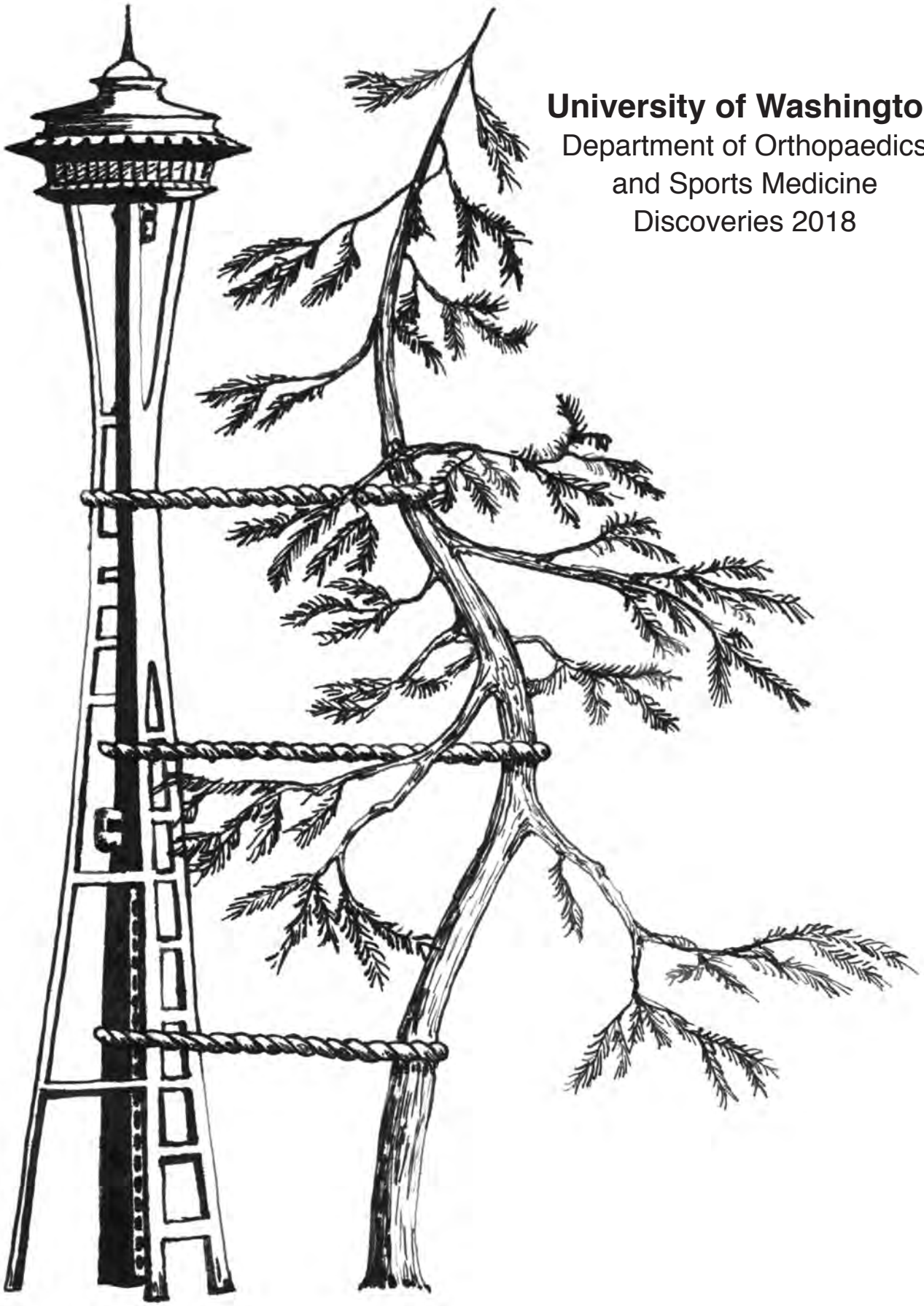
Discoveries 2018

University of Washington Orthopaedics & Sports Medicine



University of Washington

Department of Orthopaedics
and Sports Medicine
Discoveries 2018

UW Medicine
SCHOOL OF MEDICINE

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Front Cover Illustration: Angie Kennedy, MSc, is a Seattle-based mixed media artist. She specializes in custom collage pieces that use mementos and artifacts to celebrate people and special life events. She drew on her experience as a former scientific researcher to create this collage of images from the pages of the current publication. The 'W' in the background is a nod to the University of Washington with an overlay of the current imagery arranged in an abstract assemblage. For more information www.americanheavyweight.com

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

Contents

Foreword

Once again it is my privilege to present to you another stellar edition of our Discoveries research report. All of the credit for this annual summary of the Department goes to the contributors as well as to the Managing Editor Fred Westerberg, and the three assistant editors Drs. Chris Allan, Stephen Kennedy and Adam Sassoon.

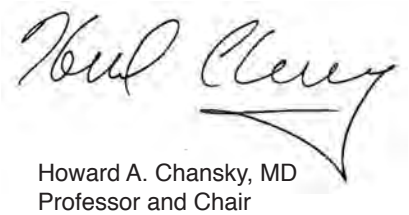
Our common pursuit of the best possible care for our patients, formalized in name as "The Triple Aim" by the Institute of Healthcare Improvement, is the mission that serves to unite the entire Department. The Triple Aim refers to improving the care of individual patients, improving the health of populations, and reducing the cost of healthcare. The goals of the Triple Aim can be addressed via improvements in quality of care, efficiency of delivered care, or by enhancing the diversity of the healthcare workforce.

Studies have proven that the highest quality healthcare is delivered when the healthcare workforce is broadly representative of our society. However, a diverse workforce alone will not guarantee high-quality teaching, healthcare, or research. Nor will diversity alone ensure a positive and productive workplace culture. The keys to a successful workplace culture begin with recognizing and respecting the differences in backgrounds, experiences and needs of our colleagues and our patients. Only then can we begin to optimally address the critical issues that are encompassed by the term "social justice" - these issues include equity in hiring and training, as well as equity in access to high-quality healthcare.

While social justice has been an important part of the mission of UW Medicine since its founding, the effort to codify and focus these efforts goes at least as far back as 2010, when the Dean of the School of Medicine, Paul Ramsey, created the Diversity Strategic Planning Committee (DSPC). While diversity and inclusion are important moral values in and of themselves, adhering to these values and encoding them into our "departmental DNA" will result in a more collegial, productive and creative work environment and this should translate into more effective teaching, research and care of the public. These efforts will ideally culminate in the best department where any person can find care for any orthopaedic condition that can benefit from our compassion and skill.

To this end, the Department has formed a Diversity and Inclusion Workgroup that includes residents, staff and faculty. The members of this workgroup have shown incredible passion that will be harnessed by the capable leadership of Drs. Lisa Taitsman and Christopher Kweon.

Our mission statement to guide these efforts is "The University of Washington Department of Orthopaedics and Sports Medicine is committed to a culture of openness, civility and respect, employing and training a diverse workforce (staff, residents and faculty), and providing equitable healthcare to any person in need of our expertise." I look forward to providing an update on this important task in our 2019 issue of Discoveries. Until then, please enjoy this edition of Discoveries and please contact Fred Westerberg or myself with questions or ideas for future issues.



Howard A. Chansky, MD
Professor and Chair

From The Assistant Editors: The Modern Art of Musculoskeletal Research, Education, and Clinical Care

The term "collage" derives from the French term "coller," "to glue." It was coined by Braque and Picasso in the early 20th century as a distinctive form of modern art. Pieces from texts, photographs, ribbons, paint, found objects, clippings, and other items are assembled together on a supporting surface to create a new whole. This year, *Discoveries 2018* features a modern art cover from Angie Kennedy – a collage that combines the University of Washington "W" across the front and back covers, the Departmental logo, and images and text from throughout this year's issue.

The research submissions this year continue to include topics from the variety of areas in our Department. We have representation from basic science articles studying the formation of synovial joints, diabetes effects on tendons, heterotopic ossification development after trauma, and how genes influence skeletal development (phenomics). We also have clinical studies on the diagnosis of finger infections, complex hip reconstruction, rock climbing injuries, and return to sport after ACL reconstruction. There are also "big picture" studies which evaluate on a population basis how Google searches might relate knee pain with local weather, and how healthcare providers as a community might overcome challenges to maintain compassionate care in a changing environment. Department Publications, Research Grants, Site Updates, and listings of our incoming and outgoing trainees, further exemplify the varied clinical, educational, and research interests of our department.

What is the glue that keeps this "collage" of our Department together? Perhaps it is our shared goal for *Discoveries*. For some of us it is our scientific understanding of how we develop, become ill, and/or heal; for others it is discovering how we can better care for our patients through improved decision-making, compassion, and surgical techniques; and for others still it is our service to the public through education and outreach. For many of us, it is all of the above. Diverse backgrounds and interests are assembled to create a whole that we can all be proud of. We were proud to be part of *Discoveries 2018*, and would like to thank the authors for their submissions, and the contributions everyone makes during the year to make this work possible.

Christopher H. Allan, MD
Stephen A. Kennedy, MD, FRCSC
Adam A. Sassoon, MD, MS

David J. Belfie, MD
2018 Distinguished Alumnus
University of Washington School of Medicine

When David J. Belfie, MD entered the University of Washington Orthopaedic Surgery and Sports Medicine Residency Program in 1993, he had already served five years in the United States Air Force, graduated from Eastern Washington University and was a practicing kinesiologist. He brought to our residency program maturity, a love of the musculoskeletal system and boundless energy. After completion of his residency and sports medicine fellowship, he served another four years in the United States Air Force.

In 2002, he returned to the Pacific Northwest and became a member of the Virginia Mason Medical Center orthopedic staff. With hard work and focus he became an admired and respected physician/surgeon who mentored 90+ residents, each of whom appreciated the privilege of spending time with Dr. Belfie in clinic and in the operating room. He lived and he practiced the basic mantra of this program, always looking at patients, staff members and residents and asking the simple question, “how can I help you”?

The impact of this approach is best exemplified in a recent evaluation submitted by a resident upon completion of his training with Dr. Belfie. It reads as follows, “His (Dr. Belfie’s) approach was consistent and predictable. He would tell you what he was going to teach you, showed you what he was doing in the operating room, and ask you to demonstrate what he had taught you upon the next encounter…. His feedback was consistent and poignant.”

On behalf of the Department of Orthopaedics and Sports Medicine, it is a privilege to have Dr. David J. Belfie as the recipient of our 2018 Distinguished Alumni Award.

New Faculty

Jennifer M. Bauer, MD, MS

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Dr. Jennifer Bauer joined the University of Washington Department of Orthopaedics and Sports Medicine in August 2017. She is an Assistant Professor in our department and is on staff at Seattle Children's Hospital where she was hired to treat all pediatric spine conditions, including cervical spine. She has published widely in a number of fields, and has presented her spine research at several conferences including the annual meetings for the Scoliosis Research Society, International Congress of Early Onset Scoliosis, and the Pediatric Orthopaedic Society of North America (POSNA). In 2017, POSNA named her their representative to the AAOS/OREF/ORS Clinicial Scholar Career Development Program. She was also selected as an Emerging Leader in the American Orthopaedic Association.

Dr. Bauer is originally from Buffalo, NY. She attended Brown University where she graduated with an ScB in Biology with Honors and competed on the sailing team. After working as an admission officer there, she returned to school at Case Western Reserve University for a dual medical and Masters of Anatomy degree. She completed her residency at Vanderbilt Medical Center, then spent a year in pediatric orthopaedic fellowship at Nemours AI duPont Hospital for Children where her time was focused on care of the pediatric spine. Her clinical interests are devoted to all aspects of spine management.

Todd J. Blumberg, MD

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Dr. Todd Blumberg joined our department as an Assistant Professor in September 2017. His practice is based out of Seattle Children's Hospital where he has a particular interest in scoliosis. He has published research on scoliosis in adolescents and non-surgical scoliosis treatment such as "Correlation between shunt series and scoliosis radiographs in children with myelomeningoceles" in the Journal of Neurosurgery and "Youth and Experience: The Effect of Surgeon Experience on Outcomes in Cerebral Palsy Scoliosis Surgery" in Spine Deformity. Most recently, he wrote articles on the pediatric hip and "Inappropriately Times Pediatric Orthopedic Referrals from the Emergency Department Result in Unnecessary Appointments and Financial Burden for Patients" for the Journal of Pediatric Orthopaedics.

Dr. Blumberg hails originally from Plano, Texas. He graduated with a BS in Biochemistry and Cell Biology from Rice University and he graduated from medical school at the Baylor College of Medicine. He was awarded the Baylor College of Medicine and Affiliated Hospitals - Outstanding Student in Orthopaedic Surgery in 2011.

Dr. Blumberg is no stranger to our department. He completed his residency here at the University of Washington from 2012 to 2016. Afterwards he completed a fellowship in pediatric orthopaedic surgery at Children's Hospital of Philadelphia.

New Faculty

Mia S. Hagen, MD

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Dr. Mia Hagen joined our department as an Assistant Professor in October 2017. She performs minimally-invasive surgery for all types of athletic injuries, including those of the shoulder, elbow, knee, and ankle, with particular interests in hip arthroscopy and injuries of young athletes.

Dr. Hagen earned her bachelor's degree from Yale University magna cum laude, followed by medical school and orthopaedic surgery residency training at the University of California San Francisco. She then completed a fellowship in sports medicine at the Cleveland Clinic. Her extensive team experience includes working with the NBA Cleveland Cavaliers, the MLB Cleveland Indians, NCAA DIII football, basketball, wrestling, lacrosse, and track and field at Baldwin-Wallace University, the MiLB Mahoning Valley Scrappers, and the San Francisco Golden Gate Rugby Club. She currently serves as a team physician for the University of Washington Husky Athletics.

She is an active member of the American Academy of Orthopaedic Surgeons, American Orthopaedic Society for Sports Medicine, Arthroscopy Association of North America, and the International Society for Hip Arthroscopy. Her research publications include original work on hip arthroscopy and patient-reported outcomes in sports medicine. Most recently, she published "A New Option for Glenoid Reconstruction in Recurrent Anterior Shoulder Instability" in the American Journal of Orthopaedics and an article on what is new in sports medicine with her colleagues Dr. Kweon and Dr. Gee in the Journal of Bone and Joint Surgery.

Matthew Thompson, MD

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Dr. Matthew Thompson specializes in the surgical management of tumors of the extremities and pelvis, with a primary focus on sarcoma and complex limb reconstruction. He practices at the Seattle Cancer Care Alliance, Seattle Children's Hospital, and University of Washington Medical Center. He originally joined our department as a fellow in 2016 and later as an Assistant Professor in August 2017.

