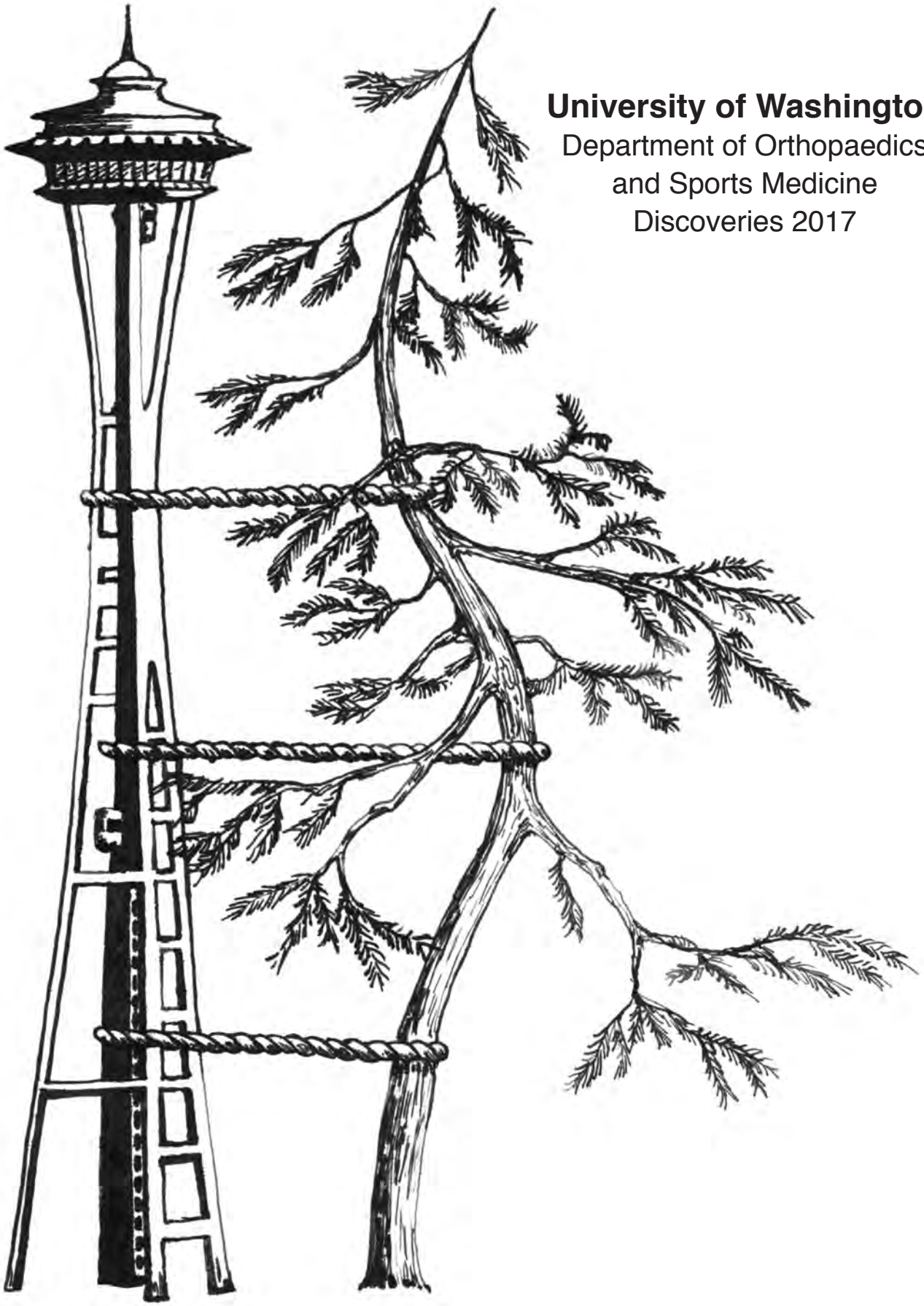
# Discoveries 2017

University of Washington Orthopaedics & Sports Medicine



# University of Washington

Department of Orthopaedics
and Sports Medicine
Discoveries 2017

UW Medicine
SCHOOL OF MEDICINE

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Front Cover Illustration: "Bridge near Perfection Lake, The Enchantments, Central Cascades, WA" photograph by Nicholas Iannuzzi, MD

A pdf of this publication is available at our website:
www.orthop.washington.edu.

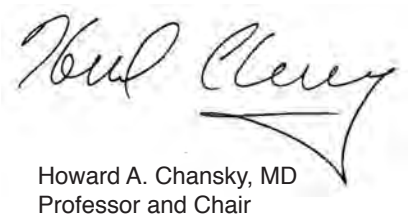
# Contents

# Foreword

It is my privilege to serve as the Chair of the Department of Orthopaedics and Sports Medicine in a time of continued challenges and change in the practice and business of medicine. Our common pursuit of the best possible care for our patients, formalized in name as "The Triple Aim" by the Institute of Healthcare Improvement, is the mission that serves to unite the entire Department. The Triple Aim refers to improving the care of individual patients, improving the health of populations and reducing the cost of healthcare.

Our faculty and staff demonstrate their commitment to these goals of the Triple Aim in myriad ways via development of clinical pathways to enhance safe and cost-effective care, teaching surgical skills to colleagues from around the world as well as our residents and fellows, and basic and clinical research to define and improve orthopaedic outcomes. Contributions to the Triple Aim do not always directly involve activity in the laboratory or the hospital. It is accepted wisdom, confirmed by research, that diversity and inclusiveness in training programs makes for better doctors. Better doctors makes for better patient care, and diversity in the orthopaedic workforce is one element in addressing persistent disparities in musculoskeletal heath and access to healthcare. While we all realize this is a long-term effort, under the guidance of Angela Weiss, Doug Hanel and Lisa Taitsman we have made recent strides in attracting very talented underrepresented minorities to our residency program. In addition, we have made early progress in diversifying our faculty. We hope to capitalize on this early success with further focused efforts to promote inclusivity and diversity throughout our Department.

In this latest issue of Discoveries we highlight annual faculty and programmatic developments at the University of Washington Medical Center, Seattle Children's Hospital, the Puget Sound VA Healthcare System, Northwest Hospital and Harborview Medical Center. However, the main focus of Discoveries remains the clinical and basic research performed by our trainees and faculty, each of our laboratories and clinical campuses. The managing editor Fred Westerberg as well as co-editors Drs. Chris Allan, Stephen Kennedy and Adam Sassoon have once again produced an excellent annual summary of the Department of Orthopaedics and Sports Medicine. Thank you for your interest in this issue and please do not hesitate to contact Fred or myself with questions or ideas for future issues.



Howard A. Chansky, MD
Professor and Chair

# From The Assistant Editors: The Winding Path Toward Perfection Lake

We would first like to express our gratitude for the invitation from Dr. Chansky to return as assistant editors for Discoveries 2017. We were honored to be involved with the process, and enjoyed reading and participating again in the variety of articles representing the ongoing work in the UW Department of Orthopaedics and Sports Medicine.

This year's cover photo was taken by Nicholas Iannuzzi MD, while hiking here in Washington State, in the Enchantments basin of the Central Cascades. A small footbridge leads to a winding path around Perfection Lake. Trees decorate the landscape in different stages of growth and a variety of curves and shapes, reminiscent of our departmental emblem of the Space Needle guiding the growth of a Douglas Fir. Dr. Iannuzzi commented on the photo "Believe it or not, that's the name of the lake. Not much of an understatement there."

As orthopaedists and sports medicine specialists, we so often seek "perfection" for our patients. As scientists, we believe in a method of investigation that consists of systematic observation, measurement, and experiment, and the formulation of questions and testing of hypotheses. This journey can be winding, and sometimes uphill, but persistence, keen observation, and serendipity can allow for discovery and a footbridge toward our goal.

Our basic science articles in this edition include studies that make use of animal models such as zebrafish or mice, or cell culture lines, combined with advanced molecular techniques and a variety of measurements, to better understand the genetics and molecular building blocks that can influence growth, joint function, and deformity.

Our clinical outcome studies reflect continued use and development of patient reported outcome instruments. Dr. Matsen first reported the Simple Shoulder Test (SST) in 1995 as a self-assessment of shoulder function in glenohumeral arthritis. Hsu et al's "Psychometric Properties of the Simple Shoulder Test in Over 400 Patients Undergoing Shoulder Arthroplasty" further validates this brief and simple instrument for assessing the outcomes of shoulder arthroplasty.

Our articles also represent the important role our Department plays in the tertiary care of patients requiring complex joint arthroplasty or multiple system injuries. Dr. Sassoon reports his early outcomes in the use of nonmodular stems for complex primary hip arthroplasty. Dr. Thayer et al share the University of Washington experience on the reconstruction of distal radioulnar joint arthrosis using a semiconstrained total DRUJ prosthesis. Dr. Domes et al report on the appropriate VTE prophlaxis in orthopaedic trauma patients.

We hope you enjoy reading this year's edition of Discoveries and that you find the articles as stimulating as we did.

Adam Sassoon, MD, MS
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Stephen Kennedy, MD

# Sigvard T. Hansen, Jr., MD
# 2017 Distinguished Alumnus
# University of Washington School of Medicine

Dr. Sigvard "Ted" Hansen is recognized both as one of the "fathers" of modern orthopaedic traumatology for his role in building Harborview Medical Center's vaunted emergency-care system, and for his worldwide prominence as a foot and ankle surgeon. His innovations of aggressive and expeditious orthopaedic care of trauma patients revolutionized the field.

Dr. Hansen was born in Spokane, Washington in 1935. He attended Whitman College, starting out in mechanical engineering but graduating with a degree in Biology in 1957. He attended medical school at the University of Washington, where he also completed his residency. Following this, he did an internship at Harborview Medical Center and then spent three years as a Navy GMO/Senior Medical Officer at a naval ammunition depot in Hawaii.

While serving in the Navy and through the late '60s, Dr. Hansen was pushing the limits of fracture care. In 1973 he became the Orthopaedist-in-Chief at Harborview Medical Center, which three years earlier had formally become affiliated with the University of Washington. Setting aside the prevailing wisdom in the United States, he adopted the then controversial new European *Arbeitsgemeinschaft für Osteosynthesefragen* (AO, or "Association for the Study of Internal Fixation") paradigm for early and aggressive surgical repair of severe fractures in trauma patients. The prevailing wisdom at the time was to put patients with long bone fractures into casts and long-term traction, resulting in the debilitating effects of long-term bed rest. Patients were at higher risk of developing pneumonia, blood clots, bone deformities, joint stiffness and bed sores. Rehabilitation after such treatment was prolonged and difficult and some patients would never fully recover and some would succumb to complications. After visiting surgeons in Davos, Switzerland, Dr. Hansen was certain there was a better way. Back at Harborview, as soon as trauma patients were stable enough to survive surgery, Dr. Hansen began surgically fixing these fractures using intramedullary hardware developed by Gerhard Kuntscher. As a result, patients were rehabilitated and mobilized much more quickly, essentially immediately, also giving them a chance to recover from other injuries such as those to their lungs. Dr. Hansen developed national and international renown for developing a systematic modern approach based on the AO principles.

Remarkably, Dr. Hansen then turned his attention to surgery of the foot and ankle and eventually developed similar renown and expertise. He also began a fellowship to advance the training of orthopaedic surgeons in surgery of the foot and ankle. As with orthopaedic trauma surgery, dozens of surgeons from around the world are now "disciples" of Dr. Hansen's approach to diseases and injury of the foot and ankle. Three of these surgeons - Stephen Benirschke, Michael Brage and Bruce Sangeorzan work in our Department and also train our fellows.

Dr. Hansen has been in the Department of Orthopaedics and Sports Medicine since 1968. He was appointed Assistant Professor at University of Washington in 1971 and is currently a Professor Emeritus at University of Washington. Dr. Hansen is listed in The Best Doctors in America and is the founder of the Department of Orthopaedics and Sports Medicine's Foot & Ankle Institute. Amongst many honors, he has been an editorial board member of Clinical Orthopedics and Related Research, the AO International Board of Directors, the Maurice E. Mueller Foundation of North America Board of Directors, and the Board of Directors for Prosthetics Research Study in Seattle.

The international field of orthopaedics and our patients have benefited greatly from Dr. Hansen's wisdom and mentorship. We are grateful that he has chosen to remain active in the Department and continues to care for patients and advise his colleagues. Reflecting these innumerable achievements and continued guidance, in June of this year, the Department of Orthopaedics and Sports Medicine awarded Dr. Hansen the Distinguished Alumnus Award for his career accomplishments as an innovative researcher, teacher, mentor, and surgeon.

# Ernest U. Conrad III, MD

Dr. Conrad arrived at the University of Washington in 1986 after an orthopaedic residency at the Hospital for Special Surgery at Cornell Medical Center and fellowships at the University of Florida and the Hospital for Sick Children in Toronto. He was hired to build the region's first program dedicated to caring for patients with cancer of bone and soft tissue. To say he was successful at this venture is an understatement. Chappie is leaving us a renowned sarcoma program at both Seattle Children's Hospital and the University of Washington Medical Center as well as at the Seattle Cancer Care Alliance. He built his program through determination, exceptional talent, and hard work. He cultivated outstanding relationships with referring physicians from throughout the Northwest as well as with his patients. He also helped establish major programs in tumor imaging and clinical outcomes. Through the fellowship he developed, he trained surgeons who now run some of the most respected orthopaedic oncology programs throughout the nation. I would estimate that 5-10% of all patients in the nation with a bone or soft tissue cancer are treated by Dr. Conrad or at a center led by one of his former trainees.

As Chief at Seattle Children's Hospital, Dr. Conrad not only directed the surgical sarcoma program but also had great vision in expanding the entire pediatric orthopaedic program. He was ahead of his time in understanding the benefits to patients and physicians of close collaborations between orthopaedic surgeons, pediatricians who specialize in non-operative orthopaedic care and Physician's Assistants. Chappie also established an impressive network of athletic trainers that care for regional high school athletes and triage the athletes to Seattle Children's as needed. In addition, Dr. Conrad had the foresight to recruit several outstanding pediatric orthopaedic surgeons from throughout the city, several of whom still work at Children's Hospital.

In fact, many of us in Seattle as well as around the country owe some of our success to Dr. Conrad's recruiting and mentoring skills. He set the example for many of us by rounding on his patients every day that he was in Seattle. Perhaps most impressive is that he accomplished all of this while helping Marjolyn to raise three wonderful children.

Chappie will be moving to Houston to develop a world class orthopaedic oncology program for the Memorial Hermann Medical System. Memorial Hermann has 16 hospitals and 8 cancer centers and is considered to be one of America's great medical systems. In Houston Chappie will be joining another of our former faculty and internationally renowned trauma surgeon, Chip Routt.

A colleague recently expressed concern that Chappie leaving must be difficult for me. It is for many of us from partners to staff to patients and their families. Chappie has been my mentor, friend and colleague. He has also worked at an almost incomprehensible pace for the last 30 years, never saying no to anyone requesting his help. At Memorial Hermann, Chappie will be able to finish out his career in a style that befits him while building what I am sure will become a great orthopaedic oncology program. I wish Dr. Ernest "Chappie" Conrad the best of luck on his new adventure in Houston.

Howard A. Chansky, MD
Professor and Chair

# New Faculty

**Amy Cizik, PhD, MPH**

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On May 1, 2017, Amy Cizik was appointed Research Assistant Professor at the University of Washington Department of Orthopaedics and Sports Medicine.

Amy Cizik was born in St. Louis, Missouri where she graduated from the University of Missouri with a BA in Psychology and a BA in Chemistry. In 2004, she completed her Masters in Public Health from the University of Kansas, writing her thesis on "The Meaning Race and Ethnicity Have on the Mammography Screening Experience." In December 2016, she added a PhD to her accomplishments, graduating from the University of Washington Department of Pharmacy. Her dissertation was "Variations in Surgeon Treatment Preferences and Their Impact on the Cost-Utility of Surgery for Soft Tissue Sarcoma."

Dr. Cizik has worked at the University of Kansas Medical Center as a Research Assistant. In 2004, she joined the University of Washington Department of Orthopaedics and Sports Medicine, where she worked as a Research Study Coordinator and later as a Research Scientist.

She has published original research on many topics including patient reported outcomes, infection in spine fusion surgery, quality of life measures in soft tissue sarcoma, as well as Medicaid status and its association with higher rates of infection after spinal surgery.

**Michael Githens, MD, MS**

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Michael Githens is a practicing orthopaedic traumatologist at Harborview Medical Center and an Assistant Professor in the University of Washington Department of Orthopaedics and Sports Medicine. He is an expert in treatment of both upper and lower extremity traumatic injuries, with a particular interest in periarticular fracture management and treatment of nonunions.

He is actively engaged in multiple clinically based research endeavors with a particular interest in fracture nonunion. Additionally, he is working to better understand the psychosocial impact of trauma on a patient's overall recovery and how various treatments may help optimize outcomes.

Dr. Githens received his bachelor's degree from Pepperdine University and then earned a M.S. in biophysics from Georgetown University. He stayed in Washington, DC to complete his MD at Georgetown University School of Medicine. Following his time there, Dr. Githens completed his surgical internship and residency in Orthopaedic Surgery at Stanford University. He then completed the Orthopaedic Traumatology Advanced Clinical Experience fellowship at Harborview Medical Center in Seattle.

He is an active member of the Orthopaedic Trauma Association and American Academy of Orthopaedic Surgeons.

**Jonah Hebert-Davies, MD**

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Dr. Hebert-Davies is an Assistant Professor in the Department of Orthopaedics and Sports Medicine and is based at Harborview Medical Center. His specialties include orthopaedic trauma with a focus on upper extremity trauma and reconstruction. He is also a Shoulder and Elbow specialist with a focus on arthroplasty.

Dr. Hebert-Davies is involved in multiple clinical research projects on shoulder and elbow fractures. He is also conducting numerous biomechanical studies evaluating the syndesmosis ligaments (high ankle sprain).

Dr. Hebert-Davies graduated with his medical degree from University of Montreal, where he also completed his orthopedic residency. He then completed an orthopedic trauma fellowship at Harborview Medical Center followed by a Shoulder and Elbow fellowship at Washington University in St. Louis.

# New Faculty

**Michael G. Saper, DO**

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Dr. Saper is a University of Washington Assistant Professor of Orthopaedics and Sports Medicine. He is an orthopaedic surgeon with fellowship training in arthroscopic surgery and the treatment of sports-related injuries. He completed additional fellowship training in pediatric orthopaedic surgery.

His surgical interests include arthroscopic and open treatment of knee, shoulder, and elbow injuries. In addition, he has particular interest in patellofemoral dysfunction and injuries of the young throwing elbow.

Dr. Saper earned his bachelor's degree in Philosophy at University of California, Berkeley and his medical degree at A.T. Still University- Kirksville College of Osteopathic Medicine. He completed his orthopaedic surgery residency at Michigan State University in Lansing, MI. He then completed a Sports Medicine fellowship at the Andrews Institute in Gulf Breeze, FL. Following his sports training, Dr. Saper completed a fellowship in pediatric orthopaedic surgery at Nemours Children's Specialty Clinic in Jacksonville, FL.

Dedicated to the field of sports medicine, he continues to maintain certifications as an athletic trainer and strength and conditioning specialist.

He is a member of the American Academy of Orthopaedic Surgeons, the Arthroscopy Association of North America, and the Pediatric Research in Sports Medicine Society.

**Ted C. Sousa, MD**

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Ted Sousa, MD joined the faculty at the University of Washington Department of Orthopaedics and Sports Medicine in October 2016. He is an Assistant Professor and his practice is based at Seattle Children's Hospital.

Dr. Sousa was born and raised in Missoula, Montana. He graduated with a BA from the University of Southern California in 2003. He attended Medical School at the University of Washington, graduating in 2009. He completed his residency here at the University of Washington School of Medicine in 2014 with a focus on Orthopaedic Surgery.

He followed with a fellowship in pediatric orthopaedic surgery at Childrens Hospital Los Angeles. He completed another fellowship at the Royale Children's Hospital Melbourne Australia in 2016 (with an emphasis on cerebral palsy).

Dr. Sousa is a member of American Academy of Orthopedic Surgeons, Pediatric Orthopedic Society of North America, American Academy for Cerebral Palsy and Developmental Medicine, and the Washington State Medical Association.

His areas of interest are pediatric orthopaedics, cerebral palsy, neuromuscular gait disorders, trauma, and spinal deformity. He has published research on musculoskeletal functional outcomes in children with osteogenesis imperfect, percutaneous hamstring lengthening surgery, accelerated discharge protocol for posterior spinal fusion, in addition to other subjects in pediatric orthopaedic surgery.

**Kushagra Verma, MD**

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Dr. Verma is an Assistant Professor in the University of Washington Department of Orthopaedics and Sports Medicine. He is an expert in disorders of the spine including pediatric and adult scoliosis surgery.

Dr. Verma has a strong interest in clinical research and has authored over 30 publications, 6 book chapters, and 80 research presentations, presented both nationally and internationally. He has a long interest in adolescent and adult scoliosis in addition to other forms of spine deformity. He regularly attends and presents at the Scoliosis Research Society meetings and has been awarded the Russell Hibbs award in 2010 for his work in reducing blood loss in spine surgery. He presently is a reviewer for the International Journal of Spine Surgery and is an editor for the AO spine.

Dr. Verma earned his bachelor's of science degree in biomedical engineering from Cornell University and went on to obtain a master's of science and medical doctorate from New York University. During this time he developed an interest in spine deformity, where leading scoliosis surgeons mentored him. He completed his residency at the Rothman Institute at the Thomas Jefferson University Hospital. Dr. Verma then completed a spine fellowship at the University of California in San Francisco. He has relocated from San Francisco to Seattle with his wife Katie.

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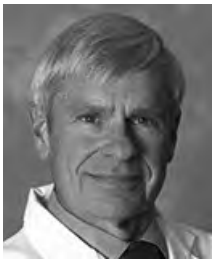

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# Visiting Lecturers

## 2017 LeCocq Lectureship

January 26-27, 2017

We were happy to host Dr. Steven R. Garfin as our guest lecturer for the 2017 LeCocq Lectureship. On Thursday January 26th, he gave a presentation on "An Algorithm to Treat Pain Related to Herniated Discs: How Has It Changed Over 20-30 Years?" At the 53rd Annual John F. LeCocq Dinner that evening, he gave the featured lecture on "Orthopaedic Surgery/Orthopaedic Industry – Financial Inter-relationships." The following day he gave his final talk on "Osteoporosis and Treatment Options for Vertebral Compression Fractures: Percutaneous Augmentation is a Valid Option?"

