K, Uster T, Aftimos S, Sutton VR, Davis EC, Kim LS, Weis MA, **Eyre D**, Byers PH. Mutations in FKBP10, which result in Bruck syndrome and recessive forms of osteogenesis imperfecta, inhibit the hydroxylation of telopeptide lysines in bone collagen. *Hum Mol Genet*. 2013 Jan 1;22(1):1-17.
154. Smith JS, Kepler CK, Kopjar B, Harrop JS, Arnold P, **Chapman JR**, Fehlings MG, Vaccaro AR, Shaffrey CI. Effect of type II odontoid fracture nonunion on outcome among elderly patients treated without surgery: based on the AOSpine North America geriatric odontoid fracture study. *Spine (Phila Pa 1976)*. 2013 Dec 15;38(26):2240-6.
155. Solanki GA, Martin KW, Theroux MC, Lampe C, **White KK**, Shediak R, Lampe CG, Beck M, Mackenzie WG, Hendriksz CJ, Harmatz PR. Spinal involvement in mucopolysaccharidosis IVA (Morquio-Brailsford or Morquio A syndrome): presentation, diagnosis and management. *J Inher Metab Dis*. 2013 Mar;36(2):339-55.
156. Sousa T, Bompadre V, **White KK**. Musculoskeletal functional outcomes in children with osteogenesis imperfecta: associations with disease severity and pamidronate therapy. *J Pediatr Orthop*. 2014 Jan;34(1):118-22.
157. Squyer E, Stamper DL, Hamilton DT, Sabin JA, **Leopold SS**. Unloader knee braces for osteoarthritis: do patients actually wear them? *Clin Orthop Relat Res*. 2013 Jun;471(6):1982-91.
158. **Srinivasan S**, Threet D, Worton LE, Ausk BJ, **Bain SD, Gardiner EM, Kwon RY, Gross TS**. Distinct cyclosporin a doses are required to enhance bone formation induced by cyclic and rest-inserted loading in the senescent skeleton. *PLoS One*. 2014;9(1):e84868.
159. **Steinman S**, Oishi S, Mills J, Bush P, Wheeler L, Ezaki M. Volar ligament release and distal radial dome osteotomy for the correction of Madelung deformity: long-term follow-up. *J Bone Joint Surg Am*. 2013 Jul 3;95(13):1198-204.
160. Stern PJ, Albanese S, Bostrom M, Day CS, Frick SL, Hopkinson W, Hurwitz S, Kenter K, Kirkpatrick JS, Marsh J, Murthi A, **Taitzman L**, Toolan B, Weber K, Wright R, Derstine P, Edgar L. Orthopaedic Surgery Milestones. *Journal of Graduate Medical Education*. 2013 March 2013;5(1s1):36-58.
161. Telleria JJ, **Gee AO**. Classifications in brief: Paprosky classification of acetabular bone loss. *Clin Orthop Relat Res*. 2013 Nov;471(11):3725-30.
162. Trask DJ, Ledoux WR, Whittaker EC, Roush GC, **Sangeorzan BJ**. Second metatarsal osteotomies for metatarsalgia: a robotic cadaveric study of the effect of osteotomy plane and metatarsal shortening on plantar pressure. *J Orthop Res*. 2014 Mar;32(3):385-93.