His published work includes articles on pediatric bone sarcomas, nerve allografts, and hip and knee arthroplasty. He is actively studying the effects that cognitive bias may impart on patient decision making, and has pending publications related to the contemporary management of metastatic skeletal disease and carbon-fiber technology in orthopaedic oncology.

Dr. Thompson studied biochemistry at the University of Kansas prior to attending the University of Kansas School of Medicine where he was honored with the Best Student Recognition of Achievement in Foundations of Medicine and was inducted into the Alpha Omega Alpha Honor Society. He completed residency in orthopaedic surgery at Virginia Commonwealth University Medical Center where he was the recipient of the Award for Excellence for Outstanding Achievement and Contribution to the Orthopaedic Residency Program.

Dr. Thompson is a current member of the Connective Tissue Oncology Society, Musculoskeletal Tumor Society (candidate), American Academy of Orthopaedic Surgeons (candidate), Fred Hutchinson/University of Washington Cancer Consortium, Seattle Translational Tumor Research, and the American Medical Association.

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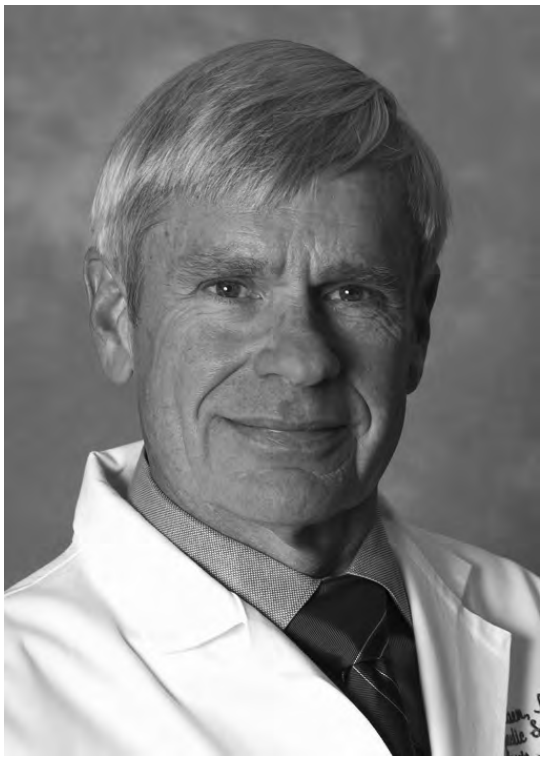
Visiting Lecturers

2018 LeCocq Lectureship

April 26-27, 2018



We were happy to host Dr. Frederick A. Matsen III as our guest lecturer for the 2018 LeCocq Lectureship. On Thursday April 26th, he gave a presentation on "Challenging the Existing Paradigm." At the 54th Annual John F. LeCocq Dinner that evening, he gave the featured lecture on "Turning Failure into Knowledge." The following day he gave his final talk "Drinking Responsibly."

Dr. Matsen, ranked as a "Top Doctor" in the category of "Orthopaedics" according to *Seattle Magazine*, has dedicated his entire professional life to developing excellence in Orthopaedics and Sports Medicine at the University of Washington. Starting with his residency here in 1971, he developed an interest in shoulder and elbow reconstruction. A fellowship with the father of modern shoulder surgery, Dr. Charles S. Neer II, confirmed his lifetime commitment to improving the art of care for patients with simple and complex problems involving the shoulder and elbow.

He has partnered with Charles Rockwood, a fellow Texan, in editing the definitive text in shoulder surgery *The Shoulder*, now in its fifth edition from Saunders. He has also written *Practical Evaluation and Management of the Shoulder* and most recently, along with a former shoulder fellow Steve Lippitt, has published *Shoulder Surgery: Principles and Procedures*, also published by Saunders.

He is the former chair of the Department of Orthopaedics and Sports Medicine, a position he held from 1986 to 2009, making him amongst the longest tenured chairs among clinical departments at the University of Washington. During his tenure, the Department has risen to being one of the top Departments according to rankings by *U.S. News and World Report* and by the National Institutes of Health. These dramatic accomplishments are a direct result of the wonderful faculty, staff, residents, fellows, postdoctoral students, graduate students, alumni and benefactors that have together made the Department what it is today.

Currently, his research includes work on Propionibacterium acnes, the relatively slow-growing bacterium. Collaborating with Drs. Pottinger, Butler-Wu, and Bumgarner, Dr. Matsen has published original research on these bacterial cultures found in revision shoulder arthroplasties. In addition, he continues his work on conflict of interest questions, chondrolysis and pain pumps, impingement syndrome, and glenohumeral arthritis. He is currently committed to providing quality free information to the world on the shoulder arthritis and rotator cuff tears via the Shoulder Blog (www.shoulderarthritis.blogspot.com) which recently passed 1,000,000 page views from over 100 countries.

Visiting Lecturers

2018 Resident Research Day

June 22, 2018

We were very happy to host Dr. Michael J. Gardner as the guest lecturer for our Resident Research Day on June 22, 2018. Dr. Gardner gave two lectures: "Proximal Humerus Fractures: Treatment Decisions and Minimizing Complications" and "Distal Femur Fractures: What a Long, Strange Trip…"

Dr. Gardner specializes in orthopaedic trauma surgery, and treating all aspects of fractures of the upper extremity (except the hand), lower extremity, and pelvis, as well as nonunions and malunions. He joined the faculty at Stanford in 2016, and is currently Chief of the Orthopaedic Trauma Service and Vice Chair of Clinical Operations. Prior to coming to Stanford, Dr. Gardner was an orthopaedic trauma surgeon at Washington University in St. Louis for the previous 7 years. He completed his residency training at the renowned Hospital for Special Surgery in New York, which included basic science studies of fracture healing as well as multiple clinical studies. During that time, he also completed a one year research fellowship in the HSS Biomechanics Laboratory. He then completed an Orthopaedic Trauma fellowship at Harborview Medical Center in Seattle, WA.

His contributions and recognition in the field of orthopaedic surgery have culminated in invitation and participation in many national activities. He has been a grant reviewer for a study section on orthopaedic trauma for the Department of Defense, is on the editorial board of Journal of Orthopaedic Trauma and Current Orthopaedic Practice, and is a reviewer for eight other major orthopaedic journals. He has also been actively involved in the Orthopaedic Trauma Association, where he has served on the Annual Meeting Program Committee from 2010 through 2016, and the Research Committee since 2014. He is an abstract reviewer for the Orthopaedic Research Society and the American Orthopaedic Association, and has been a Visiting Professor at many institutions around the country. His strong interest in research has led to several federally funded research grants, 154 publications, 32 book chapters, and three textbooks edited.

Validation of a Rabbit Model of Trauma-Induced Heterotopic Ossification

Brandon J. Ausk, PhD, Philippe Huber, BS, Ted S. Gross, PhD,
Reza Firoozabadi, MD, MA, and Steven D. Bain, PhD

Abstract

Previous studies in our laboratory have demonstrated that focal inhibition of neuromuscular signaling via intramuscular delivery of Botulinum toxin A (BTxA) prevents the formation of ectopic bone in a mouse model of BMP-induced heterotopic ossification (HO) [1]. However, as the BMP-induced HO model does not replicate HO pathogenesis in human patients, translation of this concept to clinical practice requires the development and validation of a rabbit HO model that mimics the timing and pathogenesis of human HO [2, 3]. A key objective will be to quantify the anatomical location and magnitude of HO in order to design treatment strategies that target soft tissue regions where HO is most likely to impair patient function.

Introduction

Heterotopic ossification (HO) is the pathological formation of bone in soft tissues outside of the skeleton and is a frequent complication following hip and elbow fracture, joint replacement, and amputations [4-7]. Unfortunately, current approaches to prevent HO, such as focal radiation and high-dose nonsteroidal anti-inflammatory drugs (NSAIDs), are costly, lack efficacy, and have side effects that preclude their application in patients with profound trauma [8-9]. Once HO becomes symptomatic, the only treatment is surgical removal, which is high risk, expensive, and has a high incidence of HO reoccurrence. In this context, we have recently demonstrated that precision delivery of low-dose BTxA prevents HO in a murine model of BMP-induced HO and that the inhibition of HO is not dependent upon muscle paralysis itself. Based on these observations, we have hypothesized that targeted delivery of low-dose BTxA will prevent trauma-induced HO in human patients. Furthermore, we speculate that translating this approach to human patients will require a delivery device that can focally deliver low-dose and low volume BTxA in order to safely shield anatomically sensitive areas from HO. The purpose of this project was therefore two-fold; 1) to validate the rabbit model of trauma-induced HO, and 2) to identify the soft tissue volume where HO inhibition would be most critical.

Materials and Methods

- Six, eighteen-week old male rabbits (3.5 to 4.0 kg) underwent the trauma-induced HO procedure.
- Via a skin incision over the greater trochanter, a pneumatic drill with a 4.0 mm trochar point Steinmann pins was used to enter the femoral medullary canal, followed by manual reaming with 3-4 mm micro-curettes. The bone debris and marrow produced by the reaming process was left *in situ* in the soft tissue bounded by the acetabulum and greater trochanter.
- Before closure, ischemic injury to the gluteal muscles was induced by application of a Kelly clamp to the gluteal

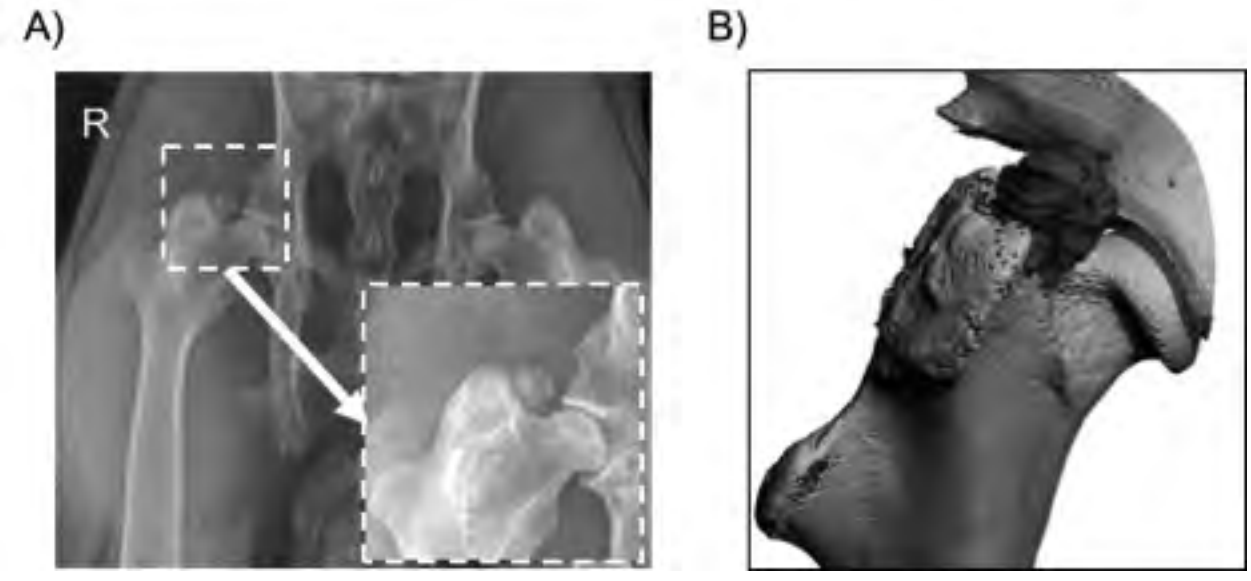


Figure 1: Substantial HO was observed within the hip joint via digital radiography at 4 weeks (A) and via high resolution ex vivo microCT imaging at 6 weeks (B).

musculature for approximately 3 minutes, as tissue hypoxia enhances HO [10].
- The anatomical location and magnitude of HO lesions post-surgery was determined using radiography (4 and 6 weeks) and high resolution μCT imaging (6 weeks).
- μCT imaging results were used to identify the volume-of-interest (VOI) for targeted HO prevention.

Results

- Consistent with the literature, the rabbits presented with radiographic evidence of HO within the femoral-acetabular musculature at 28 and 42 d post-surgery (Figure 1A).
- High resolution μCT imaging revealed focal (total volume = 137 mm^3) and highly mineralized (bone volume/total volume = 41%) HO lesions at 6 weeks (Figure 1B).
- The critical VOI was identified allowing for injection prototypes to be tested in future studies.

Discussion

Results from this study validate our ability to perform the rabbit, trauma-induced HO model, which was originally developed to test prophylactic therapies for HO [2, 3]. Further, to our knowledge, this is the first study in the rabbit model that successfully quantified HO volume and mineralization using high resolution μCT. Based upon the rabbit μCT imaging data, we have been able to identify a 3D VOI (2 cm^3 soft tissue volume) in the region between the greater trochanter and acetabulum where HO would cause pain, neural entrapment and joint ankylosis.

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Schwartz Rounds™ at the University of Washington Hospitals

Michael J. Goldberg, MD

While the epidemic of clinician burnout continues to make headlines, less has been written about evidence-based strategies that mitigate workplace strain and promote a compassionate, collaborative team culture. Individual-focused and organization-structural strategies can result in meaningful reductions in physician burnout (1,2). A business case for investing in physician well-being has been made (3). The delivery of high quality, high value healthcare is more and more team based; and if we are to deliver the care we know our patients and families need and deserve, we must focus on the well-being of every team member. Team member to team member support is essential for navigating the stressors of practice. With the norm being having lunch in front of your computer, combined with the disappearance of the traditional spaces for colleagues to connect (e.g. nurses' lounge, physician dining rooms), the opportunity for caregivers to have a safe space to escape, to have their own humanity reaffirmed, to find a place to offer support to their peers, has been all but eliminated. Scheduling time for open and honest discussion of the social and emotional issues that arise in caring for patients helps nourish caregiver to caregiver compassion.

The Schwartz Center for Compassionate Healthcare in Boston is a national non-profit leading the movement to bring compassion to every patient-caregiver interaction. Schwartz Rounds™ bring doctors, nurses and other caregivers together to discuss the human side of healthcare. More than 440 healthcare organizations throughout the United States, Canada, Australia and New Zealand are Schwartz Center members and conduct Schwartz Rounds™. In addition, 170 sites throughout the UK and Ireland offer the Schwartz Rounds™ program. Seattle Children's Hospital held its first Schwartz Rounds™ on April 23, 2012 and Seattle Cancer Care Alliance started less than a month later. The University Washington Medical Center began Schwartz Rounds™ in 2015 and Harborview in 2016 (Table 1).