Dr. Garfin is the Distinguished Professor and Chairman of the Department of Orthopaedics at the University of California, San Diego (UCSD). His training included: medical school at the University of Minnesota, Orthopaedic Surgery Residency at UCSD, and a spine surgery fellowship at Pennsylvania hospital in Philadelphia. He has received numerous research awards, including: Volvo award from ISSLS (x2), North American Spine Society (x2), Cervical Spine Research Society (x2) and the Orthopaedic Research Society New Investigator Recognition Award. He has also been given the Wiltse Award for Leadership for NASS, the Selby Award for Contributions to NASS, and the ISSLS Wiltse Lifetime Achievement Award.

Dr. Garfin is a member of: the American Academy of Orthopaedic Surgeon, American Orthopaedic Association, Cervical Spine Research Society (former President), International Society for the Study of the Lumbar Spine, North American Spine Society (former President), the Orthopaedic Research Society, Lumbar Spine Research Society, and the International Society for the Advancement of Spine Surgery (former President). For several of these he has been a board member, President and/or Program Chair.

He has edited 21 books, and authored over 140 book chapters, and published over 290 peer review articles. He is Deputy Editor of Spine and reviewer for a number of orthopaedic and spine peer review journals.

# Visiting Lecturers

## 2017 Resident Research Day

June 30, 2017


We were very happy to host Dr. Mitchel B. Harris as the guest lecturer for our Resident Research Day on June 30, 2017.

Dr. Harris is Chief of Orthopedic Trauma at Brigham and Women's Hospital (BWH), as well as the Administrative Chief of Orthopedic Trauma for Partners Health Care System. He is responsible for organizing the clinical and administrative structure of the orthopedic trauma service at BWH as well as coordinating the Partners Orthopedic Trauma Services in collaboration with Beth Israel Deaconess and Boston Children's Orthopedic Trauma Services under the umbrella of the Harvard Orthopedic Trauma Initiative.

Dr. Harris is a Professor of Orthopedic Surgery at Harvard Medical School, and in his role as the inaugural director of the Gillian Reny Stepping Strong Center for Trauma Innovation, he was awarded the Stepping Strong Chair of Orthopedic Surgery. He completed his medical degree through the University of Illinois-Chicago and his orthopedic residency at Dartmouth-Hitchcock Medical Center. He completed Fellowships in orthopedic spine and trauma at the University of Toronto, Sunnybrook Health Science Centre, and Queen's Medical Centre in Nottingham, UK. He was a recipient of the International Volvo Award for Low Back Pain Research. He has received "Teacher of the Year Awards" at the three institutions he has been employed Louisiana State University (2000), Wake Forest (2003), and at Harvard's Combined Orthopedic Residency Program (2004). He was recently awarded the Hippocrates Society's Humanitarian Award (2015) from the Brigham and Women's Physician Organization.

He is actively involved with the Orthopedic Trauma Association and North American Spine Societies. He has been a member of the Board of Directors of the North American Spine Society since 2012. He continues to be an active contributor to the orthopedic trauma and spinal literature with greater than 150 peer reviewed articles.

He is interested in Leadership Training and is the founding co-director of the Brigham and Women's Hospital- Harvard Business School's Mid-career Physician Leadership Program. He is the current Chairman of the AAOS Leadership Development Committee and has been directly involved with the development of a leadership program for NASS.

# Non-Modular Tapered Fluted Stems in Complex Primary Total Hip Arthroplasty Requiring Concurrent Osteotomy

Ryan Stancil, MD, Nathan Summers, PA-C, and Adam Sassoon, MD, MS

Primary total hip arthroplasty (THA) in patients with proximal femoral deformity are challenging technical endeavors. Non-modular tapered fluted stems and femoral osteotomies are tools commonly used in revision surgery that can be deployed during primary procedures to correct a multitude of unique deformities. We present a case series of 5 such primary THAs in 4 patients using non-modular tapered fluted stems with concurrent osteotomies. At a minimum of 3 months there have been no revisions, all osteotomies have healed, and all stems have shown stable osseous ingrowth. These are promising short term results in these 5 complex primary THAs. Long-term follow-up is needed to demonstrate further implant survivorship.

**Introduction**

In patients with distorted femoral anatomy undergoing total hip arthroplasty (THA), a surgeon has multiple reconstructive options in their arsenal. Non-modular tapered fluted stems have emerged as a popular treatment option in uncemented revision THA in cases with deficient proximal bone stock that require diaphyseal fixation. The lack of modularity avoids a potential corrosion generator as well as the potential for junctional failure that has been observed with some modular designs.(1) The conical tapered and fluted design of these components further contribute to axial and rotational stability, respectively.(2) These femoral components have shown minimal subsidence in biomechanical cadaveric studies and reliable osseous integration at 2 years in one center's case series. (3, 4) These design principles may be beneficial in primary THA in patients with proximal femoral deformity.

In instances of proximal femoral deformity, additional procedures during THA, such as femoral osteotomies, may be required to address limb length, rotational deformities, trochanteric overhang, or to to obtain access to an obliterated femoral canal. Patients with severe hip dysplasia often have several of these abnormalities.

We present short-term follow up of a small cohort of patients that required proximal femoral osteotomies during their primary THA in which a nonmodular tapered fluted stem was used.

**Patients and Operative Techniques**

Five complex primary THAs requiring femoral osteotomies were performed in 4 patients. Patients were followed for a minimum of 3 months (Range: 3-6 months). Three patients were male and 1 patient was female ranging between 18-72 years of age. The indications for THA were end stage OA in three patients. Each patient had a unique presentation for their OA: one secondary to acquired dysplasia following a cerebrovascular insult as a child [Fig 1-4], one following a varus malunion of a subtrochanteric femur fracture, and one secondary to arthrogryposis related dysplasia. The final patient had bilateral THAs in the setting of longstanding bilateral girdlestone procedures performed in

Figure 1: Pre operative Radiographs: AP Pelvis and lateral R hip in a 45-year-old female with acquired dysplasia secondary to a remote cerebrovascular insult. Notice the proximal femoral deformity with trochanteric overhang.


Figure 2: Intraoperative radiographs. A- Determining length of osteotomy (drill bit marks estimated length) B- Cable placed just distal to osteotomy with trial stem in place to prevent propagation of a fracture during stem prep.

Ghana to treat sequelae of trauma and previous infection. Each of the 5 hips was reconstructed using a cementless, nonmodular, tapered, fluted, femoral stem (Redapt; Smith and Nephew, Memphis, TN) and multi-hole press fit acetabular cups. Standard or dual mobility bearings were used depending


Figure 3: Immediate post-operative radiographs with cable fixation of ETO, Redapt stem, and dual mobility bearing acetabular component placed for significant abductor atrophy. Stimulan beads placed for history of previous surgery as infection prophylaxis.

on patient factors such as intraoperative hip stability and anticipated demand on the prosthesis. Four of the 5 osteotomies performed were extended trochanteric osteotomies and 1 was a subtrochanteric, shortening, and de-rotational osteotomy in the setting of severe dysplasia (arthrogryposis). ETO fixation was performed with cable claw plates in 3 instances, and cable fixation in 1 instance. The subtrochanteric shortening osteotomy fixation was augmented with a locking plate.

**Outcomes**

To date, there have been no revisions or failures in any of the 4 THAs. All patients but one were placed on 50% weight bearing for the first six weeks and all patients undergoing ETO were placed on active hip abduction precautions for 6 weeks post-operatively. All osteotomies healed. One patient experienced stem subsidence of 3 mm at 6 weeks post-operatively. His weight bearing precautions were continued at 50% and eventually lifted at 12 weeks. Follow-up radiographs demonstrated stable ingrowth of the femoral component at 3 months without further subsidence. One patient with a significant pre-operative flexion contracture has experienced lingering, though improved, symptoms related to hip stiffness. All hips have demonstrated evidence of osseous integration of the femoral components without radiolucent lines or a pedestal sign at final follow-up.


Figure 4: A- AP and B-lateral hip radiographs 3 months post-operatively showing no stem subsidence and a healed osteotomy site.

**Discussion**

These are short-term results of complex primary THAs requiring osteotomies treated with a nonmodular tapered femoral component. Results thus far show no significant complications; minimal, non-symptomatic, subsidence of the component; and healing of all femoral osteotomies. This series is limited by its retrospective nature, short follow up period, and lack of a control group. Long-term follow-up is required to verify continued survivorship of these femoral components.

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Figure 5: Pre-operative A- AP and B-lateral R hip radiographs in a 72-year-old male with a subtrochanteric malunion, shortening, and trochanteric overhang.

Figure 6: Immediate post-operative AP pelvis. THA performed with Redapt stem, dual mobility socket, and cable claw plate. Stimulan beads placed for infection prophylaxis in setting of previous surgery.

Figure 7: 6 month follow up A- AP and B- lateral radiographs showing ingrowth of both components and healing of the osteotomy across the medial, anterior, and posterior cortices with abundant callous formation. Small residual gap laterally as the pre-operative shortening and contracture precluded complete reduction of the osteotomized segment. Patient also has asymptomatic Brooker grade-3 heterotopic ossification.

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# Semiconstrained Total Distal Radioulnar Joint Prosthesis for Distal Radioulnar Joint Arthrosis

Mary Kate Thayer, MD, Kate Bellevue, MD, Mike Pouliot, MD, Jerry I. Huang, MD, and Douglas P. Hanel, MD

**Introduction**

The distal radioulnar joint (DRUJ) plays an essential role in forearm rotation and stable transmission of forces across the forearm and wrist. Untreated injuries to the DRUJ can result in chronic instability or arthritis, causing significant pain, weakness, and disability. Treatment options for DRUJ arthrosis include ulnar head resection (Darrach), hemiresection (Bowers), and DRUJ arthrodesis with ulnar shaft resection (Sauve-Kapandji)[1-4]. Favorable results have been described in multiple clinical series with improvement in pain and range of motion after these procedures[5-8]. However, distal stump instability with convergence of the distal ulna onto the radial shaft is a known complication with each of these procedures, leading to pain and weakness with gripping and forearm rotation[5,9-12]. Multiple tenodesis procedures have been utilized to avoid this complication in Darrach resection[13-15]. Ulnar head arthroplasty has also been described for treatment of DRUJ arthritis[16-20]. However, this hemiarthroplasty procedure relies on an intact sigmoid notch as well as preservation or reconstruction of the TFCC complex and soft tissue constraints around the DRUJ[2,21,22].

The Aptis total DRUJ arthroplasty is a semi-constrained, modular prosthesis that reconstructs the ulnar head as well as sigmoid notch of the distal radius (Figure 1). As a semi-constrained articulating prosthesis, it also provides stability to the DRUJ, obviating the need for ligamentous stabilizers. Prior studies assessing outcomes of patients undergoing DRUJ arthroplasty are limited, but report favorable outcomes with 95% or greater 5-year implant survival rates[23-27]. The current published data on outcomes following DRUJ arthroplasty is limited to case series with sample sizes ranging from 14 to 46 implants[23-27]. The majority of the studies reviewed the outcomes of procedures performed by the inventor of the device, Dr. Luis Scheker. There is a need for further studies on the implant both with larger sample sizes as well as from the perspective of other institutions and other surgeons.

**The University of Washington Experience**

At the University of Washington Medical Center and Harborview Medical Center, we treat a challenging patient population with both complex wrist pathology and social factors. From 2007 to 2016 at our institution, there were 56 cases of Aptis total DRUJ arthroplasty performed in 51 patients by two fellowship-trained senior hand surgeons, with 5 patients undergoing bilateral arthroplasties. These patients ranged from 16 to 67 years of age (mean 47) and included 27 females (48%) and 29 males (52%). Of this group, 54% were being treated for post-traumatic arthritis or instability, 18% had a Madelung's deformity, 7% had rheumatoid or inflammatory arthritis, and the remainder had non-traumatic arthritis or DRUJ instability. Seventy-five percent (38 out of 51) of the patients had undergone wrist surgeries prior to their DRUJ arthroplasty procedure. Prior procedures included surgical fixation of distal radius fractures and other DRUJ procedures including Darrach resection and DRUJ stabilization, indicating a high level of complexity in pathology of our patient population.

Additionally, there are unique social factors in play at our institution. As the referral center for a five-state catchment area in the Washington-Wyoming-Alaska-Montana-Idaho (WWAMI) region in the Pacific Northwest, we see patients from nearly one

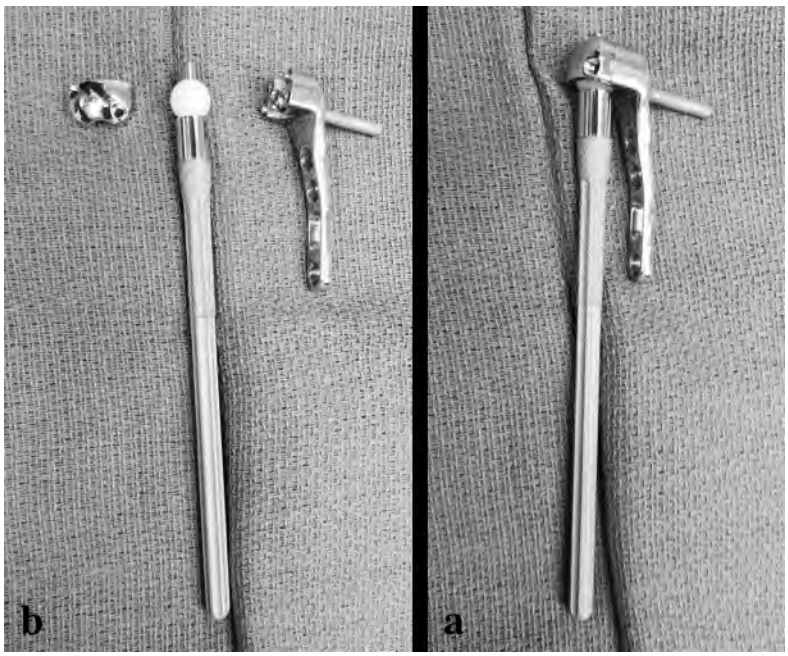


Figure 1: Intraoperative photo of the Aptis total DRUJ arthroplasty prior to implantation a) disassembled and b) assembled for demonstration.

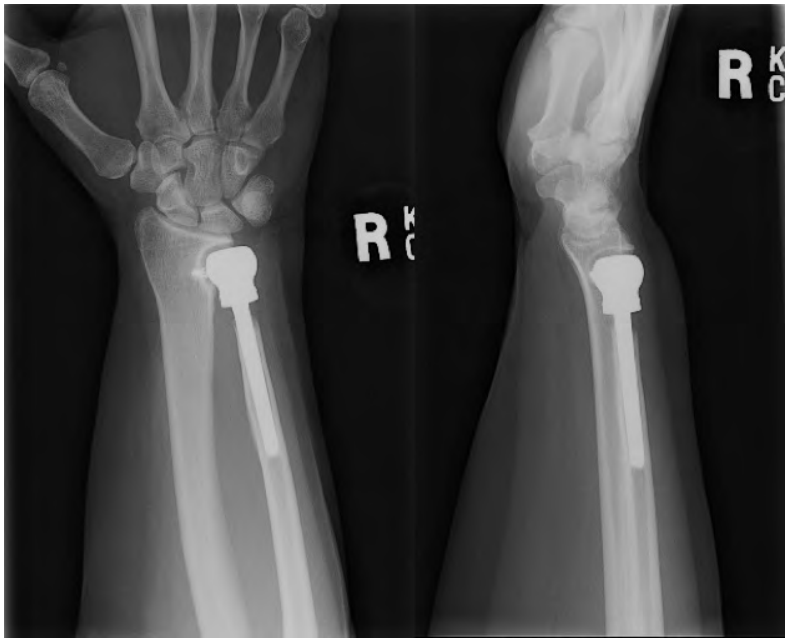

Figure 2: Radiographs of patient with prior ulnar head arthroplasty which has eroded into the radius.

quarter of the country's land mass. Harborview Medical Center represents a large county hospital facility with a socio-economically diverse patient population. University of Washington Medical Center presents a different set of challenges altogether as the main tertiary referral center for our large catchment area, with referrals from the community for complex and revision surgeries. These factors together create difficulties in follow up and postoperative care.

Given the unique perspective our experience provides with a relatively large cohort of patients treated with the Aptis implant and the paucity of data on these patients, we have begun a cohort study looking at the complications and clinical outcomes of patients following this procedure.

**Case Example**

*Preoperative evaluation*

A 64 year old female presented as an outpatient for ulnar-sided wrist pain several years after silastic ulnar head replacement and subsequent revision at an outside facility. After failing nonoperative management, she underwent removal of the silastic implant, excision of a neuroma of the dorsocutaneous branch of the ulnar nerve, and revision total ulnar head arthroplasty with an Avant prosthesis. Over time, the arthroplasty failed with erosion of the ulnar head into the radius (Figure 2). She became quite symptomatic from this, experiencing pain with pronation/supination and difficulty with simple activities of daily living such as typing or using a phone. For this, about eight years after her initial ulnar head replacement, she underwent DRUJ arthroplasty with the semi-constrained Scheker implant.

*Surgical Technique*

An incision is made over the dorsoulnar aspect of the wrist. The extensor retinaculum is incised over the dorsum of the wrist, just ulnar to Lister's tubercle, with reflection of an ulnar based retinacular flap over the ECU tendon to expose the distal ulna. A provisional cut is typically made over the ulnar neck. The posterior interosseous nerve and artery are resected at the level of the distal radius for wrist denervation, followed by excision of the interosseous membrane from the ulnar aspect of the distal radius approximately 12 cm from the radiocarpal joint. Finally, the volar lip of the sigmoid notch is excised with a sagittal saw under C-arm guidance and smoothed out with a surgical burr. This allows for creation of a flush surface to prevent inadvertent dorsal positioning or dorsal tilt of the implant.

Now with adequate exposure, the radial trial implant is placed and preliminarily held in place with K-wires and a unicortical 3.5 cortical screw proximally. After appropriate alignment and position of the trial is confirmed, the most distal hole for the peg is drilled. The trial is removed, followed by placement of the radial plate component of the prosthesis with proximal fixation with 3.5 mm cortical screws. An 18 mm unicortical screw is inserted in the most distal hole and a 10 mm unicortical screw in the most proximal hole to prevent inadvertent periprosthetic fracture postoperatively from bicortical screw penetration.

An extramedullary resection guide is used for further resection of the ulnar shaft to the appropriate level. The guidepin is placed down the medullary canal of the ulnar shaft followed by serial reaming until excellent cortical chatter is encountered. The ulnar planer is then used to smooth out the surface of the cut ulna. The ulnar stem is inserted and impacted. The polyethylene ball is placed over the distal tip of the ulnar stem and articulated with the radial plate. The cover is placed over the polyethylene ball, and the appropriate set screws inserted. The wrist is then taken through full pronation and supination to ensure smooth motion and no mechanical block. C-arm imaging is obtained to verify good positioning of the prosthesis. The ulnar based retinaculum flap is then placed under the ECU to prevent ECU tendinitis, and this is re-attached to the radial portion of the extensor retinaculum. Wounds are closed in standard fashion and a sterile dressing applied. The patient is placed in a Munster splint with the forearm supinated.

*Postoperative Course for Our Patient*

The patient's postoperative course was uncomplicated. Incisions healed well and she was started in physical therapy at her two week appointment. At her most recent follow up, over five years after DRUJ arthroplasty with Scheker prosthesis, she had full wrist flexion, wrist extension, forearm pronation and supination which were symmetric to the contralateral side. She did report intermittent concerns of pain at the dorsal wrist and forearm, especially with repetitive motions, and never returned to her prior occupation as a bus driver. She is now retired and pain free. Radiographs from her five year follow up show the implant in place in good position without signs


Figure 3: Radiographs one year after DRUJ arthroplasty with Scheker implant.

of peri-prosthetic fracture or loosening (Figure 3).

**Research Work in Progress**

We performed a retrospective chart review of our patients who underwent the Aptis DRUJ arthroplasty, using clinic notes and radiographs. Our patients had a mean follow up of 727 days (range 13-2812 days). Patients had mean forearm pronation of 69 degrees and supination of 68 degrees, with wrist flexion 48 degrees, and extension of 47 degrees. This is compared to preoperative range of motion of 59 degrees pronation, 48 degrees supination, and 44 degrees each of wrist flexion and extension. The mean postoperative pain score was 3 out of 10. There were limited functional outcomes recorded with incomplete data on DASH scores, patient satisfaction, and return to work.

As there is limited literature on this semi-constrained total joint prosthesis, we have taken special interest in the complications following this procedure. Every patient with a complication has returned to our practice and followed through the resolution of that complication. Prior published studies report low complication and explant rates of 0-5%[23-28]. In our clinical series, there were 22 complications necessitating operative management in 18 of the 51 total patients (35%), with a total of 32 procedures undertaken to address these complications. A total of 5 implants were removed: three for infection, one for aseptic loosening, and one for nonunion of a peri-implant fracture. Three patients underwent revision of their prosthesis, 1 case for aseptic loosening and 2 patients for hardware failure. The most common complication was a periprosthetic fracture, occurring in 5 cases. There was no statistically significant difference in age, number of prior procedures, smoking, L&I involvement, or etiology of injury between patients who developed complications and those who did not.

In summary, our experience with the Aptis DRUJ arthroplasty provides a unique perspective on a relatively large group of patients. Providing a different institution's experience with the Aptis DRUJ arthroplasty is important in determining functional outcomes and implant survivorship of this prosthesis as well as identifying surgical pitfalls to improve outcomes and avoid complications. At our institution, we treat a very complex patient population with both complex pathology and social factors. Despite the higher than previously reported complication rate, the Aptis DRUJ arthroplasty is a good surgical option for treatment of DRUJ arthritis as well as DRUJ instability, especially as a salvage procedure in the patient with multiple prior failed DRUJ procedures. From understanding complications after these procedures to identifying factors associated with improved outcomes, we hope to progress the wellness of our patients as documented in the literature through prospective and retrospective research on our patients.