163. Traynelis VC, Arnold PM, Fourney DR, **Bransford RJ**, Fischer DJ, Skelly AC. Alternative procedures for the treatment of cervical spondylotic myelopathy: arthroplasty, oblique corpectomy, skip laminectomy: evaluation of comparative effectiveness and safety. *Spine (Phila Pa 1976)*. 2013 Oct 15;38(22 Suppl 1):S210-31.
164. Tsai TL, **Manner PA**, Li WJ. Regulation of mesenchymal stem cell chondrogenesis by glucose through protein kinase C/transforming growth factor signaling. *Osteoarthritis Cartilage*. 2013 Feb;21(2):368-76.
165. Vaudreuil NJ, Ledoux WR, Roush GC, Whittaker EC, **Sangeorzan BJ**. Comparison of transfer sites for flexor digitorum longus in a cadaveric adult acquired flatfoot model. *J Orthop Res*. 2014 Jan;32(1):102-9.
166. von Mehren M, Randall RL, Benjamin RS, Boles S, Bui MM, Casper ES, **Conrad EU, 3rd**, Delaney TF, Ganjoo KN, George S, Gonzalez RJ, Heslin MJ, Kane JM, 3rd, Mayerson J, McGarry SV, Meyer C, O'Donnell RJ, Pappo AS, Paz IB, Pfeifer JD, Riedel RF, Schuetze S, Schupak KD, Schwartz HS, Van Tine BA, Wayne JD, Bergman MA, Sundar H. Soft tissue sarcoma, version 2.2014. *J Natl Compr Canc Netw*. 2014 Apr 1;12(4):473-83.
167. **Warne WJ**. CORR Insights: Surgical Technique: Results of Stabilization of Sternoclavicular Joint Luxations Using a Polydioxanone Envelope Plasty. *Clin Orthop Relat Res*. 2013 Apr 9.
168. **Warne WJ**. CORR Insights(R): Surgical technique: Results of stabilization of sternoclavicular joint luxations using a polydioxanone envelope plasty. *Clin Orthop Relat Res*. 2013 Jul;471(7):2231-2.
169. **White KK**, Sousa T. Mucopolysaccharide disorders in orthopaedic surgery. *J Am Acad Orthop Surg*. 2013 Jan;21(1):12-22.
170. Wood WG, Guy TS, Arora K, **Firoozabadi R**, Kim H, Kukreja J, Pagel PS, Brzezinski M. Posterior glenohumeral joint dislocation: a rare complication of central venous cannulation in a patient undergoing coronary artery surgery. *J Cardiothorac Vasc Anesth*. 2013 Feb;27(1):101-2.
171. Worton LE, Ausk BJ, Downey LM, **Bain SD, Gardiner EM, Srinivasan S, Gross TS, Kwon RY**. Systems-based identification of temporal processing pathways during bone cell mechanotransduction. *PLoS One*. 2013;8(9):e74205.
172. Yang L, Lawson KA, Teteak CJ, Zou J, Hacquebord J, Patterson D, Ghatan AC, Mei Q, Zielinska-Kwiatkowska A, **Bain SD, Fernandes RJ, Chansky HA**. ESET histone methyltransferase is essential to hypertrophic differentiation of growth plate chondrocytes and formation of epiphyseal plates. *Dev Biol*. 2013 May 4.
173. Zeltser DW, **Leopold SS**. Classifications in brief: Schatzker classification of tibial plateau fractures. *Clin Orthop Relat Res*. 2013 Feb;471(2):371-4.

# Alumni

In appreciation of the generous support over the years from the University of Washington Orthopaedic Alumni to fund Orthopaedic Resident Research and Education

## 1952

Park W. Gloyd, MD ★

## 1954

Trygve Forland, MD ★

## 1955

Robert W. Florence, MD

## 1956

J. Michael Egglin, MD ★  
John E. Goeckler, MD  
Robert L. Romano, MD ★

## 1957

John H. Aberle, MD ★★  
John R. Beebe, MD

## 1958

Harry H. Kretzler, Jr., MD ★  
James R. Friend, MD ★  
Kenneth L. Martin, MD ★  
Samuel L. Clifford, MD

## 1959

James W. Tupper, MD

## 1960

Irving Tobin, MD ★  
William V. Smith, MD ★

## 1961

Robert C. Colburn, MD ★

## 1962

Arthur Ratcliffe, MD  
Marr P. Mullen, MD ★★★★★

## 1963

Alfred I. Blue, MD  
Robert A. Kraft, MD

## 1964

David E. Karges, MD ★★★★★  
Harold J. Forney, MD ★★  
Theodore K. Greenlee II, MD  
★★★★★★  
Thomas E. Soderberg, MD

## 1966

F. Richard Convery, MD ★  
Joseph S. Mezistrano, MD ★  
William A. Reilly, Jr., MD

## 1967

Ivar W. Birkeland, MD ★★  
J. Conrad Clifford, MD ★  
Robert F. Smith, MD ★★★★★

## 1968

Lynn T. Staheli, MD ★  
Stewart M. Scham, MD ★★  
William T. Thieme, MD ★★

## 1969

Edward E. Almquist, MD ★★★★★  
Edward L. Lester, MD ★  
Hugh E. Toomey, MD ★★  
Sigvard T. Hansen, Jr., MD  
★★★★★★

## 1970

John C. Brown, MD ★★  
John M. Coletti, Jr., MD ★  
Malcolm B. Madenwald, MD ★★  
Michael T. Phillips, MD ★  
Robert D. Schrock, Jr., MD