Using a clinical case as a theme, Schwartz Rounds™ are a 60-minute facilitated discussion with 3 or 4 multidisciplinary panelists who talk about the impact of illness and the psychosocial and emotional aspects of caring for patients and their families. It is not the patient's story, but rather, it is the caregiver's story. It differs from event focused debriefings such as quality and safety responses after medical errors, root-cause analysis, or second-victim peer support programs. It is a regularly scheduled safe space for the panelists and the attendees to openly and honestly share their experience, thoughts, and feelings.

Researchers have investigated the impact of Schwartz Rounds™ and have concluded that they make a difference (4-9). The frequency of participation in Schwartz Rounds™ correlated with an increased insight into the emotional aspects of patient care; increased feelings of compassion toward patients; and increased readiness to respond to patients' and families' needs. The greater the number of rounds attended, the greater the improvement in teamwork, interdisciplinary communication, and appreciation for the roles and contributions of colleagues from different disciplines. Frequency of attendance is also correlated with significant decreases in feelings of stress and isolation, with improvements in psychological well-being, and in more openness to giving and receiving support.

An essential of Schwartz Rounds™ is the insight gained by listening to the perspective of all hospital caregivers, whether they touch the patient directly (such as nurses, doctors, and social workers) or indirectly (such as interpreters, transporters, and administrators).

At many Schwartz Rounds™ sites, physicians, nurses and social workers receive continuing education credits. Attendance can also help satisfy the ACGME core competency requirements for post-graduate residency programs. The Joint Commission includes the Schwartz Rounds™ program on its

Seattle Children's Hospital
Clinical Leader: Ross Hays, MD
Facilitator: Michael J. Goldberg, MD
Coordinator: Sarya Sos

Seattle Cancer Care Alliance
Clinical Leader: Elizabeth Loggers, MD
Facilitator: Ben Danis, PhD and Moreen Dudley, MSW, MBA
Coordinator: Petr Horak

University of Washington Medical Center
Clinical Leader: Kenneth P. Steinberg, MD
Facilitator: Shobha W. Stack MD, PhD
Coordinator: Keri Nasenbeny, RN, MHA

Harborview Medical Center
Clinical Leader: Claudia Finkelstein, MD
Facilitator: Jill Rasmussen-Baker, MDiv, BCC
Coordinator: Scott O'Neill

Table 1: Schwartz Rounds™ Leadership Teams at the University of Washington Hospitals.

list of recommended resources for improving provider-patient communication.

The Schwartz Center for Compassionate Healthcare was founded by Kenneth B. Schwartz, who in 1994 at age 40, was diagnosed with advanced lung cancer. Shortly before his death, 10 months later, he wrote an article for the Boston Globe Magazine (10), detailing his experience; many aspects of which were harrowing for him and his family. “And yet”, he went on to say, “the ordeal has been punctuated by moments of exquisite compassion. I have been the recipient of an extraordinary array of human and humane responses to my plight. These acts of kindness -- the simple human touch from my caregivers -- have made the unbearable bearable”.

What matters most during an illness is the human connection between patients and their caregivers. Schwartz Center recognizes that fact especially in the face of a healthcare delivery climate that is faster-paced, more complex, resource constrained, and over-run by non-intuitive electronic systems. Ways to deliver the benefits of Schwartz Rounds™ to those on the front lines at the point of care are being developed. Workforce well-being is a prerequisite for real engagement between caregiver and patient, and for creating a more compassionate workplace. Schwartz Rounds™ is an evidence based strategy that mitigates burnout and promotes the delivery of compassionate collaborate care (11).

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Should Explants Be Cultured at Revision Shoulder Arthroplasty?

Jason E. Hsu, MD, Davin Gong, BS, and Frederick A. Matsen III, MD

Background

Surgeons revising a failed arthroplasty need to know whether or not bacteria are present around the implanted components. The specimen harvesting and culturing practices used to recover bacteria at revision surgery vary among surgeons, with some surgeons culturing tissue and others including both tissue and removed components. Culturing explanted components has the potential benefit of revealing organisms residing in biofilms on their surface that might otherwise be overlooked. The purpose of this study was to assess the added value of culturing explants in seeking evidence of *Propionibacterium* at revision arthroplasty. We sought to answer three questions:

1. Does culturing of explants (in addition to tissue cultures) facilitate the recovery of *Propionibacterium* from revised shoulder arthroplasties?
2. In *Propionibacterium* culture-positive shoulders, how does the *Propionibacterium* load from explant cultures compare with the load from tissue cultures?
3. In *Propionibacterium* culture-positive shoulders, are some anatomic areas more likely to have positive cultures?

Methods

From December 2015 until March 2018, 122 revision arthroplasties were consented for inclusion in a revision shoulder arthroplasty database. Specimens were submitted for standardized *Propionibacterium* culturing of tissue from the collar membrane, humeral canal, and periglenoid area as well as explants of the humeral head, humeral stem, and glenoid components. In this analysis we included only those shoulders that had both tissue and explant culture results from three anatomically similar locations: 1) HEAD region: collar membrane tissue and humeral head explant (n=86), 2) STEM region: humeral canal tissue and humeral stem explant (n=58), or 3) GLENOID region: periglenoid tissue and glenoid explant (n=45). Tissue samples were homogenized with saline, and the saline was streaked onto three different anaerobic and aerobic media and observed for 21 days. Explanted components were vortexed with saline, and the saline was streaked in a similar fashion. Semiquantitative culture results were reported for each specimen as the Specimen Propi Value (SpPV). We analyzed the results for two threshold values: SpPV>0 and for SpPV≥1.

Results

For both thresholds, inclusion of explant cultures increased the percentages of cultures that were positive (Figure 1).

Importantly, explants were culture positive in shoulders in which the tissue specimens were negative in 6 of 30 (20%) HEAD specimens, 8 of 24 (33%) STEM specimens, and 9 of 19 (47%) GLENOID specimens. The *Propionibacterium* SpPVs were similar between positive explant and tissue specimens in the HEAD region (tissue 1.0 ± 0.8 vs. explant 1.5 ± 1.1, p=0.144), STEM region (tissue 1.2 ± 1.0 vs. explant 1.3 ± 1.1, p=0.873), and GLENOID region (tissue 1.0 ± 0.6 vs. explant 0.8 ± 0.8). The percentage of positive tissue or explant specimens were similar between anatomic sites: the HEAD specimens were positive in 30 of 86 (35%) samples, STEM 24 of 58 (41%), and GLENOID 19 of 45 (42%).

Conclusion

In this study, inclusion of explant cultures increased the percentages of cultures positive for *Propionibacterium* at each of three anatomic sites. These findings suggest that the identification of *Propionibacterium* in revision arthroplasty is more likely if removed implants are submitted for culture. This increase may be due to the detection of bacteria in implant biofilms in cases where it was not detectable in tissue samples.

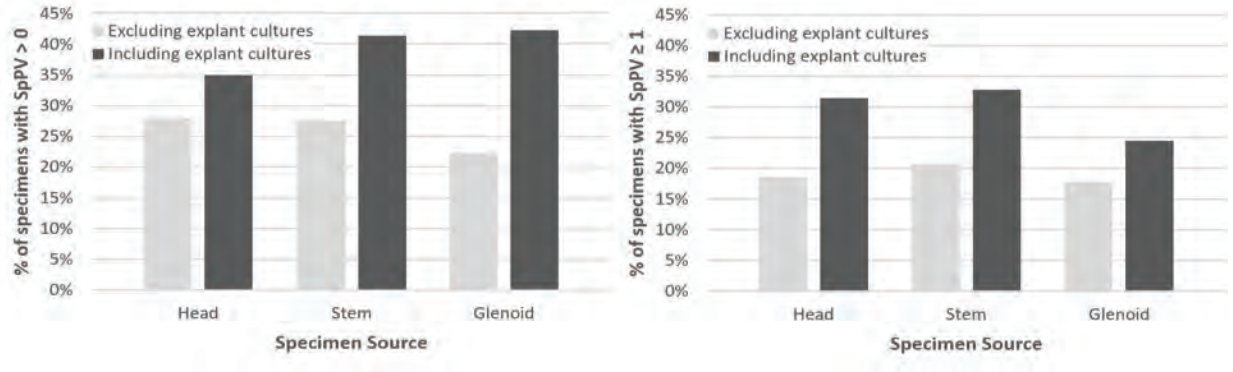

Figure 1: Inclusion of explant cultures increased the percentages of cultures that were positive.

Fusiform Swelling Does Not Distinguish Acute Pyogenic Flexor Tenosynovitis from Other Infections of the Finger, But Plain X-Rays Might Help

Anthony Yi, MD, Colin D. Kennedy, MD, Benjamin Chia, MD,
and Stephen A. Kennedy, MD, FRCSC

Background and Purpose

Pyogenic flexor tenosynovitis (PFT) is a hand infection with potential for severe consequences. Diagnosis should be timely and accurate to avoid spread of the infection, amputation of the digit, and/or permanent impairment of the hand. In 1912, Allen B. Kanavel described three signs that aid in the prompt diagnosis of PFT: (1) exquisite tenderness over the course of the sheath, (2) flexion posture of the finger, and (3) exquisite pain on extending the finger.[1,2] He later added the finding of (4) uniform swelling of the involved finger.[3] These findings became "Kaplan's Four Cardinal Signs" and are widely used in the diagnosis of PFT.[2-5] Our recent research at UW Department of Orthopaedics & Sports Medicine, however, has shown that although these findings are sensitive (i.e. most PFT infections have them), each is not necessarily specific (i.e. other hand infections have them also).[4] "Uniform swelling" was not found to independently predict PFT over other finger infections.[4]

Since the characteristic swelling of pyogenic flexor tenosynovitis is frequently referenced, but not well-defined, we wanted to study it further.[1-5] Kanavel described the swelling of PFT as "the whole of the involved finger is uniformly swollen".[1] "Uniform swelling" has been used interchangeably with the term "fusiform swelling,"[2,4,5] which means spindle-shaped or tapering at both ends. Characteristic features of the soft tissue swelling in PFT, however, have not been well described either clinically or with imaging. The purpose of this study was to identify features that distinguish the soft tissue swelling of PFT from that of non-PFT finger infections using standard digital radiographs and radiology software.

Methods

We conducted a retrospective case-control study of adults with finger infections to compare radiographic parameters of soft tissue swelling. Patients with a finger infection and radiographic evaluation at Harborview Medical Center were identified retrospectively over a 5-year period,

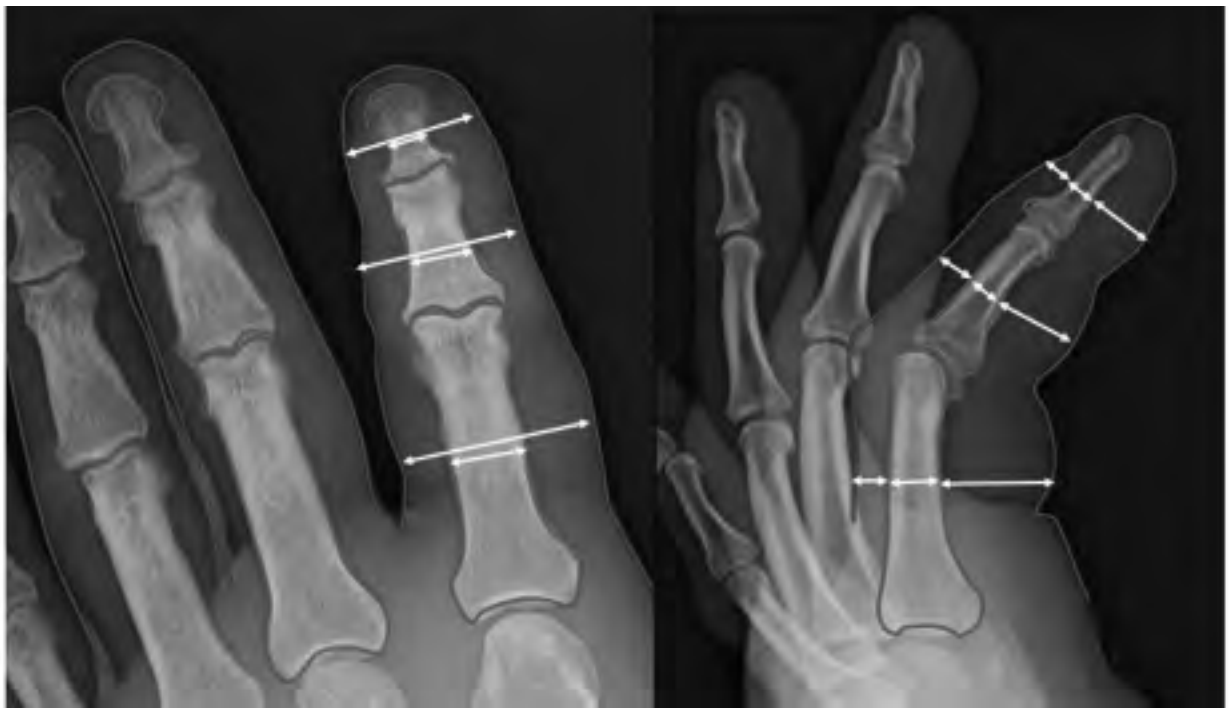

Figure 1: Depiction of measured values. Note the absence of a tapered or spindle appearance, proximally or distally.

Calculated values		PFT	Non-PFT	p-value
Ratio of volar soft tissue to dorsal soft tissue	at proximal phalanx (P1)	3.1	1.8	<0.001
	at middle phalanx (P2)	2.7	2.0	<0.001
	at distal phalanx (P3)	2.6	2.0	0.01
Difference (in mm) between volar and dorsal soft tissue thickness	at proximal phalanx (P1)	9.4mm	4.9mm	<0.001
	at middle phalanx (P2)	7.5mm	5.3mm	<0.001
	at distal phalanx (P3)	4.9mm	3.6mm	0.06

Table 1: Calculated ratios and differences, with comparison between PFT and Non-PFT finger infections. PFT infections were distinguished from non-PFT infections based on the difference between volar and dorsal soft tissue swelling, particularly at the level of the proximal phalanx. Statistically significant values (p<0.05) are highlighted in grey.

and divided into 2 groups: PFT (n=31) and Non-PFT infections (n=31). PFT was defined as purulence in the tendon sheath or positive culture growth from the sheath at surgery. Cases that did not meet these criteria, such as felons, cellulitis, paronychia, and finger abscesses, were categorized as Non-PFT finger infections.