We are currently enrolling patients prospectively to determine functional outcome on our total DRUJ arthroplasty patients who are more than 2 years out from their surgery. Outcomes measures being collected include DASH, range of motion, grip strength, PRWE, return to work, and pain levels. Our patient cohort would represent the largest case series of the Aptis DRUJ arthroplasty performed at an institution independent from Dr. Scheker, the designer of the prosthesis. Early data collection points to a predictably satisfactory procedure, and high patient satisfaction with this procedure.

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# Proline 3-Hydroxylation of Type II Collagen Synthesized by a Rat Cell Line Suggests a Nucleus Pulposus Origin

David M. Hudson, PhD, Marilyn Archer, BS, MaryAnn Weis, BS, David R. Eyre, PhD, and Russell J. Fernandes, PhD

**Introduction**

By the age of fifty, 85 percent of the US population shows evidence of intervertebral disc disease. The basis most likely is a compromised structural collagen network leading to disc herniation. The Nucleus Pulposus (NP), the jelly-like material in the central region of the intervertebral disc, is a unique tissue characterized by an extensive extracellular matrix. The molecular mechanisms that enable the NP cells to assemble a functional matrix from a complex mix of collagens, proteoglycans and matrix proteins in the correct proportions are not well understood. The instability of NP cells in long-term monolayer culture has hampered such research. A cell line with a NP phenotype is thus desirable for such studies. We have reported that the Swarm rat chondrosarcoma cell line, RCS-LTC, maintains a cartilage-like phenotype in long-term monolayer culture. The large cells synthesize and deposit collagen types II, IX and XI in the extracellular matrix which are stabilized by pyridinoline cross-links at both the amino and carboxyl terminal ends (1). We report here that the matrix is fragile and highly hydrated containing 8 times more proteoglycan than collagen on a mass basis. By electron microscopy, only very thin collagen fibrils were observed indicating a NP-like matrix. A hypothesis that the cell line type II collagen had post-translational modifications characteristic of type II collagen from NP seemed reasonable. We have shown that Proline-944 residue in the $\alpha$1(II) chain of type II collagen is highly 3-hydroxylated in type II collagen from bovine NP (2). Using mass spectrometry we investigated the level of 3-hydroylation at Proline-944 in the $\alpha$1(II) chain of type II collagen from the RCS-LTC cell line.

**Methods**

*Cell culture*

The RCS-LTC cell line was maintained as monolayer or micromass cultures in DMEM containing BCS and ascorbate for a period of 2-4 weeks. For controls NP was isolated from frozen rat and bovine intervertebral disc.

*Microscopy*

For light microscopy, micromass cultures were fixed, sectioned (1$\mu$) and treated with Mallory's stain. For electron microscopy, cultures were post fixed in osmium, embedded in plastic and thin sections stained with uranyl and lead.

*Estimation of Collagen and Proteoglycan Content*

Proteoglycan content in samples was measured by a modification of the dimethyl Methylene Blue dye binding assay of Chandrasekar et al (3). Determination of hydroxyproline as a measure of collagen content was performed by a modification of the procedure of Schwartz et al (4).

*Electrophoresis and Mass Spectrometry*

Cell layer collagen was extracted with 100 $\mu$g/ml pepsin in 3% acetic acid. Collagen chains were resolved by Laemmli SDS-PAGE and visualized by Coomassie blue staining. In-gel trypsin digests of $\alpha$1(II) chains were analyzed on an LTQ XL linear quadrupole ion-trap mass spectrometer (2).

**Results**

Light micrographs of thin sections of RCS-LTC micromass cultures cut perpendicular to the cover slip showed cellularity in multilayers and an extensive matrix between the cells (Figure 1). These cells produce 7 - 8 times more proteoglycan than collagen on a weight basis for all the days in

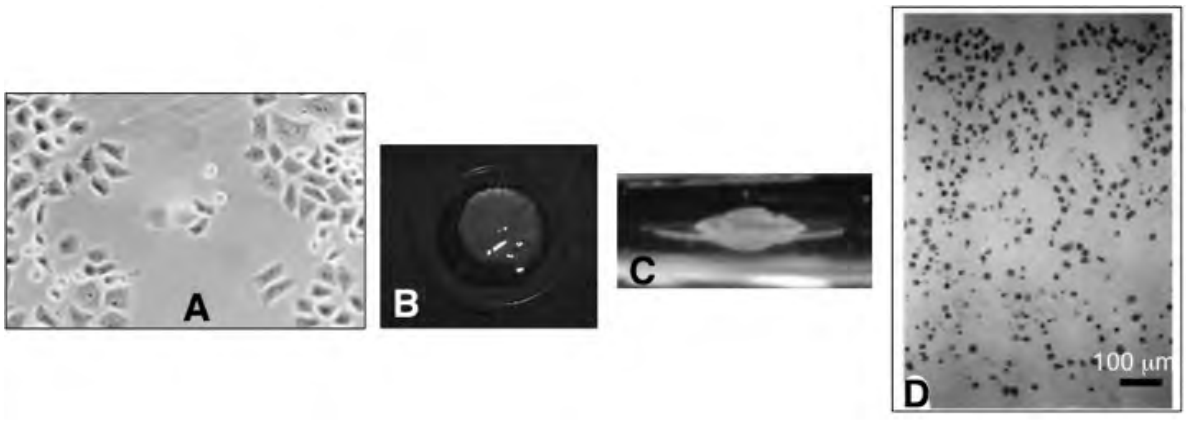


Figure 1: Morphology and general appearance of the RCS-LTC cells.
(A) monolayer (phase contrast, 20X), (B) micromass culture, 14 days top view showing a jelly-like matrix (C) micromass culture, 14 days side view showing the thickness of the neo-tissue (D) Light micrograph of 1 mm thin section of RCS-LTC micromass cultures cut perpendicular to the cover slip showing the full height of the culture, cellularity in multilayers and an matrix between the cells. (Bar =100 Bar = 100 $\mu$m)

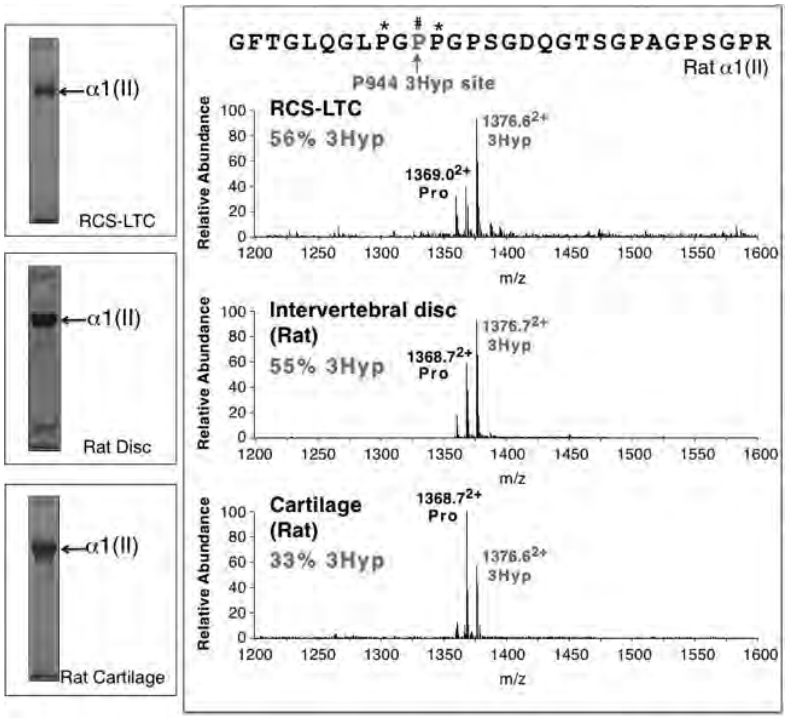


Figure 2: Mass spectrometry of Proline-944 hydroxylation in RCS-LTC type II collagen chains.
In α1(II) chains from RCS-LTC (top panel), 56% of Proline-944 is 3-hydroxylated, and comparable to 55% in α1( (II) chains from rat intervertebral disc (middle panel). Cartilage α1(II) chains show a lower 3-hydroxylation at Proline-944 (lower panel). This high 3-hydroxylation is observed in bovine and human intervertebral discs as noted in Table 1.

| | % hydroxylation Proline-944 in α1(II) collagen chain | |
|---|---|---|
| | Intervertebral disc | Cartilage |
| RAT | 40 (NP) + 65 (AF) | 33 |
| BOVINE | 35 (NP) | 10 |
| HUMAN | 40 (NP) + 64 (AF) | 10 |

Table 1: NP, Nucleus Pulposus. AF, Annulus Fibrosus.

culture. 85% of the proteoglycans accumulated in the cell layer. The high proportion of proteoglycans can explain the highly hydrated matrix that is characteristic of these cells. Mass spectrometry of Proline-944 in the α1(II) chain from the cultures showed 56% 3-hydroxylation, comparable to rat (55%) and bovine NP (40%) but very much unlike in rat cartilage (33%) (Figure 2).

**Discussion**

It was only recently, that the parental Swarm rat tumor was traced to have originated from a spinal neoplasm (5, 6). The emerging and established biochemical data from our and other labs seem to support its origin. The NP cell markers HIF-1α, glypican-3, CD44, CTGF/CNN2 and Sox 9 (8) are expressed by cells from the tumor (7-11). Within a week in micromass culture the RCS-LTC cells elaborated a highly hydrated jelly-like matrix rich in proteoglycans and collagens that resembled nucleus pulposus but not endplate cartilage. This included a high 8:1 proteoglycan:collagen ratio, a high level of 3-hydroxylation and a collagen network of thin fibrils. The type II collagen fibrillar network strengthens the jelly-like nucleus pulposus of the intervertebral disc contributing unique properties to act as a shock absorber in the spinal column. The fibrils in NP are assembled from collagen types II, IX and XI into unique thin diameter fibrils quite unlike the thick fibrils found in hyaline cartilage. How similar collagen molecules assemble together into heteropolymers of diverse diameters in tissues of different material properties is still unclear.

**Significance**

This cell line could thus be a model system for studying NP collagen fibrillogenesis and heteropolymer assembly. Recent evidence points to the basic structure of type II collagen chains as being involved in the assembly. An association of high levels of 3-hydroxylation of the Proline-944 residue and the assembly of thin collagen chains in NP and jelly like compositional homologue the vitreous humor has been observed. A biological understanding of how an evolutionarily conserved and fundamental post-translational modification in collagen subunits can alter assembly properties to create diverse polymeric architecture will significantly expand basic knowledge of collagen fibril assembly.

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# Psychometric Properties of the Simple Shoulder Test in Over 400 Patients Undergoing Shoulder Arthroplasty

Jason E. Hsu, MD, Stacy M. Russ, BA, Jeremy S. Somerson, MD, Anna Tang, BS, Winston J. Warme, MD, and Frederick A. Matsen III, MD

**Background**

As efforts to determine value of orthopaedic care increase, the use of patient-reported outcomes is becoming more important. The Simple Shoulder Test (SST) is a brief patient-reported survey that is commonly used to report outcomes after various shoulder procedures and to communicate these results to prospective patients (Figure 1). The objective of this study was to measure the validity (content, construct, and criterion) and responsiveness of the SST in patients undergoing shoulder arthroplasty.

**Methods**

SST scores, SF-36 scores, and satisfaction scores were collected pre-operatively and two-years post-operatively from 408 patients undergoing shoulder arthroplasty. Of the 408 patients, 261 (64%) were male and 147 (36%) were female. The average age was 64.0 +/- 12.1 years. Responsiveness of the SST was assessed by comparing preoperative and two-year postoperative scores. Patients graded their satisfaction on the following scale – 0: delighted, 1: pleased, 2: mostly satisfied, 3: mixed – about equally satisfied/dissatisfied, 4: mostly dissatisfied, 5: unhappy, 6: terrible. Floor and ceiling effects were determined. Criterion validity was determined by correlating the SST with the SF-36. Construct validity was tested through five clinical hypotheses regarding satisfaction, comorbidities, insurance status, previous failed surgery, and narcotic usage.

**Results**

Scores after shoulder arthroplasty improved from 3.9±2.8 pre-operatively to 10.2±2.3 post-operatively ($p<0.001$). The change in SST correlated strongly with patient satisfaction ($p<0.001$) (Figure 2). The SST had large Cohen's D effect sizes (ES) and standardized response means (SRM); the ESs and SRMs of the SST were larger than those of each individual domain of the SF-36. Floor and ceiling effects were found in 8.9% and 15.3% of patients, respectively. The correlation between SST and physical domains of the SF-36 was moderate, while correlation between SST and mental domains was fair to slight. Criterion validity was supported by significant differences between satisfied and unsatisfied patients (Table I), those with more severe and less severe comorbidities,

| Simple Shoulder Test | |
|---|---|
| # 1 | Is your shoulder comfortable with your arm at rest by your side? |
| # 2 | Does your shoulder allow you to sleep comfortably? |
| # 3 | Can you reach the small of your back to tuck in your shirt with your hand? |
| # 4 | Can you place your hand behind your head with the elbow straight out to the side? |
| # 5 | Can you place a coin on a shelf at the level of your shoulder without bending your elbow? |
| # 6 | Can you lift one pound (a full pint container) to the level of your shoulder without bending your elbow? |
| # 7 | Can you lift eight pounds (a full gallon container) to the level of the top of your head without bending your elbow? |
| # 8 | Can you carry 20 pounds at your side with the affected extremity? |
| # 9 | Do you think you can toss a softball underhand 10 yards with the affected extremity? |
| # 10 | Do you think you can throw a softball overhand 20 yards with the affected extremity? |
| # 11 | Can you wash the back of your opposite shoulder with the affected extremity? |
| # 12 | Would your shoulder allow you to work full-time at your usual job? |

Figure 1: Simple Shoulder Test (SST).

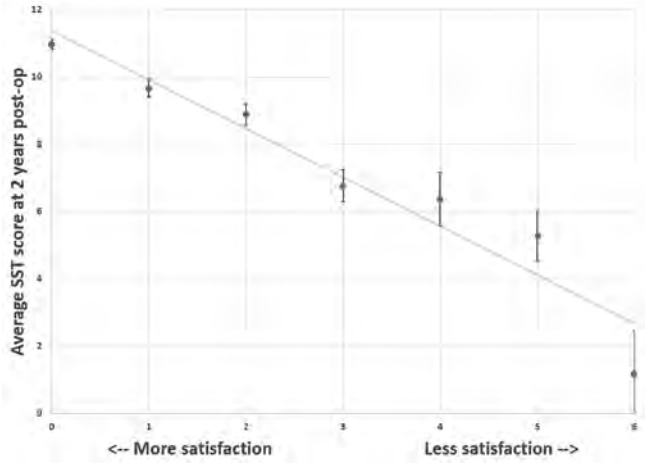


Figure 2: Criterion validity was supported by significant differences between satisfied and unsatisfied patients.

| 1) Satisfaction | Pre-op SST (mean ± SE*) | Post-op SST (mean ± SE) |
|---|---|---|
| Delighted (n = 126) | 4.0 ± 0.1 | 11.0 ± 0.3 |
| Pleased (n = 107) | 3.4 ± 0.3 | 9.7 ± 0.2 |
| Mostly satisfied (n = 61) | 3.4 ± 0.3 | 8.9 ± 0.3 |
| Mixed (n = 52) | 3.1 ± 0.5 | 6.8 ± 0.4 |
| Mostly dissatisfied (n = 19) | 4.4 ± 0.8 | 6.4 ± 0.8 |
| Unhappy (n = 14) | 3.9 ± 0.7 | 5.3 ± 0.9 |
| Terrible (n = 9) | 4.1 ± 1.3 | 1.2 ± 0.0 |
| p-value | | <0.001 |
| **2) Comorbidities** | **Pre-op SST** (mean ± SE) | **Post-op SST** (mean ± SE) |
| ASA 1 (n = 43) | 5.0 ± 0.5 | 10.3 ± 0.3 |
| ASA 2 (n = 242) | 3.8 ± 0.2 | 9.3 ± 0.2 |
| ASA 3 (n = 96) | 2.9 ± 0.3 | 7.8 ± 0.4 |
| ASA 4 (n = 3) | 1.0 ± 1.0 | 5.3 ± 1.7 |
| p-value | <0.001 | <0.001 |
| **3) Medicaid / Work Comp** | **Pre-op SST** (mean ± SE) | **Post-op SST** (mean ± SE) |
| Yes (n = 40) | 2.4 ± 0.4 | 6.6 ± 0.6 |
| No (n = 368) | 3.8 ± 0.1 | 9.3 ± 0.2 |
| p-value | 0.003 | <0.001 |
| **4) Previous Failed Surgery** | **Pre-op SST** (mean ± SE) | **Post-op SST** (mean ± SE) |
| Yes (n = 127) | 3.4 ± 0.2 | 8.2 ± 0.3 |
| No (n = 256) | 3.7 ± 0.2 | 9.3 ± 0.2 |
| p-value | 0.260 | 0.002 |
| **5) Pre-operative Narcotics** | **Pre-op SST** (mean ± SE) | **Post-op SST** (mean ± SE) |
| Yes (n = 97) | 2.9 ± 0.3 | 7.6 ± 0.4 |
| No (n = 311) | 3.9 ± 0.2 | 9.4 ±0.2 |
| p-value | 0.001 | <0.001 |

Table I: Criterion validity. *SE, standard error

Workers' Compensation or Medicaid and other types of insurance, those with and without previous failed shoulder surgery, and those on and those not on narcotic pain medication before surgery (p<.005) (Table I).

**Conclusion**

Despite its low cost, brevity and simplicity, the SST is a valid and responsive patient-reported outcome measure that is practical for assessing the outcomes of shoulder arthroplasty.

# Metatarsal Shape and Foot Type: A Geometric Morphometric Analysis

Scott Telfer, EngD, Matthew W. Kindig, MS, Bruce J. Sangeorzan, MD, and William R. Ledoux II, PhD

**Introduction**

Flat feet and feet with high arches have been associated with an increased risk of pain and disability [1]. Researchers have studied the functional differences that occur between foot types in terms of kinematics and kinetics, differences in bone-to-bone positioning, and overall morphology. However, information relating to morphological differences within bones across foot types and the implications of these, particularly at the forefoot, is more limited.

Bone is known to alter its morphology in response to altered loading conditions, perhaps most clearly demonstrated by the reduced humeral torsion seen in the dominant arm of throwing athletes [2]. Thus, the hypothesis that bone morphology differs between foot types is supported by a body of evidence showing the loading pattern on the plantar surface of the foot differs between foot types, with planus feet tending to have increased contact area and lower peak pressures [3], and cavus feet tending to show increased plantar pressures, particularly under the forefoot [4]. It is also possible that specific bone morphological features may predispose the development of the foot towards a particular type.

For this study, we hypothesized that there would be statistically significant differences in the 3D morphology of metatarsal bones between foot types and sex. The primary modes of geometric variation related to these differences were also determined.

**Methods**

In this study, 65 feet were categorized into four foot types: pes cavus, neutrally aligned, asymptomatic pes planus, and symptomatic pes planus. Metatarsal bones were segmented from CT scan data, and a geometric morphometric approach was used to quantify and assess differences in the shape of the metatarsals. This approach consists of a group of techniques that allow shape data to be processed and analyzed. Generalized Procrustes analysis was used to obtain shape variables from the bones. Principal component analysis was performed to find the modes of shape variation, and component weights analyzed to determine those that were significantly different between bone and sexual groups. Modes of variation found to be significantly different were visually inspected to determine their anatomical relevance.

| | ANOVA (*P*-value) | Foot type | *P*-value for pairwise comparisons (Procrustes distance between groups)) | | |
|---|---|---|---|---|---|
| | | | NA | APP | SPP |
| Met 1 | <0.0001 | | | | |
| | | PC | **<0.0001 (0.059)** | **<0.0001 (0.075)** | **<0.0001 (0.061)** |
| | | APP | 0.0298 (0.031) | - | **0.0045 (0.041)** |
| | | SPP | 0.1375 (0.029) | - | - |
| Met 2 | <0.0001 | | | | |
| | | PC | **0.0032 (0.027)** | **0.0001 (0.043)** | **0.0003 (0.035)** |
| | | APP | **0.0003 (0.031)** | - | **0.0003 (0.027)** |
| | | SPP | **0.0056 (0.027)** | - | - |
| Met 3 | <0.0001 | | | | |
| | | PC | 0.24 (0.02) | **0.0028 (0.031)** | 0.038 (0.027) |
| | | APP | **0.0033 (0.027)** | - | **0.0079 (0.028)** |
| | | SPP | 0.028 (0.025) | - | - |
| Met 4 | 0.0068 | | | | |
| | | PC | 0.06 (0.024) | **0.007 (0.03)** | 0.029 (0.029) |
| | | APP | 0.044 (0.024) | - | 0.14 (0.023) |
| | | SPP | 0.32 (0.02) | - | - |
| Met 5 | <0.0001 | | | | |
| | | PC | 0.024 (0.03) | **0.0003 (0.041)** | 0.12 (0.028) |
| | | APP | 0.0124 (0.029) | - | 0.028 (0.031) |
| | | SPP | 0.135 (0.025) | - | - |

Table 1: Foot type group analysis. PC: pes cavus; NA: neutrally aligned; APP: asymptomatic pes planus; SPP: symptomatic pes planus.

**Results**

All metatarsals were revealed to have significant shape differences that were associated with foot type ($p$<0.01), and subsequently several statistically significant differences were found for the pairwise comparisons (Table 1). Of particular note, all pairwise comparisons for the second metatarsal were significantly different, and across all metatarsals the cavus foot type was significantly different from the asymptomatic planus foot type. Similarly, for the first through third metatarsals, asymptomatic planus bones were found to be different from those in symptomatic planus feet. For the analysis of shape differences associated with sex, statistically significant differences were found for the first ($p$=0.022) and fourth ($p$=0.003) metatarsals.

Principal components 1 and 3, relating to the frontal and sagittal plane cross-sectional area of the bone and the transverse plane curvature respectively, were found to be the largest significantly different components for foot type differences in the second metatarsal (Figure 1).