## 1971

Bruce E. Bradley, Jr., MD ★  
Franklin G. Alvine, MD ★★★★★  
Jerome H. Zechmann, MD  
Louis A. Roser, MD ★  
Nils Fauchald, Jr., MD

## 1972

David J. LaGasse, MD ★  
David R. Nank, MD ★★  
Donald D. Hubbard, MD ★  
John A. Neufeld, MD ★★  
Thomas L. Gritzka, MD ★

## 1973

Frederick J. Davis, MD ★★  
Larry D. Hull, MD ★  
Robert P. Watkins, Jr., MD ★  
Theodore A. Wagner, MD ★★★★★

## 1974

Richard A. Dimond, MD ★★  
Ronald B.H. Sandler, MD ★★  
Samuel R. Baker, MD ★★  
Robert A. Winqvist, MD ★★★★★

## 1975

Donald L. Plowman, MD ★★  
Frederick A. Matsen III, MD  
★★★★★★  
Gunter Knittel, MD  
Larry R. Pedegana, MD ★★  
Thomas M. Green, MD ★★★★★  
William M. Backlund, MD, PS ★

## 1976

Douglas K. Kehl, MD  
Douglas T. Davidson III, MD ★  
John F. Burns, MD ★  
Peter Melcher, MD  
Richard A. Zorn, MD ★

## 1977

Carl A. Andrews, MD ★  
Geoffrey W. Sheridan, MD ★★  
Larry D. Iversen, MD ★  
Mark C. Olson, MD ★★  
Steven T. Bramwell, MD

## 1978

Arnold G. Peterson, MD ★★  
Gary J. Clancey, MD ★★  
John W. Brantigan, MD  
Richard S. Westbrook, MD ★★  
Robert J. Strukel, MD  
William Oppenheim, MD ★★

## 1979

Allan W. Bach, MD ★★★★★  
Gregory M. Engel, MD ★★  
Jonathan L. Knight, MD ★★  
Richard L. Semon, MD ★★

## 1980

Carol C. Teitz, MD ★★  
Douglas G. Norquist, MD ★  
John M. Hendrickson, MD ★★  
Michael A. Sousa, MD ★★★★★  
Stuart R. Hutchinson, MD ★

**1981**

Dennis J. Kvidera, MD ★  
 John M. Clark, Jr., MD, PhD ★★★  
 Martin S. Tullus, MD ★★★★★  
 Robert G. Veith, MD ★★★★★

**1982**

John L. Thayer, MD ★★★  
 Richard M. Kirby, MD ★★★★★  
 Steven S. Ratcliffe, MD ★★★★★  
 William D. Burman, MD

**1983**

Elizabeth Anne Ouellette, MD ★★★  
 Edward L. Farrar III, MD ★★★★★  
 Henry K. Yee, MD ★  
 Joseph D. Zuckerman, MD ★★★★★  
 Keith A. Mayo, MD ★★★★★  
 Robert M. Berry, MD ★★★★★

**1984**

Jeffrey C. Parker, MD ★  
 Jeffrey W. Akeson, MD ★★★★★  
 Kevin P. Schoenfelder, MD ★  
 Marc F. Swiontkowski, MD  
 ★★★★★  
 Thomas J. Fischer, MD ★★★★★

**1985**

Daniel L. Flugstad, MD ★★★★★  
 Jeffrey N. Hansen, MD ★★★  
 Paul J. Abbott, MD ★★★★★  
 Richard J. Barry, MD ★★  
 William P. Barrett, MD ★★★★★

**1986**

Carleton A. Keck, Jr., MD ★★★★★  
 Gary Bergman, MD ★★★★★  
 Lawrence E. Holland, MD ★★  
 Michael E. Morris, MD ★★★★★

**1987**

Craig T. Arntz, MD ★★★★★  
 Herbert R. Clark, MD ★★★★★  
 Michael K. Gannon, MD ★★  
 Steven L. Reed, MD ★

**1988**

Jonathan L. Franklin, MD ★★★★★  
 Michael A. Thorpe, MD ★★★★★  
 Richard V. Williamson, MD ★

**1989**

James P. Crutcher, MD ★★★★★  
 Lawrence V. Page, DO ★★★★★  
 Martin G. Mankey, MD ★★★★★  
 Nancy J. Ensley, MD  
 Steve C. Thomas, MD ★★★★★