Demographic data were obtained including age, sex, tobacco smoking status, and history of intravenous drug use. Using digital radiographs and software measurement tools, soft tissue and bone width measurements were made for each phalanx on anteroposterior (AP) and lateral radiographs. A total of 15 measurements were made for each infected finger (Figure 1). If the thumb was involved, the measurements were made at the proximal and distal phalanx measurement was recorded. Ratios and differences were calculated to characterize the pattern of swelling for each infected finger.

After calculating averages for each of the measurements, differences, and ratios, bivariate analysis was performed to detect significant differences between the PFT and non-PFT groups. We compared volar-to-dorsal soft tissue swelling at each phalanx using differences and ratios. The ratio of proximal-to-distal swelling was assessed to objectively characterize the nature of soft tissue swelling in PFT and non-PFT infections. A *p*-value of 0.05 was employed to determine statistical significance. Logistic regression was performed to reduce confounding and model potential relationships. No funding was received in relation to this study.

Results

Measurements were compared between the PFT and non-PFT groups. Volar soft tissue swelling was greater for patients with PFT compared to the non-PFT group, particularly at the proximal phalanx (P1). Dorsal soft tissue swelling was greater for non-PFT infections, particularly at P1 ($p < 0.05$). We found a statistically significant difference between PFT and non-PFT infections when volar soft tissue swelling was calculated as a ratio relative to the dorsal soft tissue swelling at P1, P2, and P3. The mathematical difference (in mm) between volar and dorsal soft tissue thickness was also statistically significant between PFT and non-PFT infections at P1 and P2. Ratios between the proximal and distal aspects of the finger were calculated to objectively characterize the difference in shape (e.g. spindle shape vs. tapered) between PFT and non-PFT infection and no significant differences were found.

Logistic regression was performed and the difference between volar and dorsal soft tissue swelling at the level of the proximal phalanx was an independent predictor of pyogenic flexor tenosynovitis ($p<0.001$). A difference between volar and dorsal soft tissue swelling of ≥10mm predicted PFT with ≥76% probability (95%CI=58.5% - 87.3%) and had a sensitivity and specificity of 74% and 84%, respectively. A difference of ≤0 mm predicted a non-PFT infection with ≥95% probability (95%CI=73.4%– 99.2%). Area under the receiver operating characteristic curve was 0.83.

Discussion and Conclusions

As recognized by Kanavel, this study demonstrates that fingers with PFT are uniformly swollen.[3] Uniform swelling does not, however, distinguish PFT from non-PFT finger infections. All finger infections resulted in diffuse swelling. The independent radiographic factor that differentiated between PFT and Non-PFT finger infection was differential volar-to-dorsal swelling at the level of the proximal phalanx (in mm) on lateral x-rays ($p<0.001$). This more volar swelling is in keeping with the anatomical location of the flexor tendon sheath on the volar side of the digit.

Swelling in PFT involves the proximal, middle, and distal phalanges in both the coronal and sagittal planes, and was not, therefore, "fusiform" swelling. Fusiform swelling indicates spindle-shaped swelling or tapering, and was not present in any PFT infected digit. Neither was there a difference between PFT and non-PFT groups in terms of the proximal-to-distal swelling ratios (e.g. P1 vs. P2 and P1 vs. P3) in both the coronal sagittal planes. We feel that "fusiform swelling" is a misnomer for the swelling of acute pyogenic flexor tenosynovitis and recommend that it be abandoned.

The findings in this study need to be considered in the context of its

limitations. The retrospective nature of this study limits the level of evidence and may have resulted in bias. Future prospective studies are needed to validate the findings. PFT infections were compared with a heterogeneous group of Non-PFT infections, without a series of normal controls. We felt this was acceptable because of the typical diagnostic scenario, which involves differentiation of PFT from Non-PFT infections. However, comparison with normal matched controls may better elaborate on the characteristic swelling of PFT. The measurements for each of the radiographs was performed by a single observer, and the inter- and intra-observer reliability will need evaluation in future validation studies.

Previous authors have also suggested stratifying patients according to prognosis.[5,6] Pang et al stratified patients with PFT into 3 groups, based on the presence of Kanavel's signs, subcutaneous purulence, and presence of digital ischemia.[5] Michon et al staged patients on the basis of intraoperative appearance of the synovium.[6] Future studies will need to include such prognostic stratification for accurate determination of the validity of using radiographic swelling differences for early or mild cases where it might be most useful.

Despite these limitations, our results may offer an objective and simple adjunct to the evaluation of a patient with a finger infection. We found that acute swelling associated with PFT is not fusiform and can be distinguished from non-PFT infections by the difference between volar and dorsal soft tissue swelling at the level of the proximal phalanx. Future prospective studies are needed to investigate the diagnostic utility of applying these results to clinical practice.

Type of Study/Level of Evidence: Diagnostic Study, Level III, retrospective case-control study

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Local Weather is Associated with Rates of Online Searches for Knee Pain Symptoms

Scott Telfer, EngD

It is a commonly held belief that a causal relationship exists between local weather conditions and the joint pain and stiffness associated with musculoskeletal disorders [1,2]. Weather variables including humidity, barometric pressure, and temperature have been studied to determine any influence on musculoskeletal symptoms, however the evidence in the literature tends to be conflicting, or show only a weak effect [3,4]. These previous studies have generally been limited in terms of the time period assessed [5,6], geographical scope [7,8], or have focused on seasonal variation [9] which may be confounded by factors such as global disease activity or changes in medication over these time scales.

Recently, researchers have begun to explore the potential of online search behavior as a method to infer information about health trends at the population level, exploiting the fact that the internet has become one of the primary sources used by individuals seeking health information [10,11]. If a relationship between relative search volumes for knee pain related terms and localized weather conditions exists, it may provide indirect evidence of the purported causal effect of weather conditions on these musculoskeletal issues at a population level. Therefore, we hypothesized that localized search volumes for these terms would be significantly different during time periods when weather variables were elevated.

Materials and Methods

The top 50 cities in the United States by population were identified (based on 2014 estimates from the US Census Bureau) and the Google Trends web interface was used to obtain weekly relative search volumes for terms related to knee pain and stiffness (KNEE PAIN: "knee pain + painful knee + sore knee + stiff knee + knee stiffness") between 2011/01/02 and 2015/12/26 for these municipalities. Corresponding daily summaries of historical local weather data for each city were obtained from the closest weather station that monitored relative humidity, barometric pressure, and temperature.

A nearest-neighbor propensity score matching approach [12] was used to define weekly time points that could be compared to determine if there were differences between search volumes during periods with differing weather conditions while controlling for additional confounding factors. A repeated measures t-test was used to compare search volumes between the matched humidity time periods across cities, with α adjusted via the Bonferroni correction for the number of weather variables analyzed against each search term trend dataset ($\alpha = 0.017$). For search term / weather variable combinations found to be significantly different, a simple linear regression was performed on the matched city level data to determine the degree to which the relevant weather variable explained search volumes.

Results

The results for the KNEE PAIN search terms (Figure 1) did not reveal any consistent trends in search volumes for periods with increased humidity ($p = 0.07$; 95% CI [-0.26, 4.77]). In the case of barometric pressure, the majority of cities (30/37) had a decrease in search volume during times of elevated pressure ($p < 0.001$; 95% CI [-6.1, -3.2]). The mean decrease during these periods was 4.6% (SD 4.5), and linear regression showed that this variable explained 0.9% of the variance in the search volume data ($F(1, 5058) = 45.6$, $p = <0.001$). Similarly, for elevated temperatures 25 out of 27 cities showed an increase in search volumes ($p < 0.001$; 95% CI [5.9, 10.1]). The mean increase in search volume during periods of elevated temperatures was 8.5% (SD 5.3), and this variable accounted for 3.5% of the variance in the search volume data ($F(1, 3800) = 138$, $p = <0.001$).

Discussion

This study analyzed online search volume data for musculoskeletal pain related terms in cities across the United States and found small but statistically significant associations with local weather conditions. Although search volume data is a proxy measure of symptom prevalence, the 5-year analysis period here is considerably longer than most previous studies in this area, and covers a potential sample size of tens of millions, based on the population of the cities studied and adjusted for internet users and users of the Google search engine.

The strongest associations were found between increased temperatures and increased knee pain searches. There have been previous reports of increased temperatures leading to increased pain after orthopaedic trauma [13], however studies in patients with arthritis have found no such relationship [5], or in some cases negative correlations [7]. The increases seen in the present study may relate to general increases in activity patterns during warmer temperatures that could potentially lead to overuse and acute injuries [14,15], however this does not rule out a negative effect in a smaller population of individuals with arthritis.

Overall, our results support previous findings that, while a causal relationship between weather conditions and joint pain and associated symptoms may exist, the amount of variance in the data it accounts for is relatively small (0.5-3.5%). If larger, region-specific effects do exist, this information may allow healthcare providers to allocate resources more efficiently or provide different treatment strategies during times periods when barometric pressure is low and temperature elevated, or by using a model based on the search volume data and potentially including other factors as a surveillance tool. This would require significant further development of the methodology and

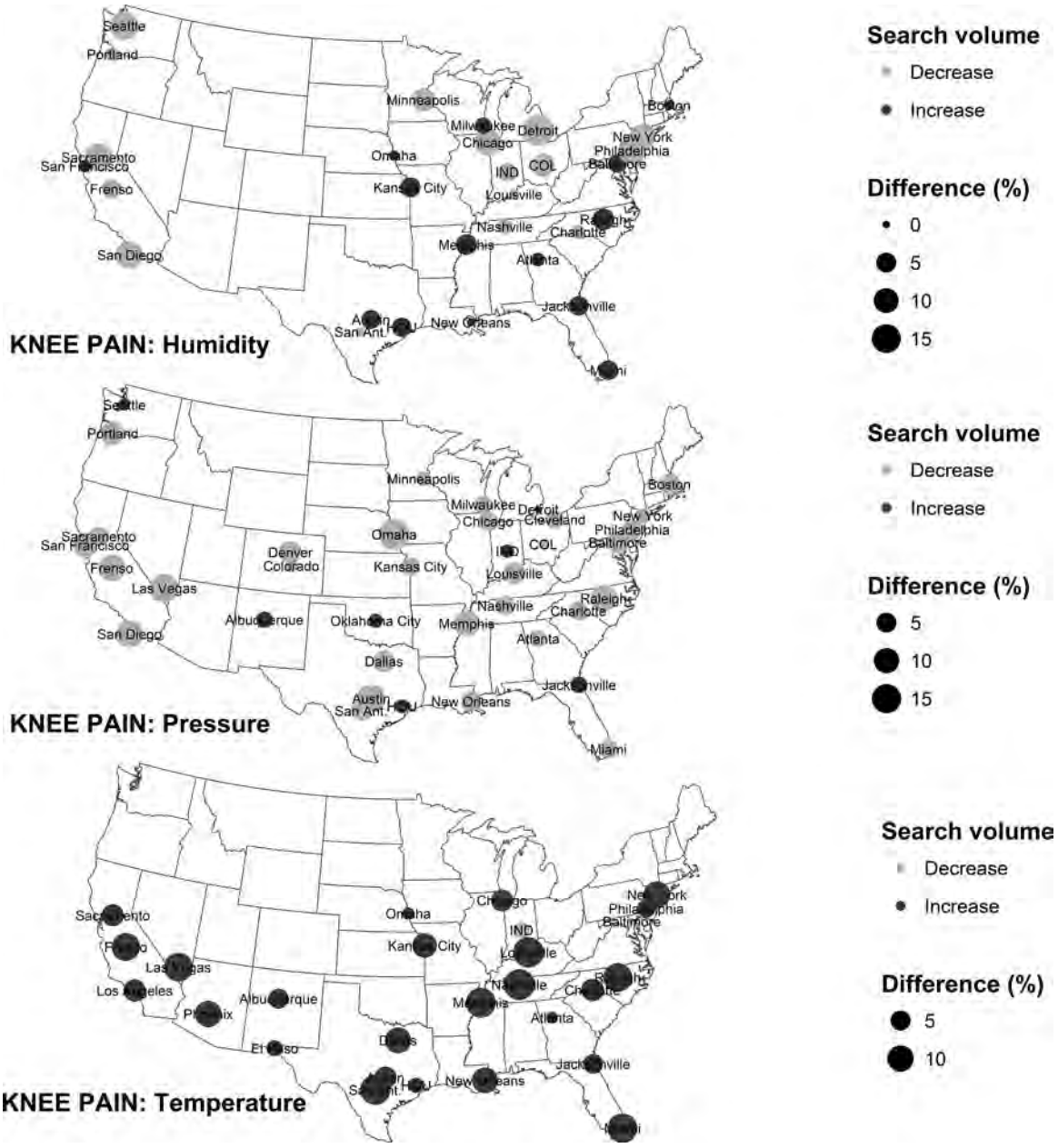

Figure 1: The results for the KNEE PAIN search terms.

likely validation against individual level data in order to validate that changes in search volumes are indeed related to changes in individual specific pain and healthcare seeking behavior. Further work is required to determine if a local clinical monitoring tool for musculoskeletal conditions can be developed based on the search volume data.

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The Novel Semilunar Pulley Orthosis (SPOrt) Decreases Flexor Tendon-Phalanx Distance in Climbers with Chronic A2 Pulley Ruptures

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Introduction

As modern rock climbing has become increasingly popular, there is an increase in the incidence of pulley ruptures. Pulley ruptures are one of the most common injuries sustained by rock climbers with a prevalence of 26% in elite climbers (1-4).

A2 pulley ruptures are associated with the "crimp grip" used by climbers when grasping small holds. In the "crimp grip" position, the distal interphalangeal joints are hyperextended, the proximal interphalangeal (PIP) joints are flexed beyond 90 degrees, and the metacarpophalangeal (MCP) joints are slightly flexed. Disruption of the pulley results in an increased tendon-phalanx distance (TPD), which can cause bowstringing of the flexor tendons and lead to flexion contractures and loss of function. Complete A2 pulley rupture is defined as TPD greater than 2mm, with distances less than 1mm defined as normal (5-8). Biomechanically, an increased TPD decreases the strength of the digit, especially in the crimp position and decreases the amount of finger flexion possible.

The senior author developed a novel, custom finger splint, called the Semilunar Pulley Orthosis (SPOrt), which is easily fabricated and applied (Figure 1A). We hypothesized that when the SPOrt was used by climbers with chronic A2 pulley ruptures, it would reduce the TPD in a statistically significant manner.