**Discussion**

Differences were seen between the asymptomatic and symptomatic

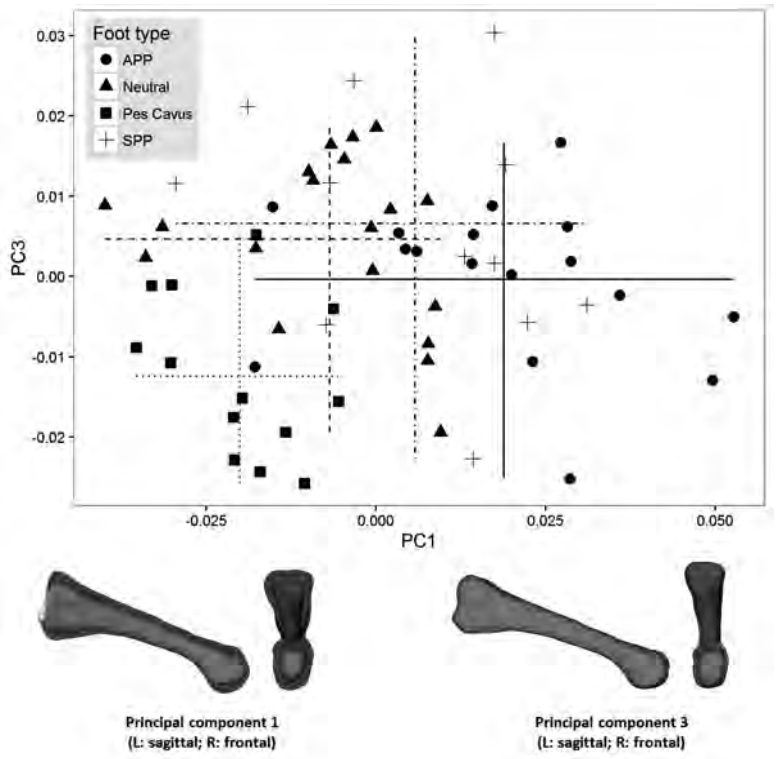


Figure 1: Largest significantly different principal components of the second metatarsal for foot type. Component scores are plotted in tangent space, with lines representing range and mean (top). Neutrally aligned, pes cavus, asymptomatic pes planus and asymptomatic pes planus ranges are represented by solid, dashed, dotted, and dotdash lines respectively. Graphical representations of maximum and minimum shape variation for each component are also shown (bottom). PC: pes cavus; NA: neutrally aligned; APP: asymptomatic pes planus; SPP: symptomatic pes planus. Please note that for visualization purposes, axes scales are not equal.

planus groups for the first through third metatarsals. This suggests that there may be altered loading conditions on these metatarsals, and we hypothesize that this may be as a result of gait modifications due to pain [5].

Male first and fourth metatarsals were found to be wider, in line with previous findings [6], and less curved than those from females. Evidence does exist that males have higher peak pressures at the forefoot [7], however differences were only found for two of the five metatarsals, making the effects of sex inconsistent.

Cohort studies with an extended follow up may provide an accurate picture of how the shape changes identified in this research continue to manifest as individuals age. However, numerical modelling approaches in combination with cadaver simulations may allow the forces applied by individual muscles and ligaments within different foot types to be studied and provide insight as to whether these could potentially explain the changes in morphology demonstrated here. Both planus and cavus foot types have been associated with an increased risk of stress fractures and this approach may provide insights into the mechanisms behind these injuries.

**Significance**

Overall, these findings suggest that the metatarsal bones have distinct morphological characteristics that are associated with foot type and sex. This has implications for our understanding of anatomy and the development of computational models of the foot for studies of injury mechanisms.

**Acknowledgments**

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# P3h3-null and Sc65-null Mice Phenocopy the Collagen Lysine Under-Hydroxylation and Cross-Linking Abnormality of Ehlers-Danlos Syndrome Type VIA

David M. Hudson, PhD, MaryAnn Weis, BS, Jyoti Rai, MS, Kyu Sang Joeng, Brendan H. Lee, Roy Morello, and David R. Eyre, PhD

**Introduction**

Collagen post-translational modifications have evolved to support animal life on land [1]. In the last decade, new insights on the significance of a relatively rare collagen modification, prolyl 3-hydroxylation, have arisen from the discovery that recessive forms of osteogenesis imperfecta (OI) are caused by biallelic mutations in prolyl 3-hydroxylase 1 (P3H1; *Lepre1*), CRTAP (*Leprel3*) or CypB (*PPIB*) [2]. These proteins, which comprise the P3H1 enzyme complex, act on nascent collagen chains in the ER. CRTAP and P3H1 are part of a family of gene products that also includes P3H2 (*Leprel1*), P3H3 (*Leprel2*) and Sc65 (*Leprel4*). Human mutations in P3H2 have been shown to cause the eye disorder high myopia [3]. We recently reported increased skin fragility and low bone mass in a mouse model lacking Sc65 compared to wild-type littermates [4]. Furthermore, a potential interplay between P3H3 and Sc65 was observed, which we predicted functions as part of a LH1 enzyme complex consisting of LH1 (*Plod1*), Sc65, P3H3 and CypB. In order to understand more about the collagen substrate specificities of P3H3 and the function of Sc65, two genetically engineered mice lacking the genes for P3H3 and SC65 were generated and screened for collagen post-translational variances. The aim was to see if any known sites of 3Hyp in the various collagen types were underhydroxylated and also if other post-translational modifications, in particular lysine modification and cross-linking quality were affected. We hypothesized that the loss of P3H3 would disrupt collagen cross-linking through tissue-specific underhydroxylation of cross-linking lysines of type I collagen.

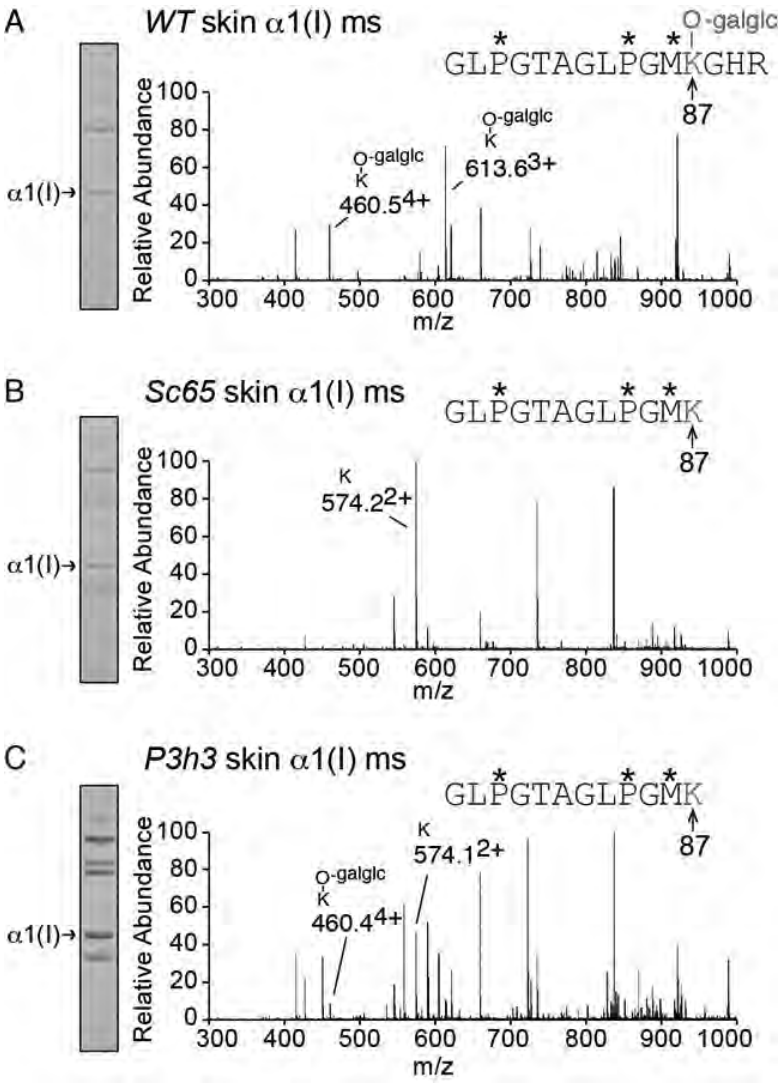


Figure 1: Underhydroxylation at cross-linking Lys87 in *P3h3*$^{-/-}$ and *Sc65*$^{-/-}$ skin collagen. LC-MS profiles of in-gel trypsin digests of the α1(I) collagen chains from WT, Sc65-/- and P3h3-/- mouse skin. (A) MS profile of α1(I) from WT mouse skin reveals 100% glucosyl-galactosyl-Hyl87. In *Sc65*$^{-/-}$ (B) and *P3h3*$^{-/-}$ (C) mouse skin, Lys87 is 100% unmodified.

**Methods**

The *P3h3* knockout (*P3h3*$^{-/-}$) mouse was generated using embryonic stem cells obtained from the Knockout Mouse Project (KOMP) repository [4]. Tissues from the *Sc65*$^{-/-}$ mice [5] were analyzed in comparison to *P3h3*$^{-/-}$ and respective WT tissues. The post-translational modifications 3-hydroxyproline, 5-hydroxylysine (Hyl), glcgal-Hyl and gal-Hyl glycosides were quantified at specific sites in collagen α-chains. Collagen α-chains were cut from SDS-PAGE gels and subjected to in-gel trypsin digestion. Samples were also digested with bacterial collagenase with and without borohydride reduction

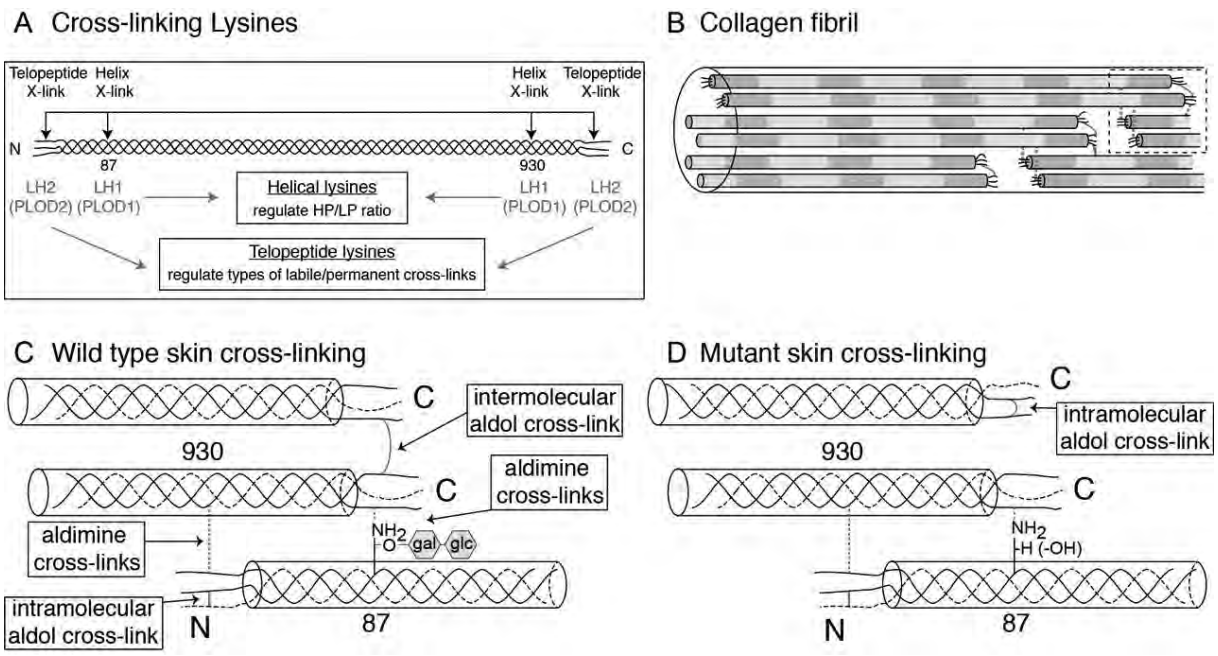


Figure 2: Model for altered collagen cross-linking in *P3h3*$^{-/-}$ and *Sc65*$^{-/-}$ mouse skin. Collagen cross-linking is a highly regulated process (A). In the fibril, collagen molecules are spatially arranged such that cross-linking conditions are optimal (B). In wild-type skin, fully glycosylated Hyl87 preferentially forms intermolecular aldimine and aldol cross-links with telopeptide lysine aldehydes (C). In the *P3h3*$^{-/-}$ and *Sc65*$^{-/-}$ mouse tissues the LH1 substrates are underhydroxylated and subsequently under-glycosylated. The result of underhydroxylated Lys87 could be a collagen fibril that is less cross-linked and consequently skin with increased laxity (D).

and total collagenase digests were resolved into peptide fractions by C8 reverse-phase HPLC and individual fractions were analyzed by tandem mass spectrometry. The pyridinoline cross-link content of collagen samples was determined by reverse-phase HPLC and fluorescence monitoring after acid hydrolysis in 6M HCl for 24 hrs at 108°C.

**Results**

Both homozygous mouse strains, *Sc65*$^{-/-}$ and *P3h3*$^{-/-}$, were viable and showed no skeletal growth defects or other obvious abnormalities when observed in the cage environment. Fibrillar collagens isolated from several tissues from both knockout mice revealed a common lysine underhydroxylation effect at helical-domain cross-linking sites. No significant effect on prolyl 3-hydroxylation was observed across the spectrum of known 3-hydroxyproline sites in any major collagen type. However, collagen type I extracted from both *Sc65*$^{-/-}$ and *P3h3*$^{-/-}$ skin revealed the same abnormal chain pattern on SDS-PAGE with an over-abundance of a $\gamma_{112}$ cross-linked trimer. The latter proved to be from native molecules cross-linked by intramolecular aldols at both ends. Furthermore, the ratio of HP/LP cross-links in bone of both *Sc65*$^{-/-}$ and *P3h3*$^{-/-}$ mice was reversed compared with wild-type, consistent with the level of lysine underhydroxylation at cross-linking sites.

**Discussion**

Collagen lysine hydroxylation is controlled by more complex protein machinery in the ER than previously appreciated. The effect on cross-linking lysines in the current mouse models was quantitatively very similar to that previously observed in EDSVIA human and *Plod1*$^{-/-}$ mouse tissues [6], suggesting that P3H3 and/or SC65 mutations could be the cause of as yet undefined EDS-variants. Together with the observed effects on cross-linking, the findings have important implications for understanding how the various prolyl 3-hydroxylase gene family members have evolved to form ER complexes and modify collagen.

**Significance**

This is the first direct evidence for a cooperative interaction between a lysyl- and a prolyl-hydroxylase in collagen biosynthesis. The functional significance of collagen post-translational variability is still not fully understood, though for fibril-forming collagens the number, placement and chemistry of covalent intermolecular cross-links seem to be critically important regulators of tissue function.

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**Note**

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# Evaluation of Appropriate Venous Thromboembolism Prophylaxis in Orthopaedic Trauma Patients with Symptom-Driven Vascular and Radiographic Studies

Christopher M. Domes, MD, Anneliese M. Schleyer, MD, James M. McQueen, BS, Ronald F. Pergamit, MPA, and Daphne M. Beingessner, MD

**Objective**

To evaluate venous thromboembolism (VTE) prophylaxis adherence and effectiveness in orthopaedic trauma patients who had vascular or radiographic studies showing deep vein thromboses (DVTs) or pulmonary emboli (PEs).

**Design**

Retrospective review

**Setting**

This study was conducted at a level I trauma center that independently services a 5 state region. The medical records of patients treated surgically between July 2010 and March 2013 were interrogated using a technical tool that electronically captures thrombotic event data from vascular and radiologic imaging studies via natural language processing.

**Patients**

476 orthopaedic trauma patients who underwent operative treatments for orthopaedic injuries and had symptom-driven diagnostic VTE studies.

**Main Outcome Measurements**

Patients were evaluated for hospital guideline directed VTE prophylaxis adherence with mechanical or chemical prophylaxis. Patient demographics, associated injuries, mechanism of injury, and symptoms that led to imaging for a VTE were also assessed.

**Results**

Of the 476 orthopaedic patients who met inclusion criteria, 100 (mean age 52.3 median 52, standard deviation (SD) 18.3, 70% men) had positive VTE studies. 376 (age 47.3, SD 17.3, 69% men) had negative VTE studies. Of the 100 patients with VTE, 63 DVTs and 49 PEs were found. Eight-five percent of all patients met hospital guideline VTE prophylaxis standards.

| Demographics | Positive VTE (N=100) | Negative VTE (N=376) | P value |
|---|---|---|---|
| Average Age | 52.3 | 47.3 | 0.039* |
| Sex, % Male | 70 | 69 | 0.8 |
| BMI | 29.3 | 29.2 | 0.9 |
| Length of Hospital Stay, Days | 19.1 | 18.2 | 0.62 |
| Hospital Day VTE Diagnosed | 7.3 | 6.7 | 0.4 |
| Injury Severity Score | 24 | 19.9 | 0.015* |
| | | | |
| **Mechanism** | | | |
| Motor vehicle collision | 36 (36%) | 121 (32%) | 0.48 |
| Fall from height | 16 (16%) | 48 (13%) | 0.4 |
| Ground level fall | 13 (13%) | 50 (13%) | 0.94 |
| Pedestrian vs Automobile | 6 (14%) | 38 (10%) | 0.06 |
| Chronic medical condition | 8 (8%) | 33 (9%) | 0.18 |
| Other | 21 (21%) | 86 (23%) | 0.69 |
| **Injury Location** | | | |
| LE | 23 (23%) | 152 (40%) | 0.005* |
| UE | 9 (9%) | 16 (4%) | 0.04* |
| Spine | 10 (10%) | 38 (10%) | 0.98 |
| Pelvis | 14 (14%) | 15 (4%) | 0.001* |
| Both LE | 8 (8%) | 23 (6%) | 0.49 |
| UE, LE | 8 (8%) | 19 (5%) | 0.26 |
| LE, Pelvis | 7 (7%) | 26 (7%) | 0.98 |
| LE, Spine, Pelvis | 7 (7%) | 12 (3%) | 0.084 |
| Other Combinations | 14 (14%) | 75 (20%) | 0.18 |
| **Associated Injury** | | | |
| None | 82 (82%) | 248 (66%) | 0.001* |

Table 1: Demographics, Mechanism, injury location, and associated injury for patients with Positive and Negative VTE studies. * Denotes significant difference p<0.05. BMI- Body Mass Index, VTE- Venous Thromboembolism, LE- Lower Extremity, UE- Upper Extremity

| Signs and Symptoms | Positive VTE (N=100) | Negative VTE (N=376) | P Value |
|---|---|---|---|
| Desaturations | 15 (15%) | 93 (25%) | 0.038* |
| Tachycardia | 14 (14%) | 28 (7%) | 0.04* |
| Desaturations, Tachycardia | 22 (22%) | 62 (16%) | 0.199 |
| Swelling | 15 (15%) | 61 (16%) | 0.77 |
| Lower Extremity Pain | 8 (8%) | 29 (8%) | 0.924 |
| Swelling, Lower Extremity Pain | 18 (18%) | 93 (25%) | 0.157 |
| Other | 7 (7%) | 10 (3%) | 0.37 |
| Lower Extremity Pain, Tachycardia | 1 (1%) | 0 | 0.052 |

Table 2: Signs and symptoms that led to VTE evaluation; * indicated p <0.05

**Conclusion**

The study population had better than previously reported VTE prophylaxis adherence, however, patients still developed VTEs. This may be due to inadequate VTE prophylaxis for this select population or despite application of VTE prophylaxis the traumatic insult is unable to be safely overcome with current preventive therapies.

**Level of Evidence**

III

# Rapid-Throughput Skeletal Phenomics in Zebrafish

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New advances in genomic sequencing have revolutionized our ability to identify genes important for human skeletal health, yet our ability to profile phenomes -- i.e. to acquire in-depth phenotypic profiles at the scale of the whole organism -- remains limited. In this context, the development of technologies for phenomic profiling that approach the scale and efficiency of genomic methods hold significant potential to advance our understanding of human health. In this project, we developed a rapid-throughput, highly sensitive workflow to test the in vivo impact of genes on adult skeletal health by exploiting the amenability of zebrafish to large-scale gene mutation and whole-body phenomic analysis. We developed microCT-based methods and a segmentation algorithm, FishCuT, that enable rapid (<5min/fish) whole-body phenomic profiling of the axial skeleton of adult zebrafish (Fig 1). Using FishCuT, we analyzed ~20,000 different phenotypic data points, comprising one of largest phenotypic analyses of the adult vertebrate skeleton performed to date. We demonstrate the potential for phenomic patterns to confer heightened sensitivity, with similar specificity, in discriminating mutant populations compared to analyzing individual vertebrae in isolation, even when the latter is performed at higher resolution. To anchor our assay to human genotypes and phenotypes, we analyzed zebrafish models of human monogenetic bone disorders. We identify new skeletal phenotypes in zebrafish models of brittle bone disease, *bmp1a-/-* and *plod2-/-*, which underlie a form of Osteogenesis Imperfecta and Bruck Syndrome, respectively. We also identify high tissue mineral density in a zebrafish model of thyroid stimulating hormone receptor (*tshr*) hyperactivity (opallus), which is associated with high BMD in humans. Finally, we develop phenome-based allometric (the growth of body parts at different rates, resulting in a change of body proportions—Ed.) models and show that they are able to discriminate mutant phenotypes masked by alterations in growth. This study advances the use of zebrafish as a rapid, high-content model of musculoskeletal health, reveals core advantages of skeletal phenomic analysis applicable to other vertebrate systems, and provides a unifying framework for systematic mapping of gene-to-phenome relationships in a large number of mutant populations. By doing so, this study makes strides towards enabling rapid testing and functional prediction of candidate skeletal genes implicated in human genetic studies.