**1990**

David M. Kieras, MD ★  
 J. Roberto R. Carreon, MD  
 Jay A. Winzenried, MD ★★★★★  
 Ken Fujii, MD ★  
 Walter F. Krengel III, MD ★★★★★

**1991**

David H. Bishop, MD ★★  
 Kit M. Song, MD  
 Mark Remington, MD ★★★★★  
 Mark E. Murphy, MD, PhD ★★  
 Tim P. Lovell, MD ★★

**1992**

Curt Rodin, MD  
 Don Striplin, MD ★★  
 Eli Powell, MD ★  
 Jeff Stickney, MD ★★  
 John D. West, MD ★★  
 Michael Sailer, MD ★★★★★

**1993**

J. Eric Vanderhooff, MD ★★★★★  
 Lyle S. Sorensen, MD ★★★★★  
 Philip J. Kregor, MD ★★  
 Susan R. Cero, MD ★★★★★

**1994**

Brodie Wood, MD ★★★★★  
 Eric Bowton, MD ★★  
 Jim Vahey, MD ★  
 Sohail K. Mirza, MD ★  
 William Obremskey, MD ★★★★★

**1995**

Ron Kristensen, MD ★★★★★  
 Scott Hormel, MD ★★★★★  
 Timothy Beals, MD ★★★★★  
 Todd Clarke, MD ★★★★★  
 William J. Mills III, MD ★★★★★

**1996**

David Deneka, MD ★★★★★  
 Peter Mitchell, MD ★★★★★  
 Peter T. Simonian, MD ★★★★★  
 Vernon Cooley, MD ★★★★★  
 William Wagner, MD ★★★★★

**1997**

Daniel Stechschulte, Jr., MD  
 ★★★★★  
 David Levinsohn, MD ★★  
 L. Anthony Agtarap, MD ★  
 Mohammad Diab, MD  
 Randall W. Viola, MD

**1998**

Colin Poole, MD ★★  
 David Belfie, MD ★  
 Don Ericksen, MD ★★★★★  
 Jay Crary, MD ★★★★★  
 Oriente DiTano, MD ★★

**1999**

Craig Boatright, MD  
 Jeffrey Garr, MD ★  
 John Michelotti, MD ★★  
 Julie A. Switzer, MD ★  
 Thomas D. Chi, MD ★

**2000**

Brett Quigley, MD ★★  
 Cara Beth Lee, MD ★  
 Daniel Jones, MD ★  
 Joel Hoekema, MD ★★★★★  
 Patrick McNair, MD

**2001**

Eric Novack, MD  
 Frederick Huang, MD ★★★★★  
 Matthew Camuso, MD  
 Michael Metcalf, MD ★★★★★  
 Richard Bransford, MD ★

**2002**

Timothy DuMontier, MD ★★  
 Scott Hacker, MD ★  
 Timothy Rapp, MD ★  
 William Sims, MD ★  
 Carla Smith, MD ★★

**2003**

Ben DuBois, MD ★★★★★  
 Andy Howlett, MD ★  
 Guy Schmidt, MD ★★  
 Brian Shafer, MD ★  
 Emma Woodhouse, MD ★

**2004**

Jon Braman, MD ★  
 Alexis Falicov, MD ★  
 Mike McAdam, MD ★★  
 Jason H. Thompson, MD ★★  
 Thea W. Khan-Farooqi, MD

**2005**

Anthony Buoncristiani, MD ★  
 Waqqar Khan-Farooqi, MD  
 Wren McCallister, MD  
 Timothy O'Mara, MD ★★  
 David W. Stevens, MD ★

**2006**

Heidi Shors, MD ★  
Stacey Donion, MD  
Eric Klineberg, MD ★  
Bill Montgomery, MD ★  
Mel Wahl, MD ★  
Burt Yaszay, MD ★

**2007**

Jamie Antoine, MD ★  
Jeremiah Clinton, MD ★  
Mary Cunningham, MD ★  
Evan Ellis, MD ★  
Joseph Lynch, MD ★  
Allison MacLennan, MD ★

**2008**

Drew Fehsenfeld, MD ★★  
Mark Freeborn, MD ★★  
Christopher Howe, MD ★  
John Howlett, MD ★  
Michael Lee, MD ★  
Gregg Nicandri, MD ★