Methods

Participant Enrollment

Climbers with a suspected pulley injury were recruited from local climbing gyms to participate in the study. Inclusion criteria consisted of self-described rock climbers over 18 years of age with no prior fractures, surgeries, or injuries to their fingers other than the suspected A2 pulley injury greater than 4 weeks prior to presentation. Institutional Review Board approval was obtained and all climbers involved in the study signed the informed consent form prior to ultrasound imaging.

Ultrasound Screening

This prospective series of climbers with a suspected history of a pulley injury were screened with an ultrasound (Philips CX50, Philips Healthcare, Inc, Bothell, WA) using a 5-12 MHz linear transducer. Those with TPD at the middle of the proximal phalanx greater than 2 mm were included in the study (5,7). TPD on the equivalent digit of the contralateral hand was measured to serve as a control.

SPOrt Fabrication

The SPOrts were fabricated from 1/12", 13% microperforated thermoplast splint material (Prism Medical, Inc, Maryland Heights, MO) and those used for testing were windowed to permit for ultrasound measurement of TPD (Figure 1B). They are fabricated to be 5/6th the circumference at P1 and cover 2/3rd the distance between the palmar digital crease and the proximal interphalangeal joint crease with the PIP joint extended.

Ultrasound Testing

The ultrasounds were done both at rest and in a custom testing jig that allowed the digit to be stressed in a slightly flexed position. Climbers pulled with at least 30N of force measured by a tensiometer (Shenzhen Times Fishing Tackle Co., Ltd., Guangdong, China) while in the testing jig (Figure 2) (9). The SPOrt is placed on the volar aspect of the finger, just distal to the palmar digital crease and snuggly secured by the wearer with six circumferential wraps of cloth athletic tape, 2/3rd the width of the SPOrt. Measurements of TPD of the affected digit were obtained both in the stressed condition in the jig and at rest.

Statistical Analysis

A paired t test was performed after verifying normal distribution using the Kolmogorov-Smirnov test (Excel 2016, StataCorp 2015). A Wilcoxon Signed-Rank test was performed when the data was not normally distributed.

Results

47 fingers were scanned in 43 climbers and 15 fingers in 15 climbers were diagnosed with a complete unilateral A2 pulley rupture. One patient was excluded who had an acute rupture of his A2 pulley (less than 2 weeks old). Average age of the climbers was 43 years (range 27 to 66 years) and 80% were male. The middle finger was injured in 53% of climbers, the ring finger in 40% and the index in 7%.

Average TPD at rest, in the unstressed condition, was 2.47±0.67 mm without the SPOrt and 2.05±0.48 mm ($p<0.005$) with the SPOrt applied. Average TPD in the stressed condition was 3.02±0.67 mm without the SPOrt and 2.25±0.45 mm ($p<0.0001$) with the SPOrt applied. Average decrease in TPD was 0.78±0.45 mm for a 26% reduction in TPD in the stressed condition.

Discussion

Historically, non-operative treatment of pulley ruptures involved a period of immobilization followed by a gradual increase in loaded finger exercises with circumferential cloth tape around the digit. Prior studies have shown that circumferential taping does not prophylactically protect against pulley injuries and is minimally effective in relieving the force on the A2 pulley (10,11). Taping in an H pattern has been shown to reduce TPD by 16% (12). A study by Schneeberger et al. reports on a custom pulley-protection splint as a conservative method to treat pulley ruptures (13). The investigators found that patients treated in this splint for two months had a decreased TPD after treatment, from 4.4±1.0 to 2.3±0.6 mm. The authors found that the smallest TPD attainable with their splint was 2 mm in forced flexion. While the pulley-protection splint is an effective treatment for pulley ruptures, the convexities

Figure 1: (A) Custom SPOrt. (B) SPOrt with window for ultrasound testing correctly positioned on a finger.

protruding into the interphalangeal spaces to avoid vessel compression are bulky and cumbersome. The SPOrt is comfortable to wear, is low profile to diminish discomfort while climbing, and can be easily adjusted by reapplying the tape to minimize constriction of digital nerves and vessels.

The SPOrt effectively decreases the TPD in climbers with A2 pulley injuries by 26%, an average of 0.78 mm while in the stressed condition. The SPOrt is better able to decrease TPD in the stressed condition than at rest, indicating that it is effective in decreasing the amount of bowstringing of the flexor tendons while climbing.

Limitations to this study include the inability to study the finger under stress in the crimp position. While the crimp position is the most important grip to study since it places the most stress on the pulley system, there was insufficient space for the ultrasound probe to image the pulley in this position. Therefore, imaging was done with the finger in a slightly bent position approximating the crimp position as closely as possible while still allowing ultrasound access as in other studies (12,14). Measurements were made through the SPOrt window which limited the ability to determine exactly where along the phalanx the ultrasound caliper was placed. However, an identical SPOrt was used on the contralateral finger and the measurement was taken at the middle of the window on both fingers to control for this. Furthermore, measurements done "without the SPOrt" were in fact done with the SPOrt in position but not secured to ensure measurements were done at the same location on the affected digit.

The SPOrt decreases the TPD in climbers with A2 pulley injuries and is effective in decreasing the amount of bowstringing of the flexor tendons while climbing. This may in turn decrease the stress on the remaining intact pulleys and prevent subsequent injuries in the remainder of the tendon sheath. The SPOrt is custom-sized, easily fabricated, facile to apply, readily adjustable, and comfortable to wear while climbing, which should increase compliance with wear and allow the climber to return to climbing with support to the pulley sheath.

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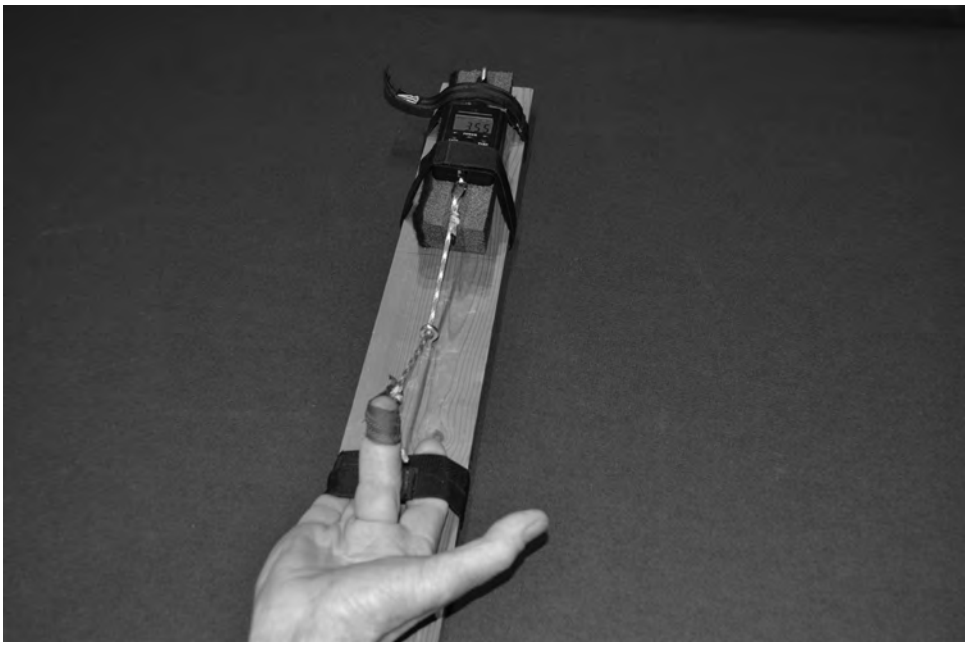

Figure 2: Testing jig used to ensure the digits were tested with the MCP and PIP joints in a flexed position and loaded with at least 30N.

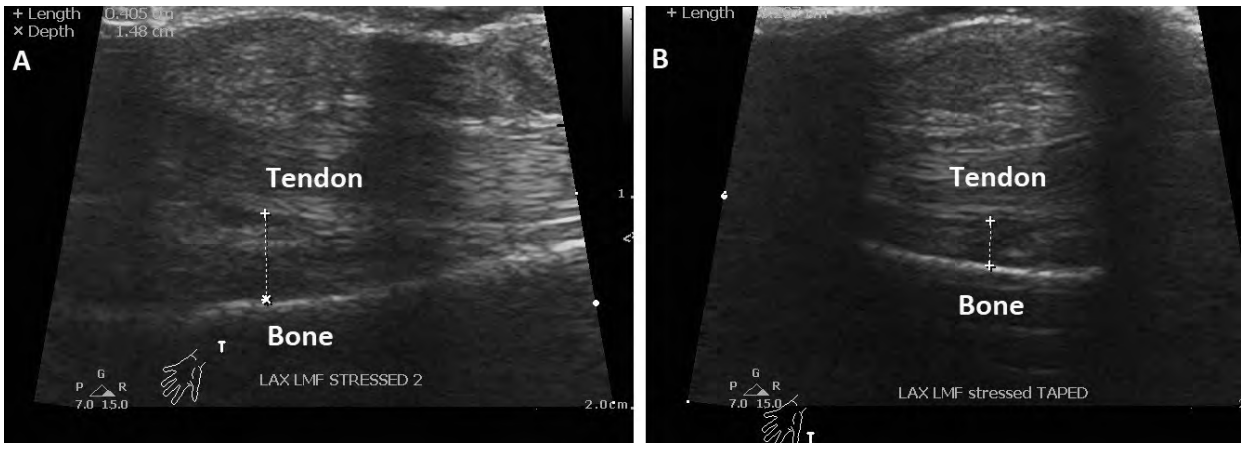

Figure 3: Representative US images (A) without and (B) with the SPOrt secured showing a decreased TPD.

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ESET Histone Methyltransferase is Essential to the Development of Synovial Joints

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Abstract

This study examines the effects of ESET (an ERG-associated protein with a SET domain) histone methyltransferase on synovial joint formation in E15.5 and E18.5 mouse embryos. In the forelimbs where knockout of ESET initiates at embryonic day E9.5, deletion of exon 4 (wiping out the entire ESET protein) did not affect interzone formation but caused complete cavitation failure at all phalangeal joints, and deletion of exons15-16 (eliminating only the H3-K9 methyltransferase activity) caused incomplete cavitation of most phalangeal joints. In the hindlimbs where knockout of ESET initiates one day later at E10.5, neither type of ESET deletions had an appreciable effect on joint formation. Therefore, our study shows that the entire ESET protein and the precise timing of its expression during embryo development are critical to joint formation.

Introduction

The synovial joint is an important component of the musculoskeletal system that allows for smooth movement and locomotion. The development of joints can be divided into three general phases. The first phase is characterized by the appearance of a cell dense region within the cartilaginous anlagen. This so-called interzone is the first overt sign of joint formation and marks the site of the future joint. The second phase of joint development is cavitation, a process in which the two opposing sides of the developing joint become physically separated within the interzone, leading to the creation of a joint space. Following cavitation is the third phase of joint development called morphogenesis, where the opposing sides of the joint mold into a reciprocally shaped and interlocking structure. The end result is the articulation of two cartilage-capped bones bound in a fibrous capsule with stabilizing ligaments and lubricating fluid.

Epigenetics involves gene regulation that is not controlled by specific DNA sequences, but rather through covalent DNA and histone modifications such as methylation/demethylation and acetylation/deacetylation. In this study we have found gross joint abnormalities in mouse embryos harboring mesenchyme-specific deletions of the ESET gene. We further analyzed the effects of two different types of ESET knockouts on phalangeal joints, and found that the entire ESET protein is critical to successful cavitation of future joints within a narrow period during embryonic development.

Materials and Methods

Generation of conditional ESET-null mice

Mice harboring the ESET(exons 15&16)^{Flox} allele were obtained from Dr. Y. Shinkai [1]. Mice harboring the ESET(exon 4)^{Flox} allele are generated by our group [2]. Prx1-Cre mice were from the Jackson Laboratory (Bar Harbor, ME, USA). All mice were back crossed to a C57BL/6 genetic background for this project. Prior to the study, animal experiments were reviewed and approved by the Institutional Animal Care and Use Committee.

Whole mount staining of cartilage and bone

Mouse embryos were skinned following a previously described protocol [3]. Soft tissues in the forelimbs and hindlimbs were removed by incubation in 1% KOH for 2 hrs, followed by frequent changes with a 20% glycerol-1% KOH solution for one day, then completed by subsequent clearing and hardening in 20%, 50% and 100% glycerol before examination with a dissecting microscope.

Immunofluorescence staining

After fixation in 4% phosphate-buffered paraformaldehyde, forelimbs and hindlimbs were embedded in OCT compound, cut as 10-12 μm thick frozen sections using a cryostat. A rabbit polyclonal anti-type II collagen (Rockland Inc, Gilbertsville, PA, USA, cat# 600-401-104) was used at 1: 200

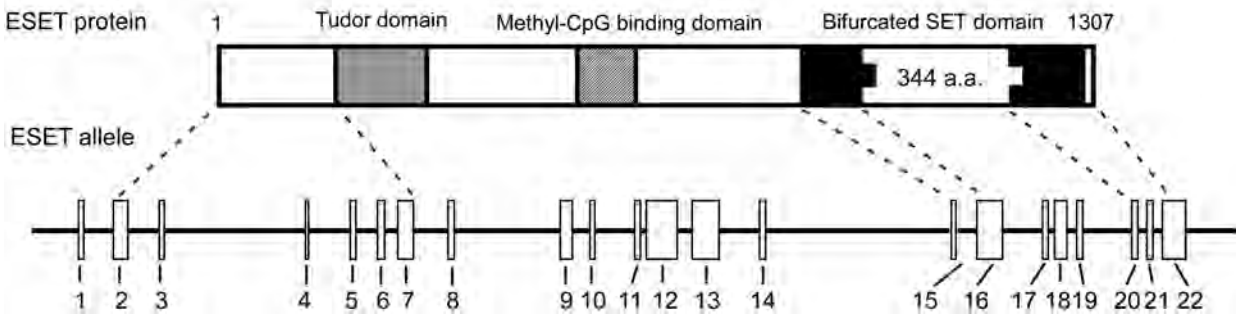

Figure 1: ESET protein domains and gene structure in E15.5 proximal phalanges. ESET protein domains and exons in wild-type ESET allele are indicated.