**Note**

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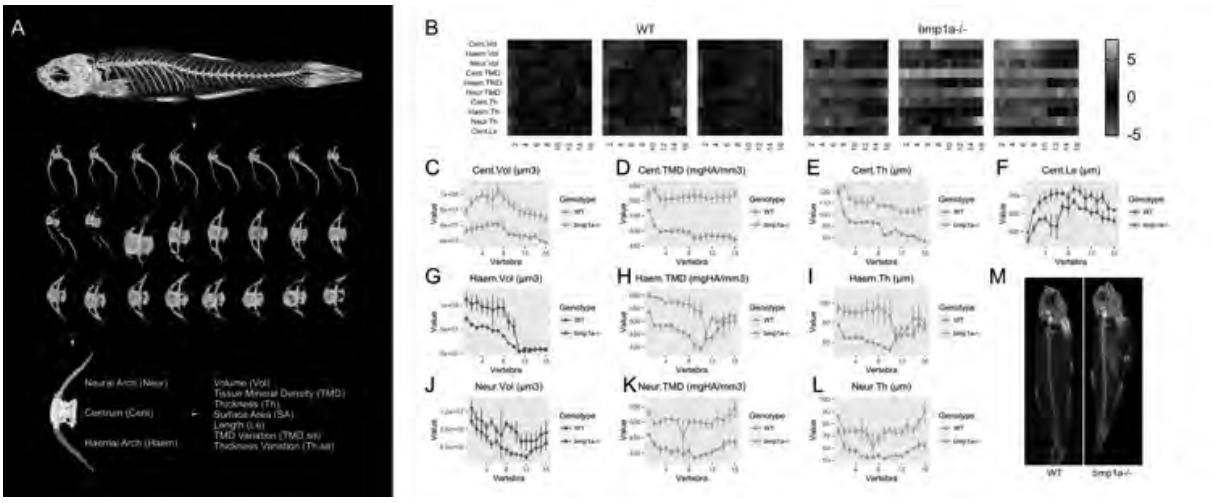


Figure 1: Schematic of workflow. (A) Using whole-body microCT scans, FishCuT isolates individual vertebrae, segments each vertebra into three elements, and computes traits in each element. (B) Standard scores are computed and arranged into "skeletal barcodes" that facilitate data visualization. Shown are barcodes for *bmp1a-/-* mutants (n=3/group). (C-L) Traits in *bmp1a-/-* mutants plotted as a function of vertebra. Those with a significant difference are colored in a lighter coloring scheme. (M) Max intensity projection of microCT scans.

# Static Preloading: A Previously Unrecognized Inhibitor of Bone Anabolism

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**Introduction**

It is well recognized that dynamic loading serves as an anabolic stimulus for bone while static loading alone is either ignored or is catabolic. However, dynamic lower limb loading during human exercise is achieved in the context of static loading (e.g., standing between exercise repetitions). Further, all animal models of skeletal loading utilize static preloading (SPL: a constant static load upon which dynamic loading is superimposed) in order to enable stable dynamic loading (Fig 1). The magnitude of SPL that has been implemented *in vivo* varies widely, even for the same model (1,2,3). For example, in the predominant model used to study trabecular bone adaptation (i.e., murine tibia axial compression), the SPLs typically range from -0.5 to -2.0 N, which are substantially larger than the forces encountered during normal ambulation (-0.1 N). Interestingly, the literature also suggests that the lower the SPL, the smaller the dynamic loading magnitude that is required to induce an anabolic response (4,5). We therefore hypothesized that SPL mitigates bone anabolism induced by dynamic mechanical loading. We tested this hypothesis in our newly developed mouse model that enables stable off-axial dynamic loading of the murine tibia but can be utilized with SPLs as small as 0.01 N.

**Materials and Methods**

Mice were calcein labeled (d 10, 19) and sacrificed at d 22. The morphology of the proximal tibia metaphysis of loaded and contralateral tibia were assessed by mCT (SCANCO VivaCT 40), and bone formation at the mid-shaft by dynamic histomorphometry.

**Results**

We found that the dynamic loading regimen, when superimposed on a very small SPL (-0.05 N), significantly increased trabecular BV/TV and mid-shaft periosteal bone formation rate (p.BFR) vs contralateral tibiae. In contrast, increasing the SPL to -0.5 N completely mitigated the anabolic response for trabecular bone. For cortical bone, the -0.5 N SPL enabled only 36% of the p.BFR response that was induced with a -0.01 N SPL. Finally, we found that a -1.5 N SPL was catabolic for trabecular bone and significantly reduced rp.BFR (vs -0.05 N SPL; Fig 2a, b).

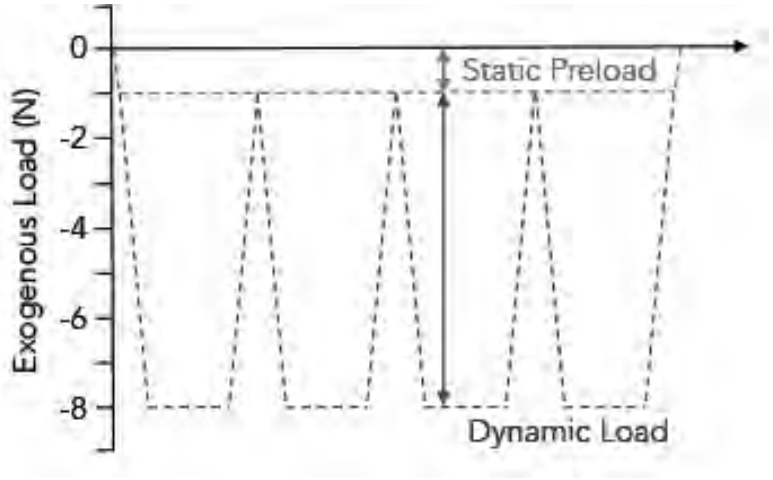


Figure 1: Schematic of static preload. All in vivo bone loading models require some magnitude of static preload to ensure reproducible dynamic loading. In this example, the bone is exposed to a -7 N trapezoidal dynamic compressive loading regimen superimposed upon a -1 N static preload.

**Discussion**

While preliminary, these data suggest that SPLs are a previously unrecognized, but critical inhibitor of bone's anabolic response to dynamic loading. We believe that this ubiquitous aspect of activity based loading may underlie, in part, why skeletal loading regimens have sometimes produced equivocal results in both pre-clinical models and human exercise trials.

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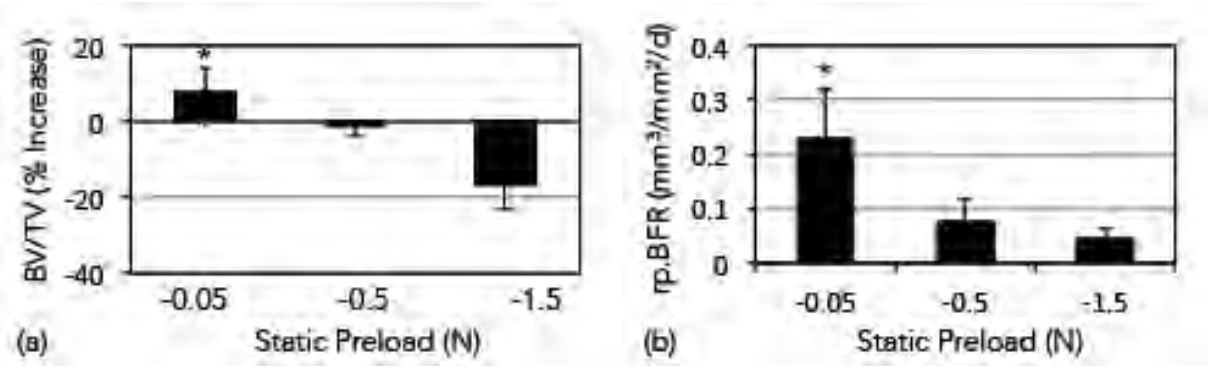


Figure 2: Static preloading mitigates bone response to dynamic loading. The SPL of -0.05 N significantly increased trabecular BV/TV (a) and periosteal bone formation at the tibia mid-shaft (b; * $p < 0.05$ vs -1.5 N SPL).

**Acknowledgements**

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# Excessive Clavicular Resection Treated with Clavicular Lengthening, Sternoclavicular and Acromioclavicular Joint Stabilization – Case Report

Winston J. Warme, MD, Jeremy S. Somerson, MD, and Galen Mills, MS3

**Introduction**

Managing arthritis at the lateral end of the clavicle is a common orthopaedic intervention and arthroscopic or open Mumford (distal clavicle resection) procedures are straightforward and effective in reducing pain when patients fail non-operative management (1). However, researchers have found that excessive resections can be associated with symptomatic instability (2). Initial recommendations in Mumford's classic article were for the resection of ½ to an inch of distal clavicle (3). This degree of resection, (12-25 mm), is now known to destabilize the joint by damaging both the AC and CC ligaments to some degree. Some compromise of the former occurs with 2.3 mm resection in women and 2.6 mm resection in men (4). Eskola reported on improved results with <10 mm resection versus a cohort with resections >/= 10 mm (5). More recent studies have found decreased stability with increasing excisions, such that the current guidance is to resect 5 mm of bone to reliably eliminate bony contact (6), maintain maximal stability (7) and yield reliably good results (8).

The surgical management of symptomatic arthritis at the sternoclavicular joint, (SCJ), is less common and guidelines for resection vary widely (9). But, as with the ACJ, the recommended amount of resection seems to decrease as time goes on as anatomical studies are carried out and clinical experience is gained. Rockwood recommended 15 mm resection of the medial clavicle (10). Pingsmann felt 10 mm was adequate in 2002 (11), as did Katthagen (12). The attachment of the rhomboid or costoclavicular ligament has been shown to begin 10.3 mm from the medial end of the clavicle and, if maintained, is associated with improved postoperative joint stability (10) (13). Excessive bony resection and damage to the rhomboid ligament can lead to instability and pain, limiting use of the ipsilateral upper extremity. We present a case of excessive medial and lateral clavicular resection that benefitted from clavicular lengthening and revision sternoclavicular joint stabilization using allograft hamstring tendon, as well as acromioclavicular stabilization and discuss the considerations around adequacy of resection.

**Case Report**

LR a DPT/physical therapist and amateur bodybuilder injured his ACJ lifting weights and underwent 2 distal clavicle resections in 2008. The latter left him with more pain and ACJ instability. He modified his workouts and tried non-operative management for several years, and began to have symptoms at his SCJ as well. Eventually he underwent an ACJ reconstruction and a SCJ debridement in 2013. Despite the ACJ dogbone reconstruction he had continued ACJ symptoms such that a plating procedure was done across the ACJ, and the plate was subsequently removed later in 2014. He had continued SCJ pain such that another SCJ resection with concomitant reconstruction was performed in 2014. After this surgery failed, he came to the UW for evaluation and treatment with persistent ACJ and SCJ pain and instability as well as scapular bursitis and dyskinesis. Sling wear was the only helpful intervention to alleviate discomfort. He was unable to work as a PT or use his arm for ADLs.

After careful deliberation, we performed a revision SCJ stabilization with a hamstring allograft, a clavicular lengthening with iliac crest autograft and a non-biologic ACJ stabilization with local tissue augmented with heavy sutures.

Postoperatively he has done well with improved SCJ and ACJ stability, scapular kinetics and resolved scapular bursitis.

**Discussion**

This case demonstrates that there is a point where both lateral and medial clavicular osseous resections may exceed the body's physiologic ability to adapt - where soft tissue stability is lost and symptomatic instability as well as functional compromise results. Complex reconstructive surgeries may be required to regain a stable shoulder girdle.

How much clavicular resection then is needed? The current conventional wisdom for the lateral clavicle is to resect a 5 mm length off the distal clavicle to ameliorate degenerative ACJ abutment issues (6). Medially, there is no consensus, but "less may be more" medially as it is laterally. van Tongel in a recent paper highlighted the anatomy noting that much of the medial clavicle was covered with capsular ligamentous attachments posterior and superiorly, and that the articular surface was isolated to the anteroinferior aspect (14).

My technique over the past 10 years has been to focus the resection on the anteroinferior articular area (Figure 3A) and resect enough bone to ensure there is no bony contact with axial loading of the clavicle (Figure 3B). I then perform a capsulorraphy and rest the arm for the next 6 weeks, after which the patient can gradually return to activity ad libitum. In so doing, the rhomboid ligament, the posterior capsule as well as the majority of the superior ligaments are preserved, and instability is not an issue postoperatively. Moreover, clavicular length is maintained obviating scapular protraction and resultant periscapular pain and bursitis.

Review of my current results to date shows that minimum two-year follow-up data were available for 15 of 22 patients in a consecutive series of patients undergoing medial clavicle resection, including 8 females and 7 males. Two of fifteen patients were treated under a worker's compensation claim and three of fifteen cases involved litigation. The mean follow-up length was 3.6 years (range, 2.3 to 6.3 years). Single Assessment Numerical Evaluation (SANE) scores improved from a

Figure 1A: Clinically-evident preoperative medial clavicle elevation, clavicular shortening and scapular drooping.

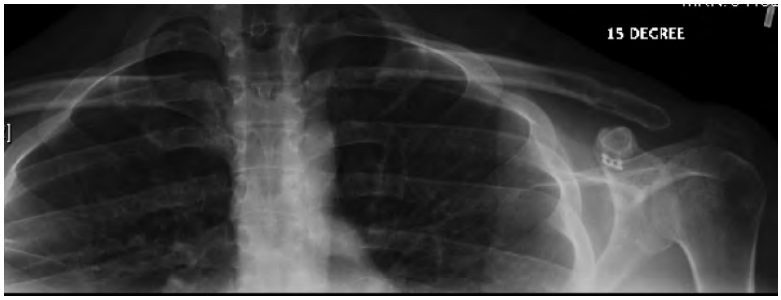


Figure 1B: Radiographically-evident preoperative medial clavicle elevation, clavicular shortening and scapular drooping.

Figure 1C: Preoperative 3DCT with clear SCJ disruption and clavicular shortening.

preoperative mean of 54 (standard deviation [SD], 20; range, 10 to 90) to a postoperative mean of 89 (SD, 13; range, 60 to 100; p<0.0001). Simple shoulder test (SST) scores improved from a preoperative mean of 5.3 (SD, 3.5; range, 0 to 11) to a postoperative mean of 10.9 (SD, 1.5; range, 8 to 12; p<0.0001). Visual analog scores for pain decreased from a mean of 6.1 (SD, 2.5; range 1 to 9) to a mean of 0.3 (SD, 1.0; range 0 to 4; p<0.0001) at latest follow-up. There was one complication of a superficial infection treated with antibiotics that resolved. No patient underwent reoperation or is planned for reoperation at this time. Twelve patients reported no functional limitations while three patients reported difficulty chopping wood, lifting heavy items or shoveling snow. No patients reported taking narcotic medications. All 15 patients reported that they would recommend the surgery to a friend or family member.

**Conclusions**

If patients with symptomatic SCJ arthritis fail non-operative measures, a limited resection to the point where all osseous contact is eliminated with axial loading of the clavicle will alleviate the patient's discomfort reliably and allow for improved shoulder function. Excessive arbitrary bony resection, managing the medial clavicle akin to traditional resections of the lateral clavicle, can be problematic and be a source of significant patient morbidity. In cases of excessive medial and/ or lateral clavicle resection, clavicular lengthening and stabilization using a hamstring tendon may be a viable option to restore shoulder function and reduce pain.

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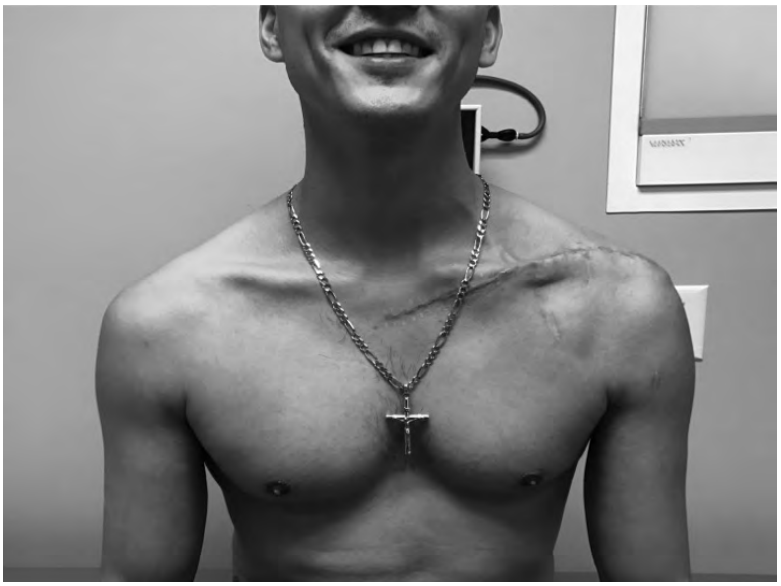

Figure 2A: Clinical restoration of scapular positioning, clavicle length and SCJ stability.

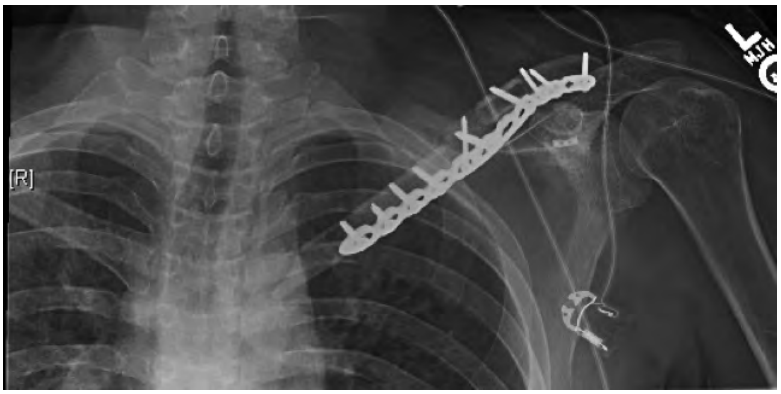


Figure 2B: Radiographic clavicular lengthening as well as SCJ and ACJ anatomic normalization.

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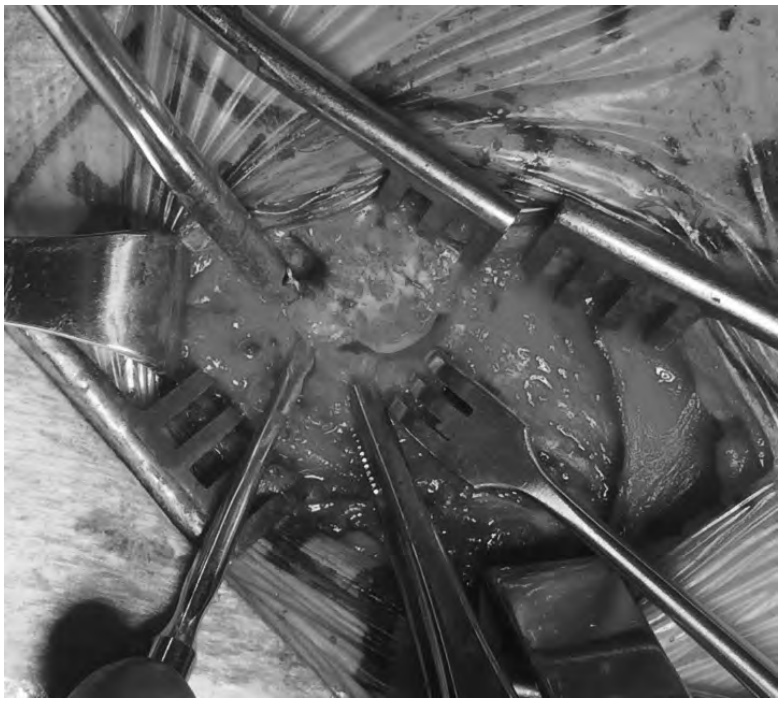


Figure 3A: SCJ with anteroinferior clavicular and superolateral manubrial osteophytosis, (seen between the suction tip and the Senn retractor).

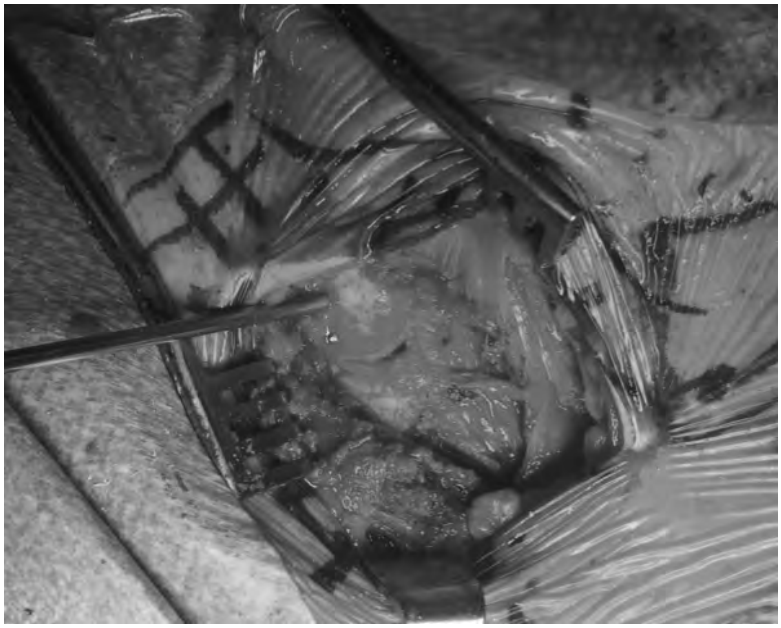


Figure 3B: SCJ with anteroinferior clavicular and superolateral manubrial osteophytes resected, (below and right of the suction tip).

# Comprehensive Assessment of Outcomes from Patients with Severe Early Onset Spine Deformity Treated with A Vertebral Column Resection: Results from An SRS Global Outreach Site (FOCOS) in Ghana

Kushagra Verma, MD, Oheneba Boachie-Adjei, Theresa Yirerong, Harry Akoto, and Irene Wulff

**Summary**

Patients requiring a vertebral column resection (VCR) for severe early onset spine deformity (EOSD) have excellent radiographic outcomes but a high complication profile. Half of these cases had transient intra-operative monitoring (IOM) changes that improved without lasting neurologic deficit.

**Hypothesis**

VCR is safe and effective for EOSD

**Design**

Retrospective review of prospective data

**Introduction**

Early onset Spine Deformity (EOSD) remains one of the most challenging pediatric conditions to manage. Occasionally severe deformities are managed with a vertebral column resection (VCR), which has not been well studied. The purpose of this study is to provide an assessment of operative, radiographic, and clinical outcomes from children with severe EOSD treated with a VCR.

**Methods**

We gathered the following demographic and clinical data: age, gender, BMI, diagnosis, procedure, FOCOS risk score, estimated blood loss (EBL), OR time, IOM events, intra and post op complications, and clinical follow-up. Coronal radiographic parameters: Cobb angles, C7 Shift, T1-12 length, T1-S1 length, chest width at T6. Sagittal radiographic parameters: instrument length, proximal and distal junctional kyphosis, segmental and global kyphosis, lordosis, pelvic tilt, sacral slope, sagittal vertical axis, and chest width at T6.