**2009**

Rajshri Maheshwari Bolson, MD ★  
Jason King, MD ★  
Annie Links, MD ★  
Soren Olson, MD ★  
Karen Perser, MD ★  
Scott Ruhlman, MD ★  
Addison Stone, MD ★  
Jason Wilcox, MD ★

**2010**

Sean Amann, MD ★  
Jeremy Bauer, MD ★  
Aric Christal, MD ★  
Wendy Emerson, MD ★  
Michael Hwang, MD ★  
Lee Pace, MD ★  
Christopher Wolf, MD ★  
Vinko Zlomislic, MD ★

**2011**

Aaron Chamberlain, MD ★  
Brian Daines, MD ★  
Cory Lamblin, MD ★  
Edward Moon, MD ★  
Derek Rains, MD ★  
Peter Scheffel, MD ★  
Christian Sybrowsky, MD ★  
Brett Wiater, MD ★

**2012**

Benjamin Amis, MD ★  
Adam Bakker, MD ★  
Gregory Blaisdell, MD ★  
Joshua Lindsey, MD ★  
Grant Lohse, MD ★  
Matthew Lyons, MD ★  
Andrew Merritt, MD ★  
Nels Sampatacos, MD ★

**2013**

Kyle Chun, MD  
Elizabeth Dailey, MD  
Andrew Ghatan, MD ★  
Brian Gilmer, MD ★  
Jennifer Hagen, MD  
Mark Miller, MD  
David Patterson, MD ★  
Emily Squyer, MD ★

**2014**

Sid Baucom, MD  
Nathan Coleman, MD  
Jacques Hacquebord, MD  
Nicholas Iannuzzi, MD  
Paul Kim, MD  
Ted Sousa, MD  
Nicholas Wegner, MD  
David Zeltser, MD

**STARS INDICATE TOTAL DONATIONS IN SUPPORT OF THE RESIDENCY**

- ★★★★★★ = \$20,000 and above
- ★★★★★ = \$15,000 - \$19,999
- ★★★★ = \$10,000 - \$14,999
- ★★★ = \$7,500 - \$9,999
- ★★ = \$5,000 - \$7,499
- ★ = \$2,500 - \$4,999
- ★ = \$1 - \$2,499

# Orthopaedic Alumni Update

It's springtime again, my favorite time of the year. Hard winter weather is behind us, and the coastal weather is settling into a reasonable pattern. Adventures in coastal kayaking, or forays into southeast Alaska, are once again top on my planning list. The excitement of coastal wilderness and the healthy marine environment that we enjoy gives me new energy. I thank our alumni colleague, the late Bill Mills, MD for that, since his experiences in Prince William Sound, Alaska inspired



Lyle Sorensen, MD, University of Washington  
Department of Orthopaedics and Sports Medicine  
- Current Alumni Chairman

Gretchen and I to explore that area as an introduction to Alaska. He was a true Alaskan Outdoorsman. He was a great surgeon, husband, father, and human being.

Spring is a natural time for transition and renewal. The upcoming Resident Graduation can be seen in that light. We all remember that day, as a day of achievement, a day of meeting our goals, and a day to pursue a new life, onward, with excitement. Our goals of achieving the knowledge and skills to take care of the injured and those in need, has reached a pivotal point. We can now pursue further education and training as our careers take shape on our own. The graduation is a personal and sometimes overwhelming experience to be shared with friends and family. There is never enough time

to say all you would like to say, and thank all those you would like to thank, on that evening of graduation. All I can say is, we understand.

The graduates become Alumni. An alumnus can also be a former member, employee, contributor, or inmate, as well as a former student. This designation comes with responsibility. We uphold the values and ethics of our respected teachers and teaching program. We support the educational goals of those that follow us. We are proud of the institution and the principles upon which it is based. After all, the institution helped us achieve the level of knowledge and skill that allows us to graduate. Stay involved.

The Residents achieved an over the top goal this year with a 99th percentile overall score on the OITE. This is amazing, and deserves recognition. The faculty deserve credit also for providing a robust learning environment that fosters excellence.