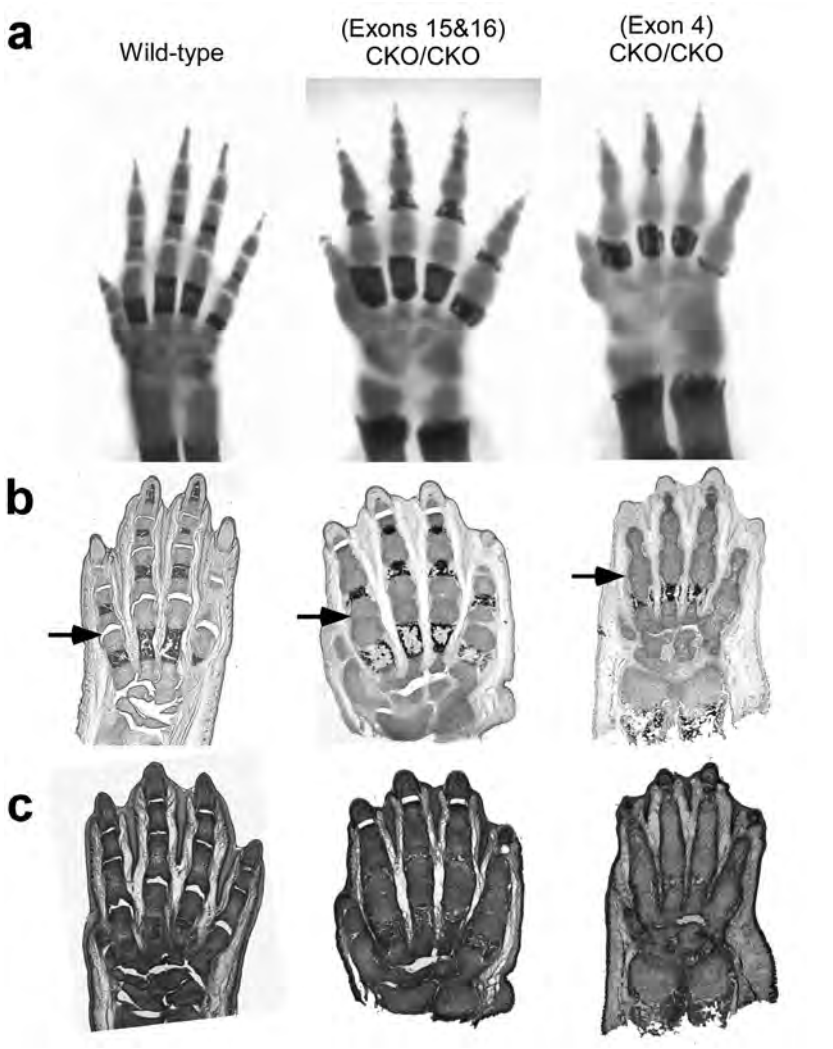

Figure 2: Phalangeal joint defects in E18.5 forelimbs harboring mesenchyme-specific ESET deletions. a, whole mount staining of E18.5 embryos was carried out with alcian blue (cartilage) and alizarin red (bone) for comparison of joint development in the forelimbs. b, E18.5 forepaws were sectioned and stained with alcian blue and alizarin red for better analysis of the forelimb autopods. Arrows indicate positions of metacarpophalangeal joints. c, H&E staining was performed to show cell morphology in E18.5 forepaws. Genotypes of the embryos are indicated on the top.

dilution followed by incubation with Cy3-conjugated goat anti-rabbit IgG (Jackson ImmunoResearch Laboratory, West Grove, PA, USA, 1: 200 dilution) at 4°C for 2 hr. After washes with 0.25% triton X-100 in PBS, sections were mounted with VectorShield medium containing DAPI for examination under a fluorescence microscope.

Results

ESET protein is encoded by a single copy gene that is evolutionarily conserved [4]. The mouse ESET gene is 36 kb in length and consists of 22 exons, giving rise to a full-length ESET protein with 1307 amino acids (Figure 1). Other minor ESET splice variants lacking the SET domain are also known to exist in certain cell types. The ESET gene itself is transcribed in various cell types but its expression appears to be regulated at the protein level.

To examine the effects of ESET deletions on phalangeal joint development, we performed whole mount staining of E18.5 embryos with alcian blue (for nonmineralized cartilage) and alizarin red (for mineralized cartilage and bone). In the forepaws at this developmental stage, phalangeal joints in wild-type embryos have been well formed as evidenced by the existence of clear joint spaces between all digits (Figure 2a). In (exons 15&16)CKO/CKO mutants, while some joint spaces between digits are indeed visible, the majority of prospective joints lack clear separation. In (exon 4)CKO/CKO mutants, there is no visible joint space within the cartilage anlagen to indicate any separation of potential digits. In addition, morphologically abnormal wrist and carpal elements are also more prominent in (exon 4)CKO/CKO mutants. To confirm that these joint defects indeed exist in ESET knockouts, the forepaws of E18.5 embryos were sectioned and stained with alcian blue and alizarin red. As shown in Figure 2b, phalangeal joints in wild-type embryos all show normal development. While only a few phalangeal joints in (exons 15&16)CKO/CKO mutants appear to be normal, no obvious phalangeal joint can be found in (exon 4)CKO/CKO mutants. Furthermore, H&E staining of these forepaw sections clearly demonstrates partial digit separation in (exons 15&16)CKO/CKO mutants and complete failure of digit separation in (exon 4)CKO/CKO mutants (Figure 2c). For this study, we have examined over fifty embryos including six E18.5 (exons 15&16)CKO/CKO embryos and eight E18.5 (exon 4)CKO/CKO embryos. All mutant embryos exhibited similar joint defects described above for the two types of ESET knockouts, and the phalangeal joint phenotype is therefore 100% penetrant.

Joint defects in $ESET^{CKO/CKO}$ embryos at E18.5 could be caused either by a failure to form interzones during the first phase of joint development, or by cavitation failure during the second phase of joint development. The interzone is located between two developing digits and characterized by a population of dense cells that do not express type II collagen. To investigate whether mesenchyme-specific deletion of ESET impairs interzone formation, we carried out immunohistostaining for type II collagen in the forepaw section of E15.5 embryos. As shown in Figure 3, type II collagen-negative interzones are easily identifiable in the wild-type as well as in $(\text{exons } 15\&16)^{CKO/CKO}$ and $(\text{exon } 4)^{CKO/CKO}$ embryos, and little difference could be found among interzones in wild-type and ESET-null embryos. This indicates that ESET is not required for the formation of interzone but instead is essential to the process of cavitation during joint development.

With Prx1-Cre as the deleter strain, deletion of ESET in the hindlimbs should initiate at E10.5 which is at

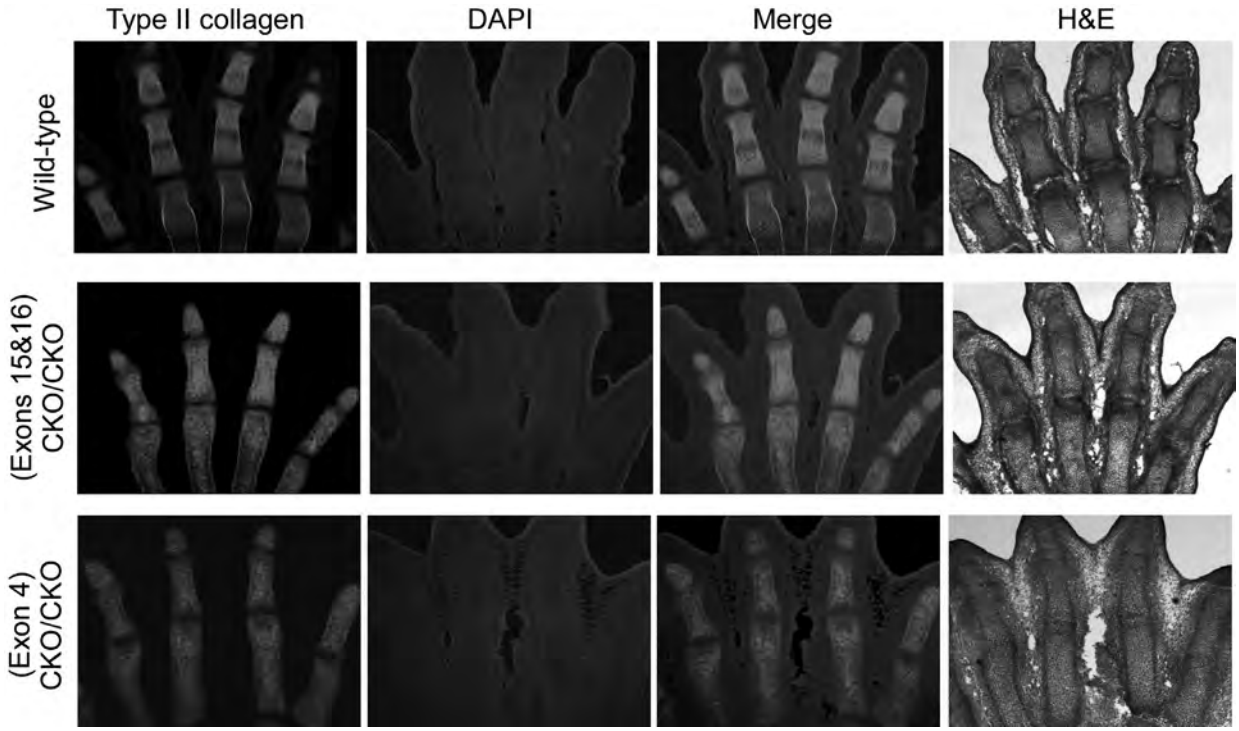

Figure 3: Interzone formation in E15.5 wild-type and ESET$^{CKO/CKO}$ forelimbs. Forepaw sections of E15.5 wild-type (top panels), (exons 15&16)$^{CKO/CKO}$ (middle panels) and (exon 4)$^{CKO/CKO}$ (bottom panels) were stained with an anti-type II collagen antibody to show the presence of interzones in the developing forelimb autopods. DAPI counter staining of nuclei was used in the merged images for tissue outline, and H&E staining shows cell morphology. Genotypes of the embryos are indicated on the left.

least one day later than in the forelimbs [5]. To investigate whether such a delay in ESET deletion had any effect on synovial joint development, we stained E18.5 hindpaws from wild-type, (exons 15&16)$^{CKO/CKO}$ and (exon 4)$^{CKO/CKO}$ embryos with alcian blue and alizarin red. As shown in Figure 4, E18.5 hindlimb autopods from wild-type, (exons 15&16)$^{CKO/CKO}$ and (exon 4)$^{CKO/CKO}$ embryos all exhibited clear separation between the digits, demonstrating that these phalangeal joints in ESET-null embryos are developmentally normal. However, phalanges of the hindpaw in wild-type E18.5 embryos are elongated whereas the same phalanges in E18.5 knockout embryos appear to be more rounded in shape.

Discussion

In this study we have provided in vivo evidence that ESET is essential to the development of synovial joints, and that ESET regulates joint formation specifically at the stage of cavitation. Since mesenchymal-specific knockout of exons 15 & 16 (deleting the catalytic SET domain from ESET protein) causes partial cavitation failure whereas knockout of exon 4 (deleting the entire ESET protein) results in complete cavitation failure, it is clear that both the intrinsic H3-K9 methyltransferase activity of ESET and additional activities conferred by ESET-associated proteins are involved in the control of cavitation. What could be these additional activities that are required for normal cavitation? The N-terminal tudor domain of ESET is known to mediate interaction with transcription repressors mSin3A/B and histone deacetylases HDAC1/HDAC2 [6]. ESET has also been reported to interact with DNA methyltransferase DNMT3A [7] or even associate with other H3-K9 mehtyltransferases such as Suv39H-G91-GLP [8]. ESET likely represents the core component of a protein supra-complex (containing various epigenetic enzymes) that regulates cavitation. In mesenchymal cells with deletion of exons 15 & 16, there should be a low level of truncated ESET proteins lacking the SET domain but retaining the tudor domain (either through translation of the mutant ESET mRNA transcript or through alternative splicing). Such truncated ESET proteins may still form a similar supra-complex, but it is either too few in number and/or too weak in activity to ensure proper cavitation. In mesenchymal cells with exon 4 deletion, however, the entire ESET protein is wiped out and no such a supra-complex could even exist to participate in the regulation of cavitation.

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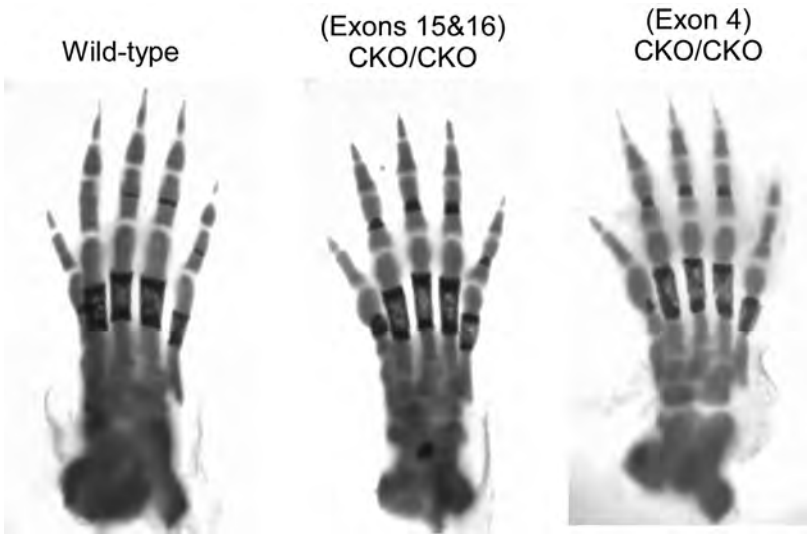

Figure 4: Examination of hindlimb autopods in E18.5 wild-type and ESET$^{CKO/CKO}$ embryos. a, whole mount staining of E18.5 embryos was carried out with alcian blue (cartilage) and alizarin red (bone) to examine joint development in the hindlimbs.

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The Use of Microsoft Kinect™ for Assessing Readiness of Return to Sport and Injury Risk Exercises: A Validation Study

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Study Design

Cross Sectional Study

Background

Assessing readiness of return to sport after procedures such as anterior cruciate ligament (ACL) reconstruction is a complex but well studied process that is complicated by the pressures that athletes face in returning to sport as quickly as possible. Current rehabilitation approaches attempt to gauge appropriate return based on tested neuromuscular movements that are thought to be relevant for safe return to sporting activities. There are few objective measures that are widely used or accepted to help guide athletic trainers, therapists, coaches, or physicians to determine when athletes are ready to return to sport after ACL reconstruction. Advances in motion analysis have been able to demonstrate movements that may be risk factors for both initial ACL injury as well as subsequent reinjury after reconstruction surgery.