**Intra-operative Events, Complications, And Follow-Up**

| | DIAGNOSIS | INTRA-OP NM CHANGES | COMPLICATIONS | FOLLOW-UP (years) |
|---|---|---|---|---|
| 1 | Congenital Kyphoscoliosis | Transient loss of Rt. LE SSEP and MEP, improved after compression of right side | none | 1 year |
| 2 | Congenital Kyphoscoliosis | Loss of MEP/SSEP during case, recovered. Pedicle screw repositioned | Distal junctional kyphosis, within 2 months post-op required extension to the pelvis. | 2 years |
| 3 | Congenital Scoliosis, T10 Hemi vertebra | No left MEP at baseline | none | 2 years |
| 4 | Congenital Kyphosis | none | requiring re-op 3/11/14, extension to T2/3 for secondary deformity. | 6 months |
| 5 | Post TB Kyphosis | none | radiographic proximal junctional kyphosis | 6 weeks |
| 6 | Post TB Kyphosis | Transient loss of LL MEP response, returned to baseline after final correction | none | 2 years |
| 7 | Congenital Kyphoscoliosis, L1 Hemi Vertebra | none | Proximal Junctional Kyphosis. At 2 years revised: T6 to Pelvis March, 2016 | 2 years |
| 8 | Congenital Kyphoscoliosis | none | none | 1 year |
| 9 | TB Kyphosis | none | Radiographic Proximal Junctional Kyphosis | 10 months |
| 10 | TB Kyphosis | none | Had Anterior/posterior staged surgery. PJK early post-op > revision and extension of fusion. Returned with exposed hardware and pseudarthrosis at osteotomy site. Underwent a removal of hardware, IV antibiotics, traction and return to OR on 6/2016 for implant replacement. | 1.5 years |
| 11 | Congenital Scoliosis | MEP to about 20% of baseline. Improved with 1.5cm compression | none | 6 months |
| 12 | Post TB Kyphosis | transient loss of Right LE MEPs which improved after correction | none | < 6 months |
| 13 | Post TB Kyphosis | Transient decrease in bilateral LE MEPs during VCR which improved after closure | none | <6months |
| 14 | Post TB Kyphosis | Decreased MEPs bilateral, recovered with increased Blood pressure | none | 2 years |

Table 1: Intra-operative Events, Complications, and Follow-up

**Results**

14 patients with a diagnosis of post-tuberculosis deformity (n=7) or congenital deformity (n=7) underwent a VCR from 2013 to 2016 (5F, 9M; age 7.7 ± 3 years; BMI 17.7 ± 2.8). Coronal parameters improvement: (primary curve: 55° to 21°, secondary: 37° to 13°, T1-12 length: 137 to 151mm, T1-S1 length: 219 to 271mm, $p < 0.05$) and sagittal parameters (kyphosis: 85° to 41°, compensatory lordosis 56° to 39°, $P < 0.0000$). There was no change in chest width, SVA, or pelvic tilt. Mean proximal junctional kyphosis (PJK) angle was 12 ± 9° as compared to mean distal junctional kyphosis (DJK) angle that was 9 ± 17°. EBL was 860 ± 520ml and operative time was 200 ± 66min. 50% (n=7) had intra-operative monitoring (IOM) changes that improved with corrective maneuvers and blood pressure elevation. 3 out of 5 patients with PJK required a re-operation, one of whom also had an additional procedure for infection.

**Conclusion**

VCR for EOSD provides excellent radiographic outcomes but a high complication rate. Half of these cases had some neuromonitoring changes that ultimately improved without lasting neurologic deficit. PJK was the most common complication requiring reoperation.

# Preoperative Opioid Use Is Associated with Early Revision After Total Knee Arthroplasty[1]

Howard A. Chansky, MD

While narcotics serve a vital role in ensuring humane care for people suffering from a variety of maladies, by now nearly everyone is aware of the epidemic of opioid abuse and misuse in our nation. The causes of this epidemic are multifactorial and include societal, patient, nursing and physician factors as well pressures from well-intentioned organizations such as the Joint Commission. Regardless of the cause, orthopaedic surgeons now care for many patients who have been on long-term opiates prior to their surgery. For decades now many, and likely most, orthopaedic surgeons have strongly suspected that there was an association, and even causation, between use of preoperative narcotics and poorer results after orthopaedic surgery. There is now a burgeoning body of scientific evidence that this is in fact the case. Functional improvement, patient reported perceptions of the success of the surgery, pain resolution, return to work, and ability to wean from postoperative narcotics are all adversely impacted by the use of preoperative narcotics. The higher the dose of preoperative narcotics the greater the postoperative consequences. The data has been suggestive, though inconclusive, that preoperative opioids might even lead to complications that are not a direct physiological consequence of opioid use. For example, could preoperative narcotic use lead to a greater need for revision surgery in patients undergoing total joint replacement?

Along with my colleagues Alon Ben-Ari, MD and Irene Rozet, MD of the Department of Anesthesiology and Pain Medicine, I sought to answer this question in a population of veterans undergoing total joint replacement within the Veterans Health Administration (VHA). We chose to study this population in part because of the tendency of patients within the VHA to stay within the VHA and in part because the VHA is the single largest provider of healthcare in our nation and has been using a searchable electronic health record since 1997. We studied 32,636 veterans who underwent total knee replacement over a period of 6 years and who had at least one year of postoperative follow-up. 2.2% of these patients required a revision knee replacement within the first postoperative year. Our main goal of the study was to account for relevant preoperative comorbidities and then determine whether there was a correlation between long-term preoperative narcotic use and the need for revision TKA.

Outpatient VA pharmacy records were assessed to determine the morphine-equivalent dose and duration of narcotic use in the year prior to knee replacement surgery. We defined long-term opiate use as greater than three consecutive months of opioid prescriptions. The VA database does not include a "searchable" text field indicating the reason for the revision knee replacement. Ideally, we wanted to identify all specific causes for revision but given the practical limitations of our database we chose to divide revisions into those due to infections and those presumably due to mechanical aseptic issues. To do this we employed a sophisticated natural language machine-learning classifier developed by Dr. Ben-Ari. This machine-learning classifier parsed the postoperative note to classify the revisions as either being due to infectious or noninfectious causes.

In our population, the prevalence of long-term preoperative opioid use in the year preceding knee replacement was 39%. Despite being demographically similar and having similar profiles of medical comorbidities, the group of patients that met our criteria for long-term preoperative use of narcotics were significantly more likely (odds ratio, 1.40) than those who were not long-term narcotic users to undergo a revision TKA within one year of their index knee replacement, as well as at any point during the observed

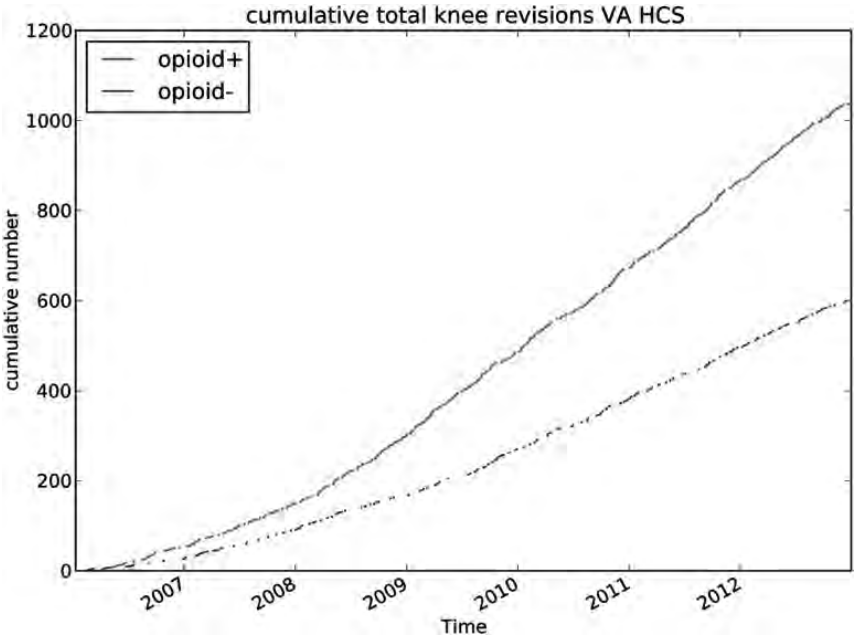



Figure 1: Cumulative number of knee revisions performed in the VA during the study period, showing that patients on long-term opioid therapy underwent a higher number of knee revisions over the study period compared with patients who were not. HCS = Health Care System. Permission received from Wolters Kluwer. Figure from: Ben-Ari A, Chansky H, and Rozet I. Preoperative Opioid Use Is Associated With Early Revision After Total Knee Arthroplasty: A Study of Male Patients Treated in the Veterans Affairs System. J Bone Joint Surg Am 99 (1), 1-9. 2017 Jan 04. Copy of article can be found at: http://journals.lww.com/jbjsjournal/pages/articleviewer.aspx?year=2017&issue=01040&article=00001&type=Fulltext

follow-up period. These patients were not any more likely to undergo a knee manipulation in the first postoperative year and thus postoperative stiffness may not have been a determining factor in the need for revision. There was no correlation between long-term opiate use and the cause for revision (infectious versus noninfectious) but there was a significant correlation between the need for revision surgery within the first postoperative year and the presence of diabetes mellitus or chronic kidney disease.

We concluded that preoperative opioid use is a modifiable and serious risk factor that can influence the need for early revision after total knee replacement. Though surprising at first glance, given other studies that have demonstrated a correlation between psychological state and surgical outcome, these results are plausible. In fact, long-term preoperative narcotic use is a risk on the order of chronic kidney disease and diabetes mellitus, two well-accepted high-risk comorbidities. Of equal importance is the fact that about 40% of the patients in our study were prescribed non-trivial amounts of opioids during the year prior to TKA.

Our results may only be specific to this population of veterans. We had a preponderance (94%) of males though nationally more total knee replacements are performed in women. All of our patients were veterans. In addition, we lacked the ability to report standard measures of functional outcome such as range-of-motion, validated outcome measures and patient reported outcomes. In addition, we could not determine etiology of revision beyond septic versus aseptic. While further studies need to be done on a broader population, we believe that these results will hold true in a more balanced population.

Knee arthroplasty is one of the most common procedures performed in the U.S. and by recent estimates that there will be 3.48 million knee arthroplasties by 2030 and the number of knee revisions will double in the period of 2005 to 2030. Given these projections as well current federal and corporate mandates to decrease the cost of care for patients undergoing knee replacement, and the possibility of financial penalties for poorer outcomes and early readmission, the costs of liberal preoperative narcotic use may burden both society and individual hospitals and surgeons. Of course the greatest effect is on our patients and It is possible that a conservative policy for opioid prescriptions in the preoperative period may reduce the rate of knee revisions, with an ensuing decrease in associated morbidity and an increase in patient satisfaction.

1.Ben-Ari A, Chansky H, and Rozet I. Preoperative Opioid Use Is Associated With Early Revision After Total Knee Arthroplasty: A Study of Male Patients Treated in the Veterans Affairs System. J Bone Joint Surg Am 99 (1), 1-9. 2017 Jan 04.

# Harborview Medical Center Orthopaedics

Chief, Carlo Bellabarba, MDCM

**Departmental Changes**

After several years of key recruitments, and of changes in general to Harborview's orthopaedic faculty, the 2016-17 academic year has seen relatively few changes. Last year's new faculty recruits, spine surgery specialist Dr. Haito Zhou, trauma specialist Dr. Michael Githens, and trauma/upper extremity specialist Dr. Jonah Hébert-Davies have joined the department within the past year and have exceeded all our expectations in terms of the expertise and energy that they have added to our department.

Dr. Stephen Kennedy, who has been a hand surgeon in the UW system for several years, has moved his primary site of practice to Harborview over the past year, swapping with Dr. Chris Allan, who, after about 20 years at Harborview, has decided to move his practice to our UWMC-Roosevelt practice site.

Perhaps the biggest faculty change over this past year has been Dr. Doug Smith's decision to transition to an Emeritus faculty position, after a long and successful career at Harborview as a limb viability specialist. Dr. Smith has become world-renowned in pioneering advances in amputee care. Having someone with his highly specialized skill set has been a tremendous asset to our department, to Harborview, and to the Pacific Northwest community. Fortunately, Dr. Smith's part-time Emeritus position will allow him to continue to participate, in an advisory role, in the treatment of patients with limbs at risk.


Doug Smith, MD

**Medical Center**

This past year brought considerable progress to various projects designed to evaluate the impact of our clinical care, with the goal of constantly looking at ways in which we can continue to improve the patient's experience and treatment outcome. To that end, a formal patient reported outcomes process was launched in various orthopaedic clinics. In addition, pathway programs that involve not only Harborview, but also the University of Washington Academic Medical Center as well as the rest of our regional Accountable Care Network continue to be an area in which considerable resources are being dedicated. These are complicated processes which, however, we feel are part of the future of surgical care, and therefore a necessary part of providing efficient, high-quality and cost-effective care to our patients.

**Clinical Care**

Once again in 2016-17, regional demand for the Harborview Orthopaedic faculty's expertise has continued to expand, with an average growth in clinical volume of approximately 6 per cent across all four of our subspecialty divisions (Foot & Ankle, Hand, Spine, and Trauma).

The Trauma Division, as well as trauma care provided by all subspecialty divisions, remains among the best and most influential globally, maintaining Harborview's widely regarded status as one of the world's premier trauma centers. The 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 Hand surgeons collaborate closely with the Plastic Surgery and General Surgery Hand surgeons 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. All four sub-specialties continue to be a key resource for patients and clinicians alike in the WWAMI region.

**Leadership**

Many of the Harborview Orthopaedic faculty have assumed leadership and administrative roles regionally and within both national and international societies and research organizations. In addition to his position as Treasurer of the AAOS, Brad Henley, MD has been appointed by the Board of Trustees as the Physician Leader of the University of Washington Physicians (UWP) Operations. Dr. Henley also serves as a member of the UWP Executive Committee, UWP Board of Trustees as a Member at Large, Chair of the AAOS Board's Revenue Enhancement Project Team and as a member of the AAOS Coding, Coverage and Reimbursement Committee. Claude Sagi, MD has been

Stephen Kennedy, MD

appointed to the American College of Surgeons' National Committee on Trauma. Conor Kleweno, MD, has been appointed Board Member to several organizations, including the Washington State Orthopedic Association, the Western Orthopedic Association and the AO Trauma North America Fellowship Board, in addition to being appointed to the Young Physician Council of the Washington State Medical Association. Reza Firoozabadi, MD serves on the Orthopaedic Trauma Association's Research Committee, and on the Executive Committee and Publication Committee of the Major Extremity Trauma Consortium. Dr. Firoozabadi also serves as grant reviewer for the OREF and on the protocol committee for three additional major multicenter clinical trials.

**Awards**

The Orthopaedic Research and Education Foundation (OREF) has launched the "Sigvard T. "Ted" Hansen Jr., MD Mentor Campaign," to honor Dr. Hansen's career in general, and to recognize his tremendous impact on orthopaedics as the "father of modern traumatology," while raising funds to support OREF-funded research in his chosen area: "the impact of required documentation on the patient-physician relationship." Additional details can be found at the web site below: http://www.oref.org/support/donate/sigvard-t-ted-hansen-jr-md-mentor-fund

**Research**

The Harborview faculty continue to be major contributors to orthopaedic research on many levels.

There are currently 72 retrospective research studies and approximately a dozen prospective studies in progress within the Orthopaedics Department at Harborview Medical Center. Under the guidance of Reza Firoozabadi, MD, our department's Director of Clinical Research, Harborview has consistently had the highest patient enrollment in the Major Extremity Trauma Research Consortium (METRC), a national multicenter combined civilian and military clinical trial network funded by the Department of Defense, with a primary focus on severe extremity injury, infection, and limb impairment. Dr. Firoozabadi is a key co-investigator in several prospective randomized trials, including a comparison of the complications and safety of blood clot prevention medicines used in orthopaedic trauma patients, the prevention of heterotopic ossification in orthopaedic trauma patients, and the effect of gut microbiome on fracture healing. Other multi-center prospective trials that involve Harborview Orthopaedics include: The evaluation of extra-articular plateau fractures nail vs plate (site PI – Dr. Dunbar), an evaluation of regional and seasonal incidence of infection in patients with open fractures (PI – Dr. Sagi), the use of pedCAT scan for early assessment of post-traumatic arthritis in pilon fractures (site PI – Dr. Kleweno), and a Department of Defense-funded assessment of the surgical timing and rehabilitation for multiligament knee injuries (PI – Dr. Gee). Other prospective studies being conducted by Orthopaedics at Harborview include the assessment of coagulopathy in patients with isolated pelvic and acetabular fractures, a study that is funded by the Department of Orthopaedics (PI – Dr. Sagi), an evaluation of the effectiveness of calcium sulfate as graft material in open fractures (PI – Dr. Sagi), a prospective study of reverse shoulder arthroplasty outcomes (PI – Dr. Hébert-Davies) and the use of transesophageal echo to evaluate for embolic phenomena during total ankle arthroplasty (PI - Dr. Brage).

With the assistance of research coordinator Julie Agel, MA, the Harborview Orthopaedic faculty have contributed over 100 peer-reviewed publications in their respective areas of expertise to the orthopaedic literature over the course of 2016 and 2017.

**Teaching**

Harborview remains the busiest teaching hospital in the University of Washington's Department of Orthopaedics and Sports Medicine. 14 orthopaedic residents, including residents doing their trauma rotation from Madigan Army Medical Center, and fourteen fellows are distributed among Harborview's four orthopaedic subspecialty divisions, in addition to additional visiting residents and fellows. Teaching opportunities abound, as our trainees are able to choose from approximately a dozen different didactic conferences per week and exposure to practical cadaver-based workshops in Harborview's Institute for Simulation in Healthcare lab, in addition to the high volume of hands-on teaching that occurs in the operating rooms, inpatient wards and outpatient clinics.

One of the major emphases of the faculty continues to be sharing Harborview's expertise with surgeons worldwide. Faculty members have remained instrumental in Continuing Medical Education projects globally, having managed to participate in a combined total of over 120 national and international courses and countless hours of local didactic teaching to students, paramedics, allied health professions, residents, fellows and other practicing surgeons over the past year, as well as having published over forty textbook chapters, despite maintaining busy clinical practices. Harborview continues to host visitors from throughout the globe year-round. In the past academic year, over 60 visitors have traveled to Harborview to observe our approach to the treatment of orthopaedic conditions, further reinforcing Harborview's role as a global leader in orthopaedic education.

# Seattle Children's Hospital Orthopaedics

Chief, Suzanne M. Yandow, MD

The Division of Pediatric Orthopaedics is one of the largest divisions of care at Seattle Children's Hospital. It provides musculoskeletal medical and surgical care with nearly 40,000 out patient clinic visits and over 2,300 surgical cases per year. Our Athletic Trainer program assessed over 21,000 high school injuries and provided over 70,000 treatments for our communities' student athletes. Our faculty are a diverse group of 15 pediatric orthopedics surgeons many with expanded fellowship training in spine, foot and ankle, limb deformity, neuromuscular disease, tumor, sports medicine, skeletal dysplasia and upper extremity surgery. We have expanded our Department to create a specialty team of physicians, nurse practitioners and physician assistants to provide consistent and rapidly accessible acute musculoskeletal care. We successfully recruited two additional pediatric orthopedic surgeons this year, Dr. Ted Sousa with additional expertise in neuromuscular disorders and Dr. Michael Saper, with expertise in sports medicine. Below we highlight several exciting programs within Pediatric Orthopedics and Sports Medicine.

**Skeletal Health Program**

The skeletal health program at Seattle Children's Hospital has experienced tremendous growth over the last ten years under the able guidance of Dr. Michael Goldberg; this year that leadership has transitioned to Dr. Klane White who was recently appointed the medical advisory board of the Little People of America. Our program is supported by Maryse Bouchard, MD, another dual-fellowship trained pediatric orthopaedic surgeon. The program continues to expand its reach and international notoriety while locally providing comprehensive care for children and adults with skeletal dysplasias, metabolic bone disease, syndromic conditions with significant orthopedic manifestations, and early onset scoliosis. Our mission is to provide comprehensive medical and surgical care for patients with skeletal dysplasias and metabolic bone disease via: 1) Clinical Care Home: comprehensive care including diagnosis, management and care coordination; 2) Consultative Services: opinions regarding bone fragility and non-accidental trauma, prenatal diagnosis, and out of state consultations; and 3) Research: to promote skeletal health clinical care. Our IRB approved Skeletal Dysplasia Registry, which focuses on the functional health of affected individuals, now has 595 enrolled patients.

**Pediatric Orthopedic Fellowship program – 2016 Summary**

Pediatric orthopedics has become an increasingly popular subspecialty choice for US orthopedic residents in the last few years. And the national trend has matched our local trend with 1 to 2 of our 8 UW orthopedic residents matching in pediatric orthopedic fellowships across the country for each of the past 8 years. Our pediatric orthopaedic fellowship training program received ACGME accreditation in 2012. We have grown from one fellow per year to two fellows per year. Fellowship size is based on faculty number, case number and diversity, and subspecialty expertise of our faculty as well as the volume and complexity of our patient population. Two of our Seattle Children's faculty, Dr. Maryse Bouchard and Dr. Antoinette Lindberg are former Seattle Children's Hospital pediatric orthopedic fellows. Both have a second fellowship, Dr. Bouchard in both adult foot and ankle and pediatric limb deformity and Dr. Lindberg in musculoskeletal surgical oncology.

**Pediatric Foot and Ankle Program**

Our nationally and internationally renowned program oversees the care of children with congenital, developmental, and neuromuscular deformities of the foot and ankle. Our main providers are Drs. Vincent Mosca and Maryse Bouchard. Both give talks and symposia nationally, and Dr. Mosca has been a guest speaker in 4-6 foreign countries each year, with 6 international speakerships in 2016, disseminating knowledge on pediatric foot and ankle deformities. Dr. Mosca provided operative foot reconstruction for 4 foreign nationals in 2016. The program had over 6500 visits in 2016 for foot and ankle concerns. Our volume has increased by 20% since 2015.