One of the most rewarding experiences of my career was answering the call for help at the time of the 2010 earthquake in Haiti. During that experience, I had to dig deep into my knowledge base to provide orthopaedic care that I sometimes had only experienced as a resident. Thankfully, the UW Ortho Program gave me the background to help those that desperately needed care. Many Orthopaedic Surgeons were there. James Krieg, MD and Greg Schmale, MD were there, as well as Marc Swiontkowski, MD, Tom Green, MD, and Lew Zirkle, MD, founder of SIGN Fracture International, a key provider of education, equipment, and nails that were essential life and limb saving components. The work in Haiti goes on.

Dr. Zirkle just hosted the Haitian Annual Assembly for Orthopedic Trauma, (HAAOT) in Port au Prince. There were many Orthopaedic Leaders there, including Dr. Swiontkowski, we all gave talks and heard talks from the Haitian Orthopaedic Residents and Attendings. It was great to see economic and social progress in Haiti. There is still much to do. There is much trauma to address, including continued recovery and reconstruction from

injuries sustained at the time of the earthquake. The oncology and tumor surgery care there is a challenge, and much needed.

I will spend more of my time focused on Haiti. I am stepping down as Alumni Chairman. It has been a rewarding job and I am grateful to all those that contribute to the program both in time and money. I am proud to welcome Mark Freeborn, MD as our new Alumni Chairman. He will champion the cause, and the annual Notethon will continue



Mark Freeborn, MD, University of Washington  
Department of Orthopaedics and Sports Medicine  
- Future Alumni Chairman

to raise funds needed for Resident Education. He has also been elected to the Washington State Orthopaedic Association Board of Directors, to provide continuity with that organization. Please join me in congratulating him. Cheers, Mark, and Thank You. Thanks also to the WSOA for the continued support of the residents and UW Ortho program. I think this alliance is very important and should be supported by membership in the organization.

Lyle Sorensen, MD

# Endowments

---

We express our appreciation to all who have contributed to the endowments of the Department of Orthopaedics and Sports Medicine. This assistance makes possible special research activities, educational programs, and other projects that we could not offer without this extra support from our alumni, faculty, and friends in the community. In this day and age of funding cutbacks and decreased returns on investment, an endowment in the University of Washington continues to provide above market returns and is a crucial way to support advancement of musculoskeletal medicine. If you have any questions, please contact our Acting Chair, Howard A. Chansky, MD (chansky@uw.edu), or our Director, Ken Karbowski (kkarb@uw.edu). Thank You!

Hansjörg Wyss Endowed Chair - Jens R. Chapman, MD

Hansjörg Wyss Endowed Chairs for the Advancement of Hip & Pelvis Surgery –  
Keith A. Mayo, MD & Howard A. Chansky, MD

Hansjörg Wyss Endowed Fellowship in Advancement of Hip & Pelvis Surgery

Ernest M. Burgess Endowed Chair for Orthopaedics Investigation - David R. Eyre, PhD

Sigvard T. Hansen Jr. Endowed Chair in Orthopaedic Traumatology - Ted S. Gross, PhD

Jerome H. Debs II Endowed Chair in Orthopaedic Traumatology -  
Stephen K. Benirschke, MD

Bob and Sally Behnke Endowed Chair for the Health of the Student Athlete -  
John W. O’Kane, MD

Endowed Chair for Women’s Sports Medicine and Lifetime Fitness -  
Peter R. Cavanagh, PhD, DSc

Surgical Dynamics Endowed Chair for Spine Research

Douglas T. Harryman II/DePuy Endowed Chair for Shoulder Research -  
Frederick A. Matsen III, MD

Synthes Spinal Surgery Outcomes Research Endowed Fund

Fracture Fixation Biology Endowed Professorship

Ostex Bone and Joint Research Endowment

# Endowments

---

Orthopaedic Traumatology Endowed Lectureship

John F. LeCocq Lectureship in Orthopaedic Surgery

Don and Carol James Research Fund in Sports Medicine and Fitness

Victor H. Frankel Endowed Award

Esther Whiting Award

Edwin L. Larnen, M.D. Award

Spine Research Endowment

James G. Garrick Endowed Lectureship in Sports Medicine

Allan Treuer - Ted Wagner, M.D. Endowed Chair in Regenerative Spine Surgery

Richard and Betsy Kirby Orthopaedic Resident Endowed Fund

Huang-Biu Orthopaedic Resident Endowed Support Fund

Orthopaedic Resident Endowed Support Fund

Josh and Max Myers Endowed Orthopaedic Fellowship Fund

Sarcoma Oncology Endowed Fund

Clawson Family Orthopaedic Library Endowed Fund