Objectives

The aim of this study is to validate the use of a simple, markerless motion capture technology (Microsoft Kinect™) as an inexpensive means to identify abnormal lower extremity movements that pose as risk factors for ACL injury and assess readiness for return to sport.

Methods

This study assessed the concurrent validity of the Microsoft Kinect against an established 3-dimensional motion analysis system in 20 healthy subjects. Knee kinematics were assessed during impact activity in the coronal and sagittal plane specifically evaluating peak knee valgus and peak knee flexion during single leg hop and jump from box exercises. Intraclass correlation coefficients and 95% limits of agreement (LoA) were determined for each kinematic variable.

Results

For the single leg hop, the mean absolute difference in the sagittal plane was 10.4° (95% LoA [-11.7°, 26.8°]), and in the frontal plane was 5.31° (95% LoA [-8°, 13.9°]). Similarly, for the jump from box landing on one leg, the results were 7.96° (95% LoA [-17.7°, 21.3°]) and 4.69° (95% LoA [-6.3°, 12.6°]) respectively. For the jump from box, two foot land, turn and pivot, the mean absolute difference between the systems was 7.39° (95% LoA [-17.8°, 19.7°]) in the sagittal and 4.22° (95% LoA [-5.9°, 11.6°]) in the frontal plane respectively. Intraclass correlation coefficients for each exercise ranged from 0.553 to 0.759.

Conclusion

The results from the Microsoft Kinect were found to be in poor agreement with those from a standard motion capture system. Measuring complex lower extremity movements with the Microsoft Kinect does not provide adequate enough information to use as an assessment tool for injury risk and return to sport timing.

Level of Evidence

Level IV

Key words

Knee, Motion analysis, ACL, Rehabilitation

Smooth Reamer Impaction Autografting for Total Hip Arthroplasty in the Setting of Acetabular Protrusio

Noah Paisner, Nathan W. Summers, PA-C, and Adam A. Sassoon, MD, MS

Introduction

Acetabular protrusio is a pelvic defect defined as medial displacement of the acetabulum and femoral head such that the medial aspect of the femoral head protrudes beyond the ilio-ischial line. When occurring in conjunction with end-stage osteoarthritis, total hip arthroplasty (THA) is the preferred treatment option. The medial defect can complicate THA in that bone stock is often deficient, offset is difficult to re-create, and restoration of the hip center requires technical acumen. The goals of THA in the setting of acetabular protrusio therefore include restoring bone stock, providing a stable scaffold for acetabular component osteointegration, and reestablishing an appropriate hip center of rotation. When these goals are not achieved component survivorship has been shown to be adversely affected[1]. Management of acetabular protrusio via the use of morselized bone grafting with reverse reaming has been described[2]. Another described technique includes impaction grafting, which has been reported with good results[3,4]. We describe the use of morselized bone grafting with solid smooth reamers as a hybrid of these techniques to manage medial wall defects, allow for restoration of acetabular bone stock, and lateralize the hip center of rotation in the setting of severe acetabular protrusio. Solid smooth reamers allow for the application of increased compressive forces to the bone graft without graft attrition through the traditional reamer holes. Therefore, the authors feel that this technique combines the efficiency of reverse reaming with the improved compression that impaction grafting creates for improved bone graft incorporation.

Methods

Eight primary THA's performed in 7 patients with severe acetabular protrusio between 4/2015 and 1/2018, by a single surgeon (AAS), were retrospectively reviewed. Patients were followed until death, revision or a minimum of 3 months. Demographic variables including patient age, gender, BMI, and ASA category were identified. Operative variables including components utilized and number of acetabular screws were reported. Post-operative variables including hospital LOS, weight-bearing status at discharge, and time until full weight-bearing (if not WBAT at discharge) were also collected.

Pre- and post-operative radiographs were analyzed to gauge improvement in offset and hip center of rotation. Hip center of rotation was measured using

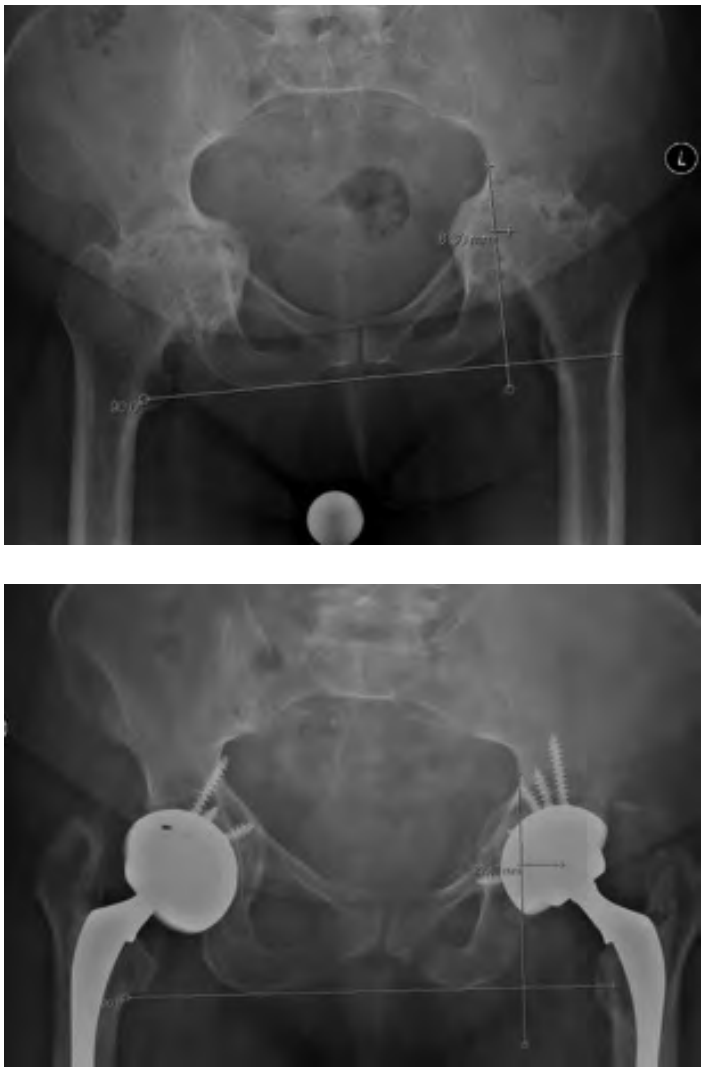

Figure 1 A&B: Hip center of rotation was measured using the following method: a reference line was created connecting the patient's ischial tuberosities. A plumb line perpendicular to the above reference line at the lateral extent of the pelvic brim was then created. The distance from this plumb line to the center of the femoral head was then measured.

Figure 2: Smooth solid reamers

the following method: a reference line was created connecting the patient's ischial tuberosities. A plumb line perpendicular to the above reference line at the lateral extent of the pelvic brim was then created. The distance from this plumb line to the center of the femoral head was then measured (Figure 1). Post-operative radiographs, at the most recent follow up, were also analyzed for acetabular component position, radiolucent lines, and bone graft incorporation.

Surgical Procedure

A posterior approach was used for all patients. Hips were dislocated and a femoral neck cut was made according to pre-operative templating unless the femoral head was entrapped within the protrusio defect. In these instances (2 cases), an in situ neck cut was performed and the femoral head was subsequently extracted. Chamfer reaming was used to prepare the acetabulum, taking great care to not create a situation leading to cup entrapment. Following acetabular component size selection, based on the chamfer reaming, the femoral head was prepared for medial bone grafting. A saw was used to remove the cortical cap of the femoral head and acetabular reamers were then used to procure the cancellous bone within the femoral head for bone grafting. The autograft was then introduced into the defect and solid smooth reamers (shown in Figure 2) were used to impact the bone within the defect, thereby lateralizing the hip center and providing a medial backstop for the acetabular component (Figure 3). The acetabular component was then impacted to achieve a press fit which was subsequently augmented with multiple cancellous screws. Screws configuration varied, but often included screws in the anterior column, posterior column and ischium. Femoral preparation and trialing were subsequently performed. Intra-operative x-rays were obtained to confirm appropriate acetabular and femoral component sizing, positioning and restoration of limb lengths. Placement of the real acetabular liner, femoral component and femoral head then proceeded. Closure, including a repair of the capsule and short external rotators, was then completed.

Results

Eight THA's in 7 patients with severe acetabular protrusio were performed between 4/2015 and 1/2018, which included 4 females and 3 males, with an average age of 71.4, BMI of 29.1, and ASA of 2. No patients were lost to follow up. Mean follow up was 9.75 months (range 3-16). The bone graft

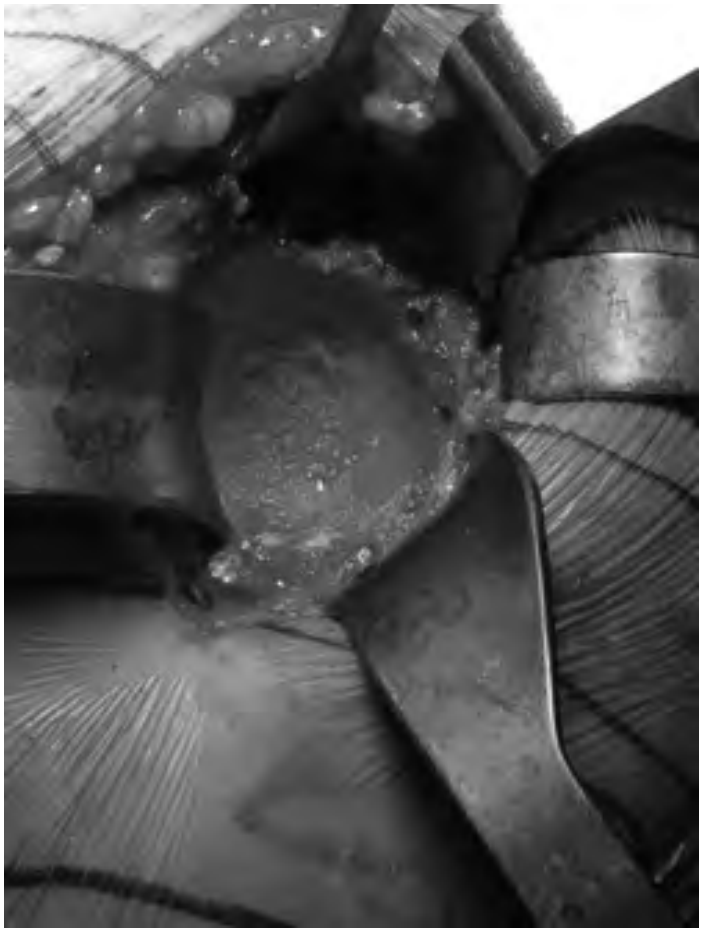

Figure 3: Intraoperative photograph of bone grafted defect

	Acetabular Component	Acetabular Component Fixation	Femoral Component	Femoral Component Fixation	Femoral Head	Bearing Couple
Hip 1	Zimmer Continuum (52 mm outer diameter)	Cementless	Zimmer VerSys Heritage	Cemented	Zimmer Biolox (36 mm)	Ceramic on highly cross-linked polyethlyene
Hip 2	Zimmer Continuum (56 mm outer diameter)	Cementless	Zimmer VerSys Heritage	Cemented	Zimmer VerSys (36 mm)	Ceramic on highly cross-linked polyethlyene
Hip 3	Biomet G7 (54 mm outer diameter)	Cementless	Zimmer VerSys Heritage	Cemented	Zimmer Biolox (28 mm)	Dual mobility
Hip 4	Zimmer Continuum (58 mm outer diameter)	Cementless	Zimmer Versys Heritage	Cemented	Zimmer Biolox (40 mm)	Ceramic on highly cross-linked polyethlyene
Hip 5	Zimmer Continuum (56 mm outer diameter)	Cementless	Zimmer Versys Heritage	Cemented	Zimmer Biolox (36 mm)	Ceramic on highly cross-linked polyethlyene
Hip 6	Biomet G7 (58 mm outer diameter)	Cementless	Zimmer M/L taper	Cementless	Zimmer Biolox (28 mm)	Dual mobility
Hip 7	Biomet G7 (54 mm outer diameter	Cementless	Zimmer M/L taper	Cementless	Zimmer Biolox (40 mm)	Ceramic on highly cross-linked polyethlyene
Hip 8	Biomet G7 (58 mm outer diameter)	Cementless	Zmmer M/L Taper	Cementless	Zimmer Biolox (40 mm)	Ceramic on highly cross-linked polyethlyene

Table 1: Results of patients with severe acetabular protrusio.

incorporated in all patients. There were no revisions. The acetabular component showed osseous integration without evidence of loosening in all patients. Uncemented femoral components were utilized in 3 cases while hybrid fixation was utilized in the other 5 cases. There was no evidence of femoral component loosening. The average number of acetabular screws used was 4 (range 3-5). The bearing couple was ceramic on highly cross-linked polyethylene in 6 cases, and dual-mobility in 2 cases. In both cases employing dual-mobility bearing couples, ceramic inner heads were utilized (component details are shown in Table 1). Average operative time was 125 minutes (range 86-177). Average hospital length of stay was 2 days (range 1-3). Five patients were WBAT at discharge; 3 patients were restricted to 50% weight-bearing at discharge and released to WBAT at 6 weeks post-op. Hip center lateralization averaged 11.5 mm (range 7.4-16.78), and the average abduction angle of the acetabular component was 46 degrees (range 42-49.9). There were no post-operative complications.

Discussion

From this case series, we feel confident in our technique of procuring autologous femoral head bone graft, impacting it into the acetabular defect via smooth reamers, and reinforcing the acetabular component with multiple cancellous screws. Our study shows that we have had excellent incorporation of autologous bone graft with the native pelvic bone stock, and no evidence of component loosening at a maximum of 3 years.

We feel that while reverse reaming techniques have been shown to be useful, bone graft attrition can occur through reamer slots when standard reamers are used on a reverse setting. Uniform compaction and ultimate compression force during application of the bone graft is at risk for not being achieved due to holes in the standard reamers. While impaction grafting has been shown to be useful[4] – with Mullaji et all showing bone graft incorporation in 30 out of 30 patients by 6 months post-operatively – historically, this technique can often be quite time consuming. Mullaji et al failed to report operative time or incidence of transfusion.

The limitations to this study are those inherent in any retrospective review. This represents the work of a single surgeon and the study size is limited. Given rarity of defect and the limited time range from which

these cases were selected, we feel our numbers are representative of the incidence of this presentation at other academic sites. Mullaji et al, for example, described a single surgeon case series that included 30 primary hips over the course of 10 years, which is comparable with our treatment rate. Even with a small group of patients, we feel our method can still be seen as effective, given the benefit of increased efficiency in terms of operative time, which can lead to downstream effects of decreased cost of care, infection rates, and transfusion rates.