In 2016, our clubfoot program cared for over 500 idiopathic or syndromic clubfoot patients, including 117 new patients. We have two non-operative providers who help with Ponseti non-operative clubfoot treatment, Drs. Thomas Jinguji and Carol Mowery. We have initiated a workshop series for pediatric orthopedic fellows, orthopedic technicians, and orthopedic providers to improve/maintain Ponseti


Seattle Children's Hospital

technical skills and maintain up to date knowledge of clubfoot literature and management. We are one of six sites in a Shriners Hospitals-funded multi-center, prospective, randomized, controlled trial (RCT) on duration of clubfoot bracing.

**Limb Lengthening and Reconstruction Program**

In the last two years, our limb lengthening and reconstruction program has grown exponentially. With the arrival of Dr. Bouchard, a newly established dedicated multi-disciplinary limb lengthening and reconstruction clinic has been established. We have close ties with Child Life, Social Work, Occupational Therapy, and Psychologists who help support our patients. Our group manages children with congenital, post-traumatic, and developmental deformities. We are now a site for validation of the first pediatric patient reported outcome questionnaire for lower limb deformity. Other research involves reviewing our populations of children undergoing novel applications of guided growth, congenital pseudoarthrosis of the tibia, and lower limb hypoplasia.

**Athletic Trainers Program at Seattle Children's**

Now in its ninth year, the Athletic Trainers Program, managed by Andrew Little, MA, LAT, ATC, has emerged as a regional leader in providing on-site health care for young athletes and is one of the largest programs of its kind in the nation. Beginning in 2008 with just 1 district and 7 schools, we have expanded into 18 different school districts covering 34 high schools and over 100 different community organizations in the Puget Sound area. We encourage young athletes to take part in an active lifestyle and strive to keep them in the game by making sure they are well-prepared for their activities and properly treated when injuries occur.

**Research Program**

Led by Viviana Bompadre, PhD, Research Manager the division had 30 publications and 5 abstracts accepted at the Pediatric Orthopedics Society of North America annual meeting this year. We continue participating and getting recognition in multi-center clinical trials and registries such as the FAB 24 clubfoot study (Dr. Mosca) and the Children's Spine Foundation study (Dr. White). Dr. Steinman has been invited to participate as the site PI in a national hand registry (CoULD). She runs a robust clinical registry at SCH in collaboration with the hand team, which gained her national recognition. Additionally, Dr. Lindberg will serve as a site PI for the Regional Variation in Pediatric Musculoskeletal Infection Multi-center Study; and Dr. Schmale will be the site PI for the ABOS PRISM Pediatric Knee Registry. Our registries continue to grow. Dr. Conrad's Sarcobase registry collects functional data in children with bone and soft tissue tumors which yielded several publications this year. The Skeletal Dysplasia registry has more than 600 entries. This year, Dr. Mark Dales was the recipient of a Seattle Children's Academic Enrichment Fund for his randomized controlled trial on the treatment of toddler's fractures. The study compares the use of cast vs. a removable boot in this fairly common childhood trauma. It is our goal to strengthen our involvement in outcomes research and continue to increase the national recognition of our research program.

**Hand and Upper Extremity**

The multidisciplinary Hand and Upper Extremity Service at Seattle Children's continues to grow with one full-time pediatric orthopaedic surgeon (Suzanne Steinman) and additional colleagues from orthopaedic and plastic surgery. In the last year, the four providers of our team saw over 2900 patients with hand and upper extremity conditions ranging from congenital differences and neuromuscular disorders to brachial plexus injuries and trauma. Patients from across the region are able to get outstanding care from a multidisciplinary approach that includes members from pediatric orthopedics, plastics, orthopedics, rehab medicine, and occupational therapy. Not only do we provide clinical and surgical care for our patients, we are also able to offer social support through our Limb Difference Social Group. Our summer time meet has proven to be a huge success with the event being held at the Mountainiers Club. The children and their families are taught to rock climb with Outdoors for All. There is nothing more satisfying than seeing the smile on one of our children when they reach the top of the wall or sit in the harness for the first time.

Based off of our work with our local upper limb difference registry that was started 2 years ago, our program has been asked to participate in the CoULD (Congenital Upper Limb Difference) National Registry. Through research, social support and medical treatment, we continue to strive to improve our patients' lives.

**Fracture Service**

Fracture care and musculoskeletal injury continues to be a "growth" area in Pediatric Orthopedics. The volume of fracture management continues to grow at Seattle Childrens. In 2016, 6,317 fractures were cared for. In response to this, in 2016, after 2 years of planning in conjunction with Seattle Childrens administration, a dedicated fracture service came to fruition. The components of this include a core team of surgeons and APPs dedicated to fracture care, specialized fracture clinics, a dedicated morning trauma room in the OR, and further evolution of the clinical pathways for management of fracture types that have been developed over the past 5 years. In the near future, projects include initiation of a robust database of fractures managed, creating emphasis on outcome and value, participation in multicenter studies, and increasing collaboration with our Harborview trauma colleagues to maximize the strengths of both institutions in optimizing pediatric musculoskeletal trauma care.

**Spine Program**

The Spine program at Seattle Children's continues to work on improvements in safety for our patients receiving both inpatient surgical care and outpatient clinic care. The hospital recently purchased a state of the art 3D capable imaging system called EOS with the generous support of many donors. This system utilizes uniplanar or biplanar fluoroscopic technology to produce images of quality similar to CR digital systems while decreasing radiation by 3-10 fold and allowing production of 3D modeling. It is a significant advance in ability to plan and evaluate 3D deformity correction for lower extremity and Spinal deformities.

We are seeing thousands of patients

every year through the hard work of our nonsurgical Pediatric and adolescent medicine physicians, physician assistants and nurse practitioners along with our surgeons. Dr. White continues to focus on Early Onset scoliosis and Spinal deformities associated with the skeletal dysplasias and in collaboration with the skeletal dysplasia team and pulmonary specialists is a leading international expert in advancement of the treatment and outcomes assessments for these challenging conditions. Dr. Ted Sousa has joined our faculty and is now focusing on patents with complex neuromuscular deformities of the limbs and spine. Dr. Krengel continues to focus on adolescent idiopathic scoliosis, spondylolisthesis, tumors of the spine, conditions leading to back pain in children and adolescents, and collaborates with a neurosurgeon, Dr. Browd, on treatment of cervical spine disorders. Dr. Krengel will be assuming a more nonsurgical role in the next year as we recruit and support the developing practice of two just-recruited spine surgery colleagues – Drs. Jennifer Bauer and Todd Blumberg.

**Neuromuscular**

Neuromuscular care in children continues to grow. In 2015 a total of 574 neuromuscular patients were seen by orthopaedics, increasing to 738 patients in 2016. Multiple faculty members have provided outstanding care to this group of patients. This expertise has grown under the mentorship of Dr. Vince Mosca, Dr. Klane White and Dr. Mark Dales and further expanded with care provided by Dr. Suzanne Yandow. Neuromuscular diseases such as cerebral palsy, spina bifida, and muscular dystrophy have always been taken care of by pediatric orthopaedic surgeons, but there is an expanding expertise and collaboration providing combined clinics with rehabilitation medicine. One of our former UW residents, Dr. Ted Sousa received additional fellowship training and has dedicated interest in pediatric neuromuscular disease. During his pediatric orthopedic fellowship at Children's Hospital Los Angeles he developed a passion for the care of children with these musculoskeletal conditions and he subsequently spent eight months in Melbourne, Australia focusing more on the care of these children and while also honing his skills in gait analysis. He started his practice at Seattle Children's Hospital in the fall of 2016.

The current concept for the management of musculoskeletal deformities is Single Event Multilevel Surgery (SEMLS). In the past children with these disorders would have what was caricatured as a "birthday syndrome" where annually they would come to the hospital for an orthopaedic surgery at one joint as their gait progress through the "natural history" of their disorder. SEMLS, on the other hand, attempts to have a diagnostic matrix of all the deformities and contractures that are occurring within a child's lower extremities that affect their gait and perform all those procedures at a single operation. Then, in coordination with the rehabilitation service and our specialized team of therapist, the child is given the year of rehabilitation that is often required with continued requirement over the 2nd and 3rd years. Last year we performed 74 such procedures and look forward to expanding our numbers this year with Dr. Sousa in the department.

**Seattle Children's Sports Medicine Program**

The Seattle Children's Sports Medicine Program is composed of orthopaedic surgeons, sports medicine trained pediatricians and a physiatrist, an adolescent medicine physician, physician assistants, certified athletic trainers, and sports physical therapists. In March 2017, Dr. Michael Saper, a sports medicine and pediatric subspecialty trained orthopaedic surgeon, joined Dr. Greg Schmale, a surgeon, Dr. Monique S. Burton, a pediatrician, in caring for pediatric athletic injuries. His special interests include patellar instability, shoulder and elbow injuries in throwing and upper extremity athletes. Our mission is to provide excellent care to the athlete, as a collaborative team, serving all children, adolescents and young adults in play and sport, including those of diverse populations of all abilities. We provide care at multiple sites including Seattle, Bellevue, Mill Creek, and South campuses. Our sports orthopedic surgeon performs over 200 sports related surgeries annually and volume will continue to increase with our new additional sports surgeon. We also have a large number of athletes with non-surgical conditions such as chronic pain, we work closely with biofeedback therapists to help them return to play with lifelong skills to return to their sports with confidence and hope. A child's "job" is to learn and play. Our program's goal is to provide multi-disciplinary collaborative care to patients of all abilities to help restore, and ideally, enhance their level of function whatever that may be.

# University of Washington Medical Center and Northwest Hospital Orthopaedics

Chief, Howard A. Chansky, MD

At the UWMC we have robust programs in shoulder, elbow, and hand surgery (Drs. Hsu, Warme, Matsen, Allan and Huang), spine (Dr. Verma), sports (Drs. Kweon and Gee), tumor (Dr. Davidson), general orthopaedics and a small adult reconstruction program (Drs. Manner and Chansky). At Northwest Hospital, the focus is on geriatric fracture care, (Dr. Clawson who continues to lead and build the "Strong Bones" program) total joint replacement (Drs. Fernando, Manner, Sassoon, Leopold and Chansky) and hand surgery (Drs. Kennedy and Beshlian). In each of these programs the focus is on complex cases that are best handled in an academic center. Our orthopaedic case mix index, a national measure of complexity of care, remains one of the highest measures of complexity in the University Health Systems Consortium (now Vizient), a group that includes the nation's premier academic medical centers. Despite this high case mix index our infection, readmission and mortality rates remain lower than expected.

University of Washington Medical Center

We had a swap of sorts this year with Stephen Kennedy moving half of his hand practice to HMC and Chris Allan moving his practice from HMC to UWMC. Dr. Kennedy continues to cover a busy elective hand practice at NWH with Dr. Beshlian while Dr. Allan joins Jerry Huang at the Bone and Joint Clinic and UWMC. Dr. Huang also directs the combined hand fellowship program while remaining one of the busiest surgeons in the Department.


Totem Pole Dedication at Northwest Hospital

Adam Sassoon, Paul Manner and Navin Fernando continue to develop the Centers for Medicare & Medicaid Services (CMS)-mandated clinical pathways and bundled pricing for our total joint practice. On the administrative side, Patty O'Leary Crutcher and Arkan Kayihan have been working with us on this project. We have been joined in this endeavor by Brad Henley who contributes a unique understanding of the intersection of orthopaedic practice and government regulation. Years of hard work are literally paying off as this year we beat our CMS mandated "episode targets" by 7%. This exceeded the maximum "gain share" target for the year which was 5%. These targets include a mix of health quality and cost measures and exceeding them results in a financial bonus for Northwest Hospital. We are all very proud of this accomplishment as the arthroplasty practice at Northwest Hospital could not involve a more complex group of patients, referred from throughout Western Washington and beyond. Work on the bundled pricing and pathways will continue with a focus on establishment of a UW Post-Acute

Network and the development of a TJR Recovery Care pathway for post-discharge patients. Much of the cost of caring for total joint patients occurs after discharge from the hospital so this focus is critical in establishing competitive bundled pricing.

Our SCCA and UWMC orthopaedic tumor service (Dr. Davidson) remains very busy though the founder of the program, Dr. Ernest "Chappie" Conrad, has left to head the nascent sarcoma program at Memorial Hermann Hospital – University of Texas Houston. Chappie is a legendary surgeon in the Pacific Northwest and in this edition of Discoveries I have summarized Dr. Conrad's career at the University of Washington.

Dr. Winston Warme is Chief of the Shoulder and Elbow Service which is rounded out by the founder of the service, Dr. Rick Matsen, as well as by Dr. Jason Hsu. Dr. Matsen and Dr. Hsu continue to advance the study of periprosthetic infections in the shoulder via frequent publications and presentations around the country. Our highly regarded semiannual arthroscopy "boot camp", led by Dr. Warme, has become a "destination" feature of our residency. Dr. Hsu has rapidly developed a busy referral practice and it is fair to say that he is quickly developing an excellent reputation in the clinical, scientific and teaching realms of his career at UW.

Our sports service is anchored by Drs. Gee and Kweon. They have been busier than ever, particularly with the Huskies football team competing for the national championbship in the Peach Bowl. As touted on local media, John Ross, a Husky wide receiver who ran the fastest 40-yard dash ever at this year's NFL combine, had both knees surgically reconstructed by Albert Gee prior to this season. Mia Smucny will join the Department this fall. She will partner with Drs. Gee and Kweon and focus on hip arthroscopy.

Dr. Wagner retired from his surgical spine practice but continues to see outpatients with complex spine problems at the Bone and Joint Clinic and in this regard he supports Kushagra Verma, MD as he builds a busy practice in adult spine deformity at UWMC. In partnership with Neurosurgery, Dr. Verma has begun to reconstitute an adult spine deformity program at UWMC.

I would be remiss in not mentioning that we are all supported in important ways by our advanced practice providers. Janice Olivo, PA and Kristin Dahlberg, RN, FNP-BC and Katie Moore, ARNP who help with the care of our orthopaedic inpatients at UWMC and NWH. Our outpatient and surgical practices are also supported by the best physician assistants one could ask for. They take excellent attentive care of our patients, enhancing access for patients while permitting the surgical faculty to devote some time to our non-clinical career goals. Our physician assistants are listed with the rest of the faculty on page 12.

# VA Puget Sound Orthopaedics

Chief, Albert O. Gee, MD

I am happy to report that the state of the Orthopaedic Surgery service at the Puget Sound VA remains strong and busy serving the Veterans of the Northwestern United States. We continue to strive for excellence in patient care, education and training and research.

The year has been a steady and stable one for our service. The faculty base has remained unchanged. We continue to have the best support staff at the VA and hard-working and dedicated residents to help us provide the highest level of care for our Vets.

Dr. Howard Chansky is entering his 22nd year of service and dedication to our Vets. The only change is that he has scaled his VA practice back a bit in order to have time for his duties as the Chair of our department. Nonetheless, he continues to operate several days a week and is our specialist for knee and hip arthroplasty taking care of both primary and complex revision cases.

Dr. Nicholas Iannuzzi remains full-time at the VA and is now our anchor. He is in the 2nd year of his practice and has brought fresh ideas which have made the care of Vets, especially in our busy clinics, more manageable and efficient. In the OR he provides specialty upper extremity and general orthopaedic surgery services. Our residents and medical students all enjoy working and learning from him.

Dr. Bruce Sangeorzan continues to split time between our VA and Harborview Medical Center. Here, he balances time between his clinical duties as our expert foot and ankle surgeon and director of the prestigious Seattle Center of Excellence in Limb Loss Prevention and Prosthetic Engineering. The Center continues to produce meaningful and innovative research while maintaining high levels of extramural funding.

Dr. Sangeorzan's lab will be moving later this year to a brand new research space in the new Mental Health and Research Building (see photo). As the name implies, the building will house mental health clinics and research facilities as well as other labs, and Dr. Sangeorzan's Center will be given the entire 1st floor of this 203,000 square foot building which is scheduled to be completed this year.

Dr. Fred Huang provides orthopaedic care to our Veterans on a per-diem basis and remains engaged with our residency despite their part-time status at the VA.

My role as Chief of the service has not changed and I am still engaged with the residents and enjoy working with them. My clinical practice at our VA remains unchanged and consists of specialty sports medicine and shoulder surgical care.

Our residents remain the heart of the orthopaedic service. The team consists of 2 PGY-5 chiefs, 1 PGY-4, 1 PGY-3 and 1 PGY-2. They are hard-working and make our jobs as faculty fun and meaningful. We rely on them heavily and they are always up to the challenge.

If our residents are the heart, our physician extenders are, for sure, the life-blood of the service. They continue to do outstanding work and provide exemplary care to our Veterans. Dustin Higbee, PA-C, Steve Casowitz, PA-C, Amy Katzenmeyer, and Renato Rafi, PA-C and Annette Testa, LPN continue to be the cornerstone of our patient care team. We added a new PA this year, Raymond Punzalan, PA-C. Although he is new to orthopaedics, he is learning and improving on the job and helping to increase our access in clinic.

Our service continues to be supported by the best surgical coordinators in the Puget Sound VA. Monette Manio, RN and Katherine German, RN can handle any situation, however complex or arising at the last-minute. Our day-to-day lives at the VA continues to be supported by Cindy Lostoski and Lyra Bryant who are our administrative assistants. Both are great, work-hard and care about their jobs and the care of our Vets.

The Puget Sound VA Medical Center continues to be a high-volume tertiary-care center in orthopaedic surgery serving the many Veterans of the Northwest U.S. We remain dedicated to high-level care of our Vets while training the next generation of surgeons and furthering the bounds of musculoskeletal care through research.

A rendering of the soon to be completed Mental Health and Research Building on the campus of the Puget Sound VA. Courtesy of Stantec and Nakano Associates.

# Graduating Residents

**Ahmad Bayomy, MD**

After residency, Ahmad will complete a fellowship in Pediatric Orthopaedics at Columbia University/Children's Hospital of New York followed by a fellowship in Sports Medicine at the Cleveland Clinic. He and his wife Hager plan to return to the Pacific Northwest.

**Kevin Hug, MD**

After residency, Kevin and his wife Emily will move to the San Francisco Bay Area where he will complete a fellowship in joint reconstruction at Stanford University. Upon completion of fellowship, they are considering career locations in Colorado or Seattle.

**Christopher Domes, MD**

Chris will be completing a trauma fellowship at the R. Adams Cowley Shock Trauma Center in Baltimore, Maryland. He is planning on returning to family and friends in the Pacific Northwest after completion of his fellowship.

**Alexander Lauder, MD**

Alex will be completing a Hand, Microvascular & Upper Extremity Surgery Fellowship at Duke University following graduation. He is seeking to return to Washington after completion of fellowship.

# Graduating Residents

**Calvin Schlepp, MD**

After residency, Calvin and his wife Madeline, will move to Taos, New Mexico to pursue a fellowship in Sports Medicine at the Taos Orthopedic Institute. Upon completion of fellowship, he plans to pursue a general orthopedics practice in Montana.

**Neil Tarabadkar, MD**

After residency, Neil will be completing a fellowship in Hand and Microvascular Surgery at Barnes-Jewish/Washington University in St. Louis in Missouri, while his wife, Erica, finishes her Dermatology Residency at the University of Washington. After fellowship, they plan to settle in the Southeast.

**Shawn Schoch, MD**

Following residency, Shawn and her husband are moving to Grand Rapids where she will complete a Foot & Ankle fellowship at the Orthopaedic Associates of Michigan. Upon completion of fellowship, they are considering starting their careers in the Northwest or Midwest.

**Sara Shippee Wallace, MD, MPH**

After residency, Sara, her husband Gabe, and their loyal dog Tater will return to Chicago. Sara will complete a fellowship in Adult Hip and Knee Reconstruction with Midwest Orthopaedics at Rush University, while Gabe begins his fellowship in Vascular Surgery at Northwestern University.

# Incoming Residents

**Jacquelyn Dunahoe, MD**

Jacquelyn Dunahoe comes from Anchorage, Alaska with interests in Trauma and Joint specialties. She attended Washington State University, later going on to medical school at the University of Washington. She enjoys hiking, sailing, ice climbing, and soccer as pastimes. A fun fact about Jackie is that she is a seaplane pilot.

**Mark Kohn, MD**

From Sherman Oaks, California, Mark studied at the University of California, Berkley. He obtained his medical degree from Saint Louis University School of Medicine. His areas of interests are adult reconstruction, hand, and trauma. He enjoys soccer, golf, squash, and skiing.

**Andrew Hulet, MD**

Andrew is from Summit, Utah and attended Brigham Young University. Upon graduation, he continued his education and attended medical school at the University of Utah. He enjoys snowboarding, wakeboarding, football, and spending time with his wife and kids.

**Kacy Peek, MD, MS**

Kacy comes from Keller, Texas where she earned her degree from the University of Texas in Austin. She later earned her medical degree from the University of California, San Francisco. Her areas of interests are pediatric orthopaedics, trauma, hand, and rural health. Outside of work, she enjoys hiking, rowing, baking, and traveling.

# Incoming Residents

**Megan Terle, MD**

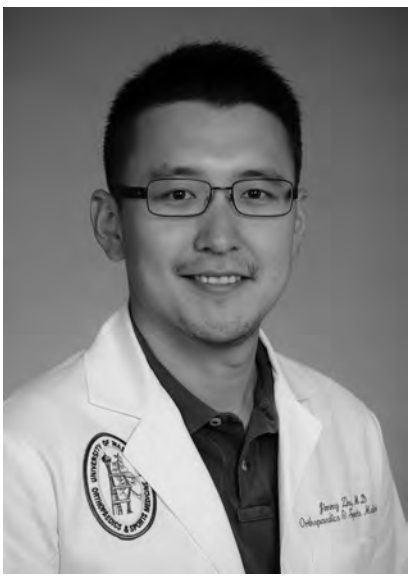
From Tehachapi, California, Megan went to Washington University in St. Louis. She got her medical degree from Tulane University School of Medicine. She enjoys hiking, camping, cooking, and hanging out with her dog.

**Aditya Yerrapragada, MD**

From Houston, Texas, Aditya went to the University of Texas at Austin where he completed his undergraduate degree. Upon graduation, he went to medical school at the University of Louisville. His areas of interest include sport, hand, and the upper extremity specialties. Outside of work, his interests include ultimate frisbee, basketball, friends, food, and family.

**Greg Walker, MD**

From Los Angeles, Greg came to the UW for his BA and to Alpert Medical School of Brown University for his MD. His areas of interest are hand, sport, and joint. He enjoys watching Husky football, spending time with his wife, and going to church. A fun fact about Greg is that he served as a safety for the UW football team from 2008-2011.



**Jimmy Zhu, MD**

Jimmy grew up in Skokie, Illinois and attended Cornell University. Jimmy then pursued his medical degree from the University of Illinois. His areas of interest are adult reconstruction and trauma. For fun, he likes hiking, taking pictures, traveling with his wife, and playing with his Maltese-poodle mix.

# ACEs and Fellows

**Anna Acosta, MD**
Pediatrics

**Samia Ghaffar, MD**
Spine

**Christopher Johnson, DO**
Oncology

**Benjamin Bluth, MD**
Hand

**Lea Gunnell, MD**
Foot & Ankle

**Farhan Karim, DO**
Spine

**Benjamin Chia, MD**
Hand

**Daniel Hackett, MD**
Shoulder & Elbow

**Rahul Kasukurthi, MD**
Hand

**Joseph Cohen, MD**
Trauma

**Adam Hirschfeld, MD**
Trauma

**Angelo Lipira, MD**
Hand

# ACEs and Fellows

**Ian MacNiven, MBBCh, BAO**
Shoulder & Elbow

**Motasem Refaat, MD**
Trauma

**Nicole Zappa, DO, MHA**
Foot & Ankle

**Bryan Monier, MD**
Foot & Ankle

**Nicholas Romeo, DO**
Trauma

**Alex Mortimer, MD**
Pediatrics

**Matthew Thompson, MD**
Oncology

**Kevin Murr, MD**
Trauma

**Brett Walker, DO**
Spine

# Research Grants

**National Institutes Of Health**

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

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

Modeling, Design, and Testing of a Joint Replacement for MTPJ1
Peter R. Cavanagh, PhD, DSc
William R. Ledoux II, PhD
Bruce J. Sangeorzan, MD
Scott Telfer, EngD

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

Neuroskeletal Systems Biology in Zebrafish
Ronald Y. Kwon, PhD

Suppression of Bone Mechanotransduction by the Beta 2 Adrenergic Receptor
Edith M. Gardiner, PhD
Sundar Srinivasan, PhD
Steven D. Bain, PhD
Leah E. Worton, PhD
Ronald Y. Kwon, PhD

**Veterans Affairs Rehabilitation Research and Development Service**

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

Quantitative Prescription of Foot Orthoses: A Dose Response Study of Kinematics in Patients with Foot and Ankle Pain Using Biplane Fluoroscopy
William R. Ledoux II, PhD
Peter R. Cavanagh, PhD, DSc
Scott Telfer, EngD
Bruce J. Sangeorzan, MD

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

**AO Foundation**

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

**AO North America**

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

AO Spine North America Fellowship
Richard Bransford, MD

**Arthrex, Inc.**

Arthrex Education Grant
Jerry I. Huang, MD

Arthrex Fellowship Educational Grant
Winston J. Warme, MD

**Baylor College Of Medicine**

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

**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

**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

**Foundation for Orthopedic Trauma**

Assessing Coagulopathy in Trauma Patients with Pelvic and Acetabular Fractures
H. Claude Sagi, MD

**Johns Hopkins University**

A Prospective Randomized Trial to Assess PO Versus IV Antibiotics for the Treatment of Early Post-Op Wound Infection after Extremity Fractures
Reza Firoozabadi, M.D.

# Research Grants

Streamlining Trauma Research Evaluation with Advanced Measurement: STREAM Study
Conor P. Kleweno, MD

The Major Extremity Trauma Research Consortium
Reza Firoozabadi, MD

**Histogenics Corporation**

A Randomized Comparison of Neocart to Microfracture for the Repair of Articular Cartilage Injuries
Albert O. Gee, MD

**Medical University Of South Carolina**

Pulmonary Embolism Prevention after Hip and Knee Replacement (PEPPER)
Navin D. Fernando, MD

**Omega Medical Grants Association, LLC**

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

Omega Spine Fellowship
Richard Bransford, MD

Omega Trauma Fellowship
David P. Barei, MD

**Orthopaedic Research And Education Foundation**

Nano-Engineered Hybrid Scaffolds for Cartilage Tissue Regeneration
Albert O. Gee, MD
Paul A. Manner, MD

Propionibacterium Skin Load and Subtype Distribution on Risk of Positive Deep Cultures in Shoulder Arthroplasty
Jason E Hsu, MD
Frederick A. Matsen, MD
Roger E. Bumgarner, MD

**Orthopaedic Trauma Association**

A Multi-Center Prospective Cohort Study of Sacral Fractures Using Patient Based and Objective Outcomes
Carlo Bellabarba, MD

COTA Trauma Fellowship
David P. Barei, MD

Fluoroscopic Assessment of Rotation in Tibial Shaft Fractures
David P. Barei, MD

**Pac-12 Student-Athlete Health and Well-Being Grant Program**

Simple Motion Capture Technology for Readiness of Return to Sport Assessment and Injury Risk Prediction
Christopher Kweon, MD
Scott Telfer, EngD

**Synthes USA**

Spine End-Results Research Fund
Howard A. Chansky, MD

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

**US Army Research Office**

Patient Enrollment
Reza Firoozabadi, MD

**UW Department Of Bioengineering**

Coulter Cavanagh 2015
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

**Washington State Life Sciences Discovery Fund Authority (LSDFA)**

Allan LSDF REHEAL Glove
Christopher H. Allan, MD

# Department Publications 2016-2017

A list of publications authored by our faculty from January 2016 through April 2017. Our faculty members names are in **bold type**.


1. Ahsan ZS, **Hsu JE**, **Gee AO**. The Snyder Classification of Superior Labrum Anterior and Posterior (SLAP) Lesions. Clin Orthop Relat Res. 2016 Sep;474(9):2075-8.

2. Ahsan ZS, Somerson JS, **Matsen FA, 3rd**. Characterizing the Propionibacterium Load in Revision Shoulder Arthroplasty: A Study of 137 Culture-Positive Cases. J Bone Joint Surg Am. 2017 Jan 18;99(2):150-4.

3. Anissipour A, Agel J, **Bellabarba C**, **Bransford RJ**. Cervical facet dislocations in the pediatric population: a report of 21 cases at a Level 1 trauma center. Eur Spine J. 2017.

4. Anissipour AK, Agel J, Baron M, Magnusson E, **Bellabarba C**, **Bransford RJ**. Traumatic cervical unilateral and bilateral facet dislocations treated with anterior cervical discectomy and fusion has a low failure rate. The Global Spine Journal. 2017;7(2):110-5.

5. Au B, Groundland J, Stoops TK, Santoni BG, **Sagi HC**. Comparison of 3 Methods for Maintaining Inter-Fragmentary Compression After Fracture Reduction and Fixation. J Orthop Trauma. 2017 Apr;31(4):210-3.

6. Austin MS, Urbani BT, Fleischman AN, **Fernando ND**, Purtill JJ, Hozack WJ, Parvizi J, Rothman RH. Formal Physical Therapy After Total Hip Arthroplasty Is Not Required: A Randomized Controlled Trial. J Bone Joint Surg Am. 2017 Apr 19;99(8):648-55.

7. **Barei DP**. Invited Commentary Related to: "Does a Staged Posterior Approach Have a Negative Effect on OTA 43C Fracture Outcomes?". J Orthop Trauma. 2017 Feb;31(2):94-5.

8. Bauer K, **Mosca VS**, Zionts LE. What's New in Pediatric Flatfoot? J Pediatr Orthop. 2016 Dec;36(8):865-9.

9. Beadling L, **Leopold SS**. A New Way to Read, Write, and Review for CORR®. Clinical Orthopaedics and Related Research®. 2016:1-2.

10. Ben-Ari A, **Chansky H**, Rozet I. Preoperative Opioid Use Is Associated with Early Revision After Total Knee Arthroplasty: A Study of Male Patients Treated in the Veterans Affairs System. J Bone Joint Surg Am. 2017 Jan 04;99(1):1-9.

11. **Benirschke SK**, Kramer PA. Joint-Preserving Osteotomies for Malaligned Intraarticular Calcaneal Fractures. Foot and ankle clinics. 2016 Mar;21(1):111-22.

12. **Benirschke SK**, Kramer PA. Gastrocnemius or Achilles Lengthening at Time of Trauma Fixation. Foot and ankle clinics. 2017 Mar;22(1):117-24.

13. Bennett C, Behn A, Daoud A, **Nork S**, **Sangeorzan B**, Dikos G, Bishop J. Buttress Plating Versus Anterior-to-Posterior Lag Screws for Fixation of the Posterior Malleolus: A Biomechanical Study. J Orthop Trauma. 2016 Dec;30(12):664-9.

14. Blair JA, Stoops TK, Doarn MC, Kemper D, Erdogan M, Griffing R, **Sagi HC**. Infection and Non-union Following Fasciotomy for Compartment Syndrome Associated with Tibia Fractures: A Matched Cohort Comparison. J Orthop Trauma. 2016 Mar 5.

15. Blumberg T, Bompadre V, **Steinman S**. Operative management of pediatric floating elbow: is forearm fixation necessary? . J Pediatr Orthop. 2016 Accepted for publication in April 2016.

16. Blumberg TJ, Bremjit P, Bompadre V, **Steinman S**. Forearm Fixation is Not Necessary in the Treatment of Pediatric Floating Elbow. J Pediatr Orthop. 2016 May 19.

17. Bompadre V, Mattioli-Lewis T, Yassir WK, **Goldberg MJ**. A comparison of the functional health of children with Costello syndrome in 1999 and in 2015. American journal of medical genetics Part A. 2017 May 09.

18. Bosse MJ, Morshed S, Reider L, Ertl W, Toledano J, **Firoozabadi R**, Seymour RB, Carroll E, Scharfstein DO, Steverson B, MacKenzie EJ, Metrc. Transtibial Amputation Outcomes Study (TAOS): Comparing Transtibial Amputation With and Without a Tibiofibular Synostosis (Ertl) Procedure. J Orthop Trauma. 2017 Apr;31 Suppl 1:S63-S9.

19. Bosse MJ, Murray CK, Carlini AR, **Firoozabadi R**, Manson T, Scharfstein DO, Wenke JC, Zadnik M, Castillo RC, Metrc. Assessment of Severe Extremity Wound Bioburden at the Time of Definitive Wound Closure or Coverage: Correlation With Subsequent Postclosure Deep Wound Infection (Bioburden Study). J Orthop Trauma. 2017 Apr;31 Suppl 1:S3-S9.

20. Bosse MJ, Teague D, Reider L, Gary JL, Morshed S, Seymour RB, Toledano J, Cannada LK, Steverson B, Scharfstein DO, Luly J, MacKenzie EJ, Metrc (**Firoozabadi, R** & **Sangeorzan B**). Outcomes After Severe Distal Tibia, Ankle, and/or Foot Trauma: Comparison of Limb Salvage Versus Transtibial Amputation (OUTLET). J Orthop Trauma. 2017 Apr;31 Suppl 1:S48-S55.

21. **Bouchard M**, Bartlett M, Donnan L. Assessment of the Pediatric Foot Mass. J Am Acad Orthop Surg. 2017 Jan;25(1):32-41.

22. Bus SA, Armstrong DG, van Deursen RW, Lewis JE, Caravaggi CF, **Cavanagh PR**, International Working Group on the Diabetic F. IWGDF guidance on footwear and offloading interventions to prevent and heal foot ulcers in patients with diabetes. Diabetes/metabolism research and reviews. 2016 Jan;32 Suppl 1:25-36.

23. Bus SA, van Deursen RW, Armstrong DG, Lewis JE, Caravaggi CF, **Cavanagh PR**, International Working Group on the Diabetic F. Footwear and offloading interventions to prevent and heal foot ulcers and reduce plantar pressure in patients with diabetes: a systematic review. Diabetes/metabolism research and reviews. 2016 Jan;32 Suppl 1:99-118.

24. Cabral WA, Ishikawa M, Garten M, Makareeva EN, Sargent BM, Weis M, Barnes AM, Webb EA, Shaw NJ, Ala-Kokko L, Lacbawan FL, Hogler W, Leikin S, Blank PS, Zimmerberg J, **Eyre DR**, Yamada Y, Marini JC. Absence of the ER Cation Channel TMEM38B/TRIC-B

Disrupts Intracellular Calcium Homeostasis and Dysregulates Collagen Synthesis in Recessive Osteogenesis Imperfecta. PLoS Genet. 2016 Jul;12(7):e1006156.

25. **Cavanagh PR**, Rice AJ, Glauberman M, Sudduth A, Cherones AL, Davis S, Lewis M, Hanson A, G. W. Ground Reaction Forces During Reduced Gravity Running in Parabolic Flight. Aerospace Medicine and Human Performance. 2017; In Press.

26. **Cavanagh PR**, Rice AJ, Novotny SC, Genc KO, Englehaupt RK, Owings TM, Comstock B, Cardoso T, Ilaslan H, Smith SM, Licata AA. Replacement of daily load attenuates but does not prevent changes to the musculoskeletal system during bed rest. Bone Reports. 2016 12//;5:299-307.

27. **Chansky HA**. CORR Insights(R): What are the Functional Results, Complications, and Outcomes of Using a Custom Unipolar Wrist Hemiarthroplasty for Treatment of Grade III Giant Cell Tumors of the Distal Radius? Clin Orthop Relat Res. 2016 Dec;474(12):2591-3.

28. Chiem J, Ivanova I, Parker A, **Krengel W, 3rd**, Jimenez N. Anaphylactic reaction to tranexamic acid in an adolescent undergoing posterior spinal fusion. Paediatric anaesthesia. 2017 Mar 21.

29. Child Z, Rau D, Lee MJ, Ching R, **Bransford R**, Chapman J, **Bellabarba C**. The provocative radiographic traction test for diagnosing craniocervical dissociation: a cadaveric biomechanical study and reappraisal of the pathogenesis of instability. Spine J. 2016 Sep;16(9):1116-23.

30. Chou SS, Hippe DS, Lee AY, Scherer K, Porrino JA, **Davidson DJ**, Chew FS, Ha AS. Gadolinium Contrast Enhancement Improves Confidence in Diagnosing Recurrent Soft Tissue Sarcoma by MRI. Acad Radiol. 2017 May;24(5):615-22.

31. **Davidson D**, Barr RD, Riad S, Griffin AM, Chung PW, Catton CN, O'Sullivan B, Ferguson PC, Davis AM, Wunder JS. Health-related quality of life following treatment for extremity soft tissue sarcoma. Journal of surgical oncology. 2016 Dec;114(7):821-7.

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35. Eastman JG, **Firoozabadi R**, Cook LE, **Barei DP**. Incarcerated Cortical Fragments in Intramedullary Nailing. Orthopedics. 2016 Apr 18:1-5.

36. **Firoozabadi R**, Alton T, **Sagi HC**. Heterotopic Ossification in Acetabular Fracture Surgery. J Am Acad Orthop Surg. 2017 Feb;25(2):117-24.

37. **Firoozabadi R**, Cross III WW, Krieg JC, Routt Jr ML. Acetabular Fractures in the Senior Population–Epidemiology, Mortality and Treatments. The archives of bone and joint surgery. 2017;5(2):96-102.

38. **Firoozabadi R**, Little M, Alton T, Scoloro J, Agel J, Kogut M. Does Pelvic Embolization Increase Infection Rates in Patients Who Undergo Open Treatment of Acetabular Fractures? J Orthop Trauma. 2017 Apr;31(4):185-8.

39. **Firoozabadi R**, Schneidkraut J, Beingessner D, Dunbar R, Barei D. Hyperextension Varus Bicondylar Tibial Plateau Fracture Pattern: Diagnosis and Treatment Strategies. J Orthop Trauma. 2016 May;30(5):e152-7.

40. **Firoozabadi R**, Thuillier D, **Benirschke S**. Obtaining Correct Ankle Alignment Using Intraoperative External Fixation for Ankle Arthrodesis. The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons. 2017 Mar - Apr;56(2):242-6.

41. Fratzl-Zelman N, Barnes AM, Weis M, Carter E, Hefferan TE, Perino G, Chang W, Smith PA, Roschger P, Klaushofer K, Glorieux FH, **Eyre DR**, Raggio C, Rauch F, Marini JC. Non-Lethal Type VIII Osteogenesis Imperfecta Has Elevated Bone Matrix Mineralization. The Journal of clinical endocrinology and metabolism. 2016 Sep;101(9):3516-25.

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43. Gistelinck C, Witten PE, Huysseune A, Symoens S, Malfait F, Larionova D, Simoens P, Dierick M, Van Hoorebeke L, De Paepe A, Kwon RY, Weis M, **Eyre DR**, Willaert A, Coucke PJ. Loss of Type I Collagen Telopeptide Lysyl Hydroxylation Causes Musculoskeletal Abnormalities in a Zebrafish Model of Bruck Syndrome. J Bone Miner Res. 2016 Nov;31(11):1930-42.

44. Githens M, Alton TB, **Firoozabadi R**, Bishop JA. Intraoperative Distal Femoral Fine Wire Traction to Facilitate Intramedullary Nailing of the Femur. Orthopedics. 2016 Mar 1;39(2):e380-5.

45. Godfrey J, Choi PD, Shabtai L, Nossov SB, Williams A, **Lindberg AW**, Silva S, Caird MS, Schur MD, Arkader A. Management of Pediatric Type I Open Fractures in the Emergency Department or Operating Room: A Multicenter Perspective. J Pediatr Orthop. 2017 Mar 10.

46. **Goldberg MJ**, Shin A, Lown BA. Mitigating Surgeon Burnout. Journal of the American College of Surgeons. 2016 Oct;223(4):675-6.

47. Gorbaty JD, **Hsu JE**, **Gee AO**. Classifications in Brief: Rockwood Classification of Acromioclavicular Joint Separations. Clin Orthop Relat Res. 2017 Jan;475(1):283-7.

48. Gorbaty JD, Lucas RM, **Matsen FA, 3rd**. Detritic synovitis can mimic a Propionibacterium periprosthetic infection. Int Orthop. 2016 Jan;40(1):95-8.

49. Gundle KR, Mickelson DT, **Hanel DP**. Reflections in a time of transition: orthopaedic faculty and resident understanding of

accreditation schemes and opinions on surgical skills feedback. Medical education online. 2016 Jan;21(1):30584.

50. Gundle KR, Punt SE, Mattioli-Lewis T, **Conrad EU, 3rd**. Can a Made-for-Consumer Activity Monitor Assess Physical Activity in Adolescents and Young Adults After Lower Extremity Limb Salvage for Osseous Tumors? J Pediatr Orthop. 2017 Apr/May;37(3):e192-e6.

51. Guo Y, Chen E, **Davidson DJ**, Pillarisetty VG, Jones RL, Pollack SM. The Imaging and Pathological Features of Metastatic Leiomyosarcoma in the Gallbladder. Rare tumors. 2016 Nov 17;8(4):6618.

52. Haller JM, Githens M, Scolaro J, **Firoozabadi R**. Does provisional plating of closed tibia fractures have higher complication rates? J Orthop Trauma. 2017 Apr 27.

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56. Hosseininia S, Weis MA, Rai J, Kim L, Funk S, Dahlberg LE, **Eyre DR**. Evidence for enhanced collagen type III deposition focally in the territorial matrix of osteoarthritic hip articular cartilage. Osteoarthritis Cartilage. 2016 Jun;24(6):1029-35.

57. **Hsu JE**, Bumgarner RE, **Matsen FA, 3rd**. Propionibacterium in Shoulder Arthroplasty: What We Think We Know Today. J Bone Joint Surg Am. 2016 Apr 06;98(7):597-606.

58. **Hsu JE**, **Gee AO**, Lucas RM, Somerson JS, **Warme WJ**, **Matsen FA, 3rd**. Management of intraoperative posterior decentering in shoulder arthroplasty using anteriorly eccentric humeral head components. Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons [et al]. 2016 Dec;25(12):1980-8.

59. **Hsu JE**, Gorbaty J, Lucas R, Russ SM, **Matsen FA, 3rd**. Treatment of irreparable cuff tears with smoothing of the humeroscapular motion interface without acromioplasty. Int Orthop. 2017 Apr 28.

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61. **Hsu JE**, Horneff JG, **Gee AO**. Immobilization After Rotator Cuff Repair: What Evidence Do We Have Now? Orthop Clin North Am. 2016 Jan;47(1):169-77.

62. **Hsu JE**, Russ SM, Somerson JS, Tang A, **Warme WJ**, **Matsen FA, 3rd**. Psychometric Properties of the Simple Shoulder Test (SST) in Patients Undergoing Shoulder Arthroplasty. Journal of Shoulder and Elbow Surgery. 2017; In Press.

63. **Hsu JE**, Somerson JS, Vo KV, **Matsen FA, 3rd**. What is a "periprosthetic shoulder infection"? A systematic review of two decades of publications. Int Orthop. 2017 Feb 21, 2017;41(4).

64. **Hsu JE**, Tang A, **Matsen FA, 3rd**. Patient Self-assessed shoulder comfort and function and active motion are not closely related to surgically documented rotator cuff tear integrity. Journal of Shoulder and Elbow Surgery. 2017; In Press.

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68. Ibrahim DA, **Fernando ND**. Classifications In Brief: The Paprosky Classification of Femoral Bone Loss. Clin Orthop Relat Res. 2017 Mar;475(3):917-21.

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**1952**
Park W. Gloyd, MD ★

**1954**
Trygve Forland, MD ★

**1955**
Robert W. Florence, MD

**1956**
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John E. Goeckler, MD
Robert L. Romano, MD ★

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**1959**
James W. Tupper, MD

**1960**
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**1961**
Robert C. Colburn, MD ★

**1962**
Arthur Ratcliffe, MD
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**1963**
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Robert A. Kraft, MD

**1964**
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**1966**
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William A. Reilly, Jr., MD

**1967**
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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 Chair, Howard A. Chansky, MD (chansky@uw.edu), or our Director, Ken Karbowski (kkarb@uw.edu). Thank You!

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