In conclusion, our technique of impaction autografting with solid smooth reamers manages these defects well. We have demonstrated operative efficiency, cost savings (there is no need to purchase allograft or augments), and is effective, as shown by our ability to lateralize the hip center by an average of 1.15 cm. Furthermore, if a revision was required sometime in the future, patients would have ample bone stock with which to work. We recommend this technique for patients undergoing THA for severe protrusio in the setting of end-stage arthritis.

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Diabetes Alters Collagen Cross-Linking in Tendon

David M. Hudson, PhD, Marilyn Archer, BS, Karen B. King, PhD, and David R. Eyre, PhD

Introduction

The non-enzymic glycation of collagen has long been associated with the progression of complications in diabetes mellitus [1]. How these glycations can result in tissue impairment in diabetes is still poorly understood. Because of the slow turnover rate of many collagens, particularly in tendon, these structural proteins are more susceptible to be spontaneously modified by glycations over time. These random glycations result in accumulated advanced glycation end products (AGEs), some of which have the potential to act as cross-links and stiffen tissues. However, we suggest that site-specific glycation of lysines involved in lysyl oxidase-mediated cross-linking may have a significant effect on normal, biologically controlled collagen cross-linking. Type I collagen of mouse tendons contains predominantly intermolecular acid-labile aldimine cross-links, which are formed by the addition of telopeptide lysine aldehydes to hydroxylysines at either residue 87 or 930 of the triple helix. We hypothesize that glycation of the helical collagen cross-linking sites (K87 and K930) may hinder the normal cross-linking process in tendon, so altering the content and/or placement of mature cross-links.

Methods

Animal model

TallyHo mice are a naturally occurring polygenic model of obesity and type 2 diabetes derived from the selective breeding of hyperglycemia in mice. Five-week old TallyHo mice (n=5) were purchased from Envigo Teklad and maintained on a standard diet until euthanasia at 26 weeks. Inclusion criteria for the study included HbA1c levels (>6%) and blood glucose levels (>250mg/dl). Tendon collagens were characterized in TallyHo (test) and C57Bl6 (control) mice.

Collagen isolation

Intact type I collagen was solubilised from the tissues by acid extraction in 3% acetic acid for 24h at 4C. Tissues were also digested with pepsin or

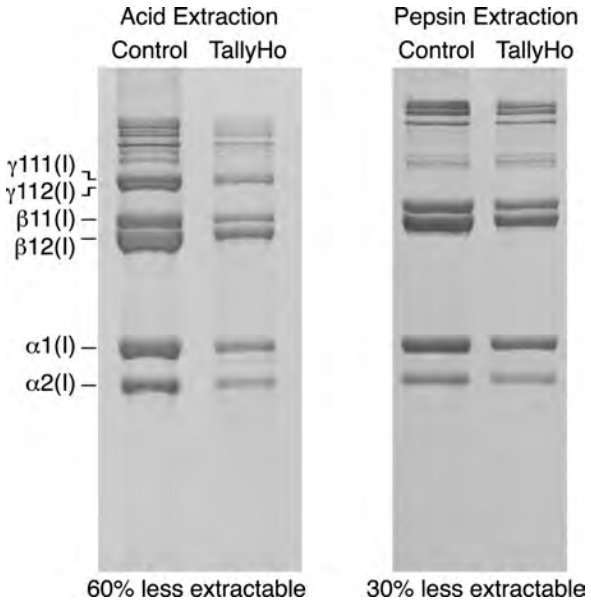

Figure 1: SDS-PAGE reveals reduced collagen extractability in diabetic mouse tail tendon. (A) Acid labile aldimine cross-links are broken with mild acetic acid treatment, extracting type I collagen from the tissue. The TallyHo mouse tendon was less acid extractable than control mice (~22%; n=5). (B) Pepsin digestion had a similar, but slightly reduced effect (~11%; n=2), between control and diabetic tissues. These data support the presence of AGE cross-links. This pattern of reduced extraction is observed in tendon, skin and bone.

Glycated Cross-linking Lysines

	α1(I)K87	α2(I)K90	α1(I)K930	α2(I)K933
Control	5%	10%	1%	3%
TallyHo	14%	26%	10%	20%

Non-Glycated Cross-linking Lysines

Sequence

α1(I) QMSYGYDE**K**SAGVSVPGPM (N-telopeptide)

α1(I) FLPQPPQE**K**SQDGGRYY (C-telopeptide)

α2(I) QYSD**K**GVSSGPGPMGLM (N-telopeptide)

Non-Glycated Helical Lysines

Sequence

α1(I) GFSGLDGA**K**GDAGPA (Lys99)

α1(I) G**K**DGLNGLP (Lys974)

α2(I) GFSGNVGPSG**K**EGPVGLPGIDGRP (Lys374)

Figure 2: Glycation of helical collagen cross- linking lysine residues is elevated in diabetic mouse. Percentage of glycation at the helical cross-linking sites of type I collagen from tendon (n=2). The percentages were determined based on the ratio the m/z peaks of each posttranslational variant as previously described [2]. It should be noted that, in mouse, α2(I) K90 is glycated rather than α2(I) K87. In rat and human, there is no Lys at position 90.

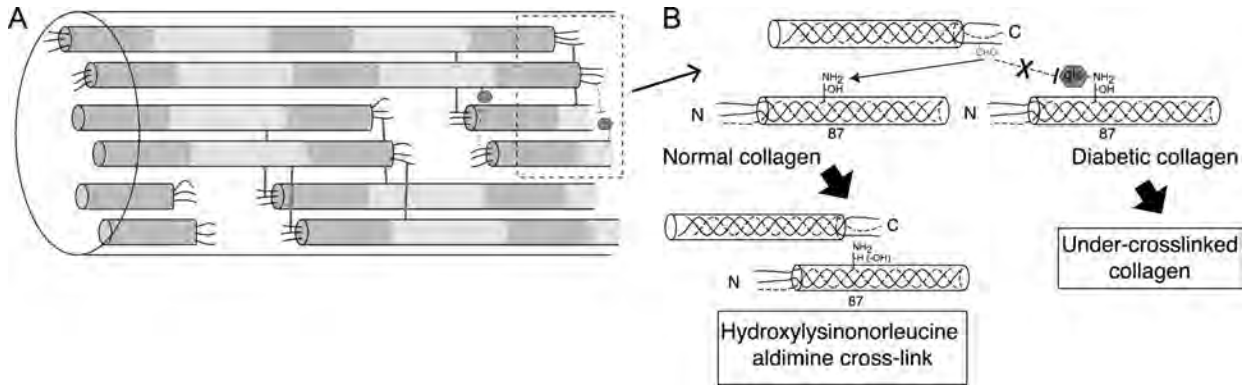

Figure 3: Model of altered collagen cross-link formation in a diabetic model. (A) In the fibril, collagen molecules are spatially arranged such that intermolecular cross-link placement is optimal. (B) In normal tendon, type I collagen preferentially forms intermolecular aldimine cross-links between helical Hyl and telopeptide Lys aldehydes. In diabetic collagen, partially glycated helical cross-linking Lys are sterically and/or chemically hindered from participating in normal collagen cross-linking chemistry. The net effect is a tendon with compromised material properties resulting from fewer physiologically stable cross-links yet subsequent tissue stiffening from potential AGE cross-links.

bacterial collagenase with and without borohydride reduction and resolved by C8 reverse-phase HPLC [2].

Mass spectrometry

Collagen glycations were analyzed by electrospray mass spectrometry using an LTQ XL linear ion-trap mass spectrometer equipped with in-line liquid chromatography.

Results

Differences in type I collagen extractability in 3% acetic acid and pepsin from lyophilized tissue samples supported an effect on intermolecular cross-linking in diabetic tendon collagens. As seen in Figure 1, densitometry of stained SDS-PAGE collagen chains (α, β, γ) revealed that collagen was less extractable from TallyHo mouse tendon (n=3) compared to control tissues (n=3) with acid and pepsin extraction. It is tempting to correlate the decrease in collagen extractability with a decrease in acid-labile cross-links. Mass spectral analysis of collagenase-digested collagen peptides revealed the presence of non-enzymic glycations on specific helical cross-linking residues. All four helical cross-linking residues (α1(I)K87, α1(I)K930, α2(I)K90 and α1(I)K933) from diabetic tendon type I collagen were found to be partially glycated (Figure 2). Control tissues were negligibly glycated at these sites. Despite as many as one in three collagen molecules being glycated at α2(I)K90 in the TallyHo mouse tendon, only aldimine cross-links from non-glycated helical sites were found in our digests. The absence of glycated cross-links in diabetic tissue suggests that glycated helical lysine residues are unable to participate in physiological collagen cross-linking with telopeptide lysine aldehydes, which could result in a tissue with fewer collagen cross-links and, therefore, weakened structural properties.

Discussion

The prevalence of AGE cross-links in diabetic tissue has been proposed to significantly alter the material properties of tendon [3]. The present findings suggest that although AGE cross-links may be expected to cause tissue stiffening, the deleterious effects on diabetic tissues may be attributed to the consequences of glycation at known cross-linking sites (Figure 3). The structural and mechanical properties of connective tissues depend heavily on lysyl oxidase-dependent collagen cross-linking. In diabetic tendon, site-specific collagen glycations may decrease or misdirect the normal collagen cross-linking pathway and ultimately result in a potentially weaker tissue. Future studies are required to quantitate changes in lysyl oxidase-driven collagen cross-linking associated with diabetes.

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MicroCT-Based Phenomics in the Zebrafish Skeleton Reveals Virtues of Deep Phenotyping in a Distributed Organ System

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The ability to characterize phenomes–i.e., to acquire in-depth phenotypic profiles at the scale of the whole organism–holds promise to enhance our understanding of genetic variation. Yet, phenomic profiling in vertebrates remain limited. A better understanding of the biological insights that may be attained through analyzing patterns in a large number of traits is essential to both guide and drive the development of next generation phenotyping technologies.

In a recent publication[1], we described microCT-based methods and a segmentation algorithm, FishCuT, enabling profiling of hundreds of phenotypic measures at a large number of anatomical sites in the axial skeleton of adult zebrafish. In doing so, we describe one of the first instances of large-scale, deep phenotyping in a single organ system at the organism-wide scale. We profiled over 20,000 data points derived from over 2500 skeletal elements in wildtype fish of different degrees of developmental progress as well as mutant lines associated with human disease. Vertebral patterns conferred heightened sensitivity, with similar specificity, in discriminating mutant populations compared to analyzing individual vertebrae in isolation. Skeletal phenotypes associated with human brittle bone disease and thyroid stimulating hormone receptor hyperactivity were identified. Finally, allometric modeling-based methods were developed to aid in the discrimination of mutant phenotypes masked by altered growth. This study established virtues of microCT-based phenomics in zebrafish. To facilitate community use, we made FishCuT freely available for download as a beta release[2].

Collectively, our studies reveal virtues of deep phenotyping within a single organ system at the whole-organism scale. The enhanced sensitivity afforded by the analysis of phenomic patterns may not only increase productivity in genetic screens, but also opportunities to study genetic variants of smaller effect size, such as those which underlie the overwhelming majority of complex diseases.

We anticipate that our studies will be of broad interest to zebrafish researchers interested in post embryonic physiologies, including aspects of musculoskeletal biology, due to the increasing use of microCT to image hard and soft tissues in adult zebrafish, as well as calls for the use of microCT for large-scale phenome projects. Further, due to the fact that a) instances of organism-scale, deep phenotyping in a single organ system are rare and b) the analytical strategies in this project may serve as a paradigm in other model systems, we believe our studies may be of interest to researchers interested in the rapidly growing field of phenomics. Additionally, given that we demonstrate the viability of systematically mapping gene-to-phenome relationships as a means to accelerate our functional understanding of human skeletal genes, we anticipate that a third target audience is musculoskeletal researchers interested in understanding the genetic basis of human skeletal health. Finally, while our studies were biomedically-focused, we have found that the tools developed in this project have garnered significant interest from researchers interested in comparative, evolutionary, and aquaculture-related aspects of fish skeletal biology.

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Tranexamic Acid with Limited Use Tourniquet in Total Knee Arthroplasty

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Introduction

Total knee arthroplasty (TKA) is a common elective procedure in the United States, and with an aging population it is projected to become one of the most common surgical procedures by 2030 [1]. Despite the relative safety of TKA, perioperative blood loss resulting in the need for transfusion remains a concern. Allogenic blood transfusions are sometimes necessary but carry risks including longer hospital stays, transfusion reactions, and infection [2, 3]. In one systematic review transfusion rates in TKA ranged from 7.5% to 51.9% [4].

Recently, the use of anti-fibrinolytic agents including tranexamic acid (TXA) has grown in arthroplasty. TXA decreases fibrinolysis by competitively blocking plasmin from binding sites on fibrin. A multitude of different administration routes including intravenous (IV), intramuscular (IM) and intra-articular have been investigated and employed in arthroplasty, with no clear consensus on optimal dose or method of administration [5-8]. Despite differences in dosing strategies, TXA in arthroplasty patients has been associated with reduced blood loss and transfusion rates [9-11], earlier mobility [12], and has not been associated with increased perioperative complication rates [11, 13].

While the use of TXA in TKA has shown promising results, another controversial operative factor remains the use of a tourniquet. In one 2009 survey of hip and knee surgeons 95% of respondents reported that they used a tourniquet for the duration of the case, with only 5% utilizing solely for exposure and cementation [14]. The use of a tourniquet has not been demonstrated to significantly reduce blood loss or transfusion requirements [15]. They are primarily utilized to improve visualization of the surgical field, with some studies also noting decreased operative time [16]. However, tourniquets are also associated with a variety of risks including neuropraxia, local muscle damage [15, 17], and decreased range of motion in the early postoperative period [18]. Additionally, increased rates of hematoma formation, deep vein thromboses (DVT), pulmonary embolisms (PE) [17], perioperative wound complications [19] and paradoxically increased blood loss in the postoperative period [20] have been associated with their use. The most recent American Association of Orthopaedic Surgeons (AAOS) guidelines for TKA also highlights strong evidence for decreased postoperative pain when forgoing the use of a tourniquet [21].

In this study we demonstrate one surgeon's experience with TXA in combination with a limited-use tourniquet employed only during component cementation. We hope to demonstrate that this method may provide the benefits of TXA in reduced blood loss while avoiding possible complications associated with tourniquet use. To serve as comparison, we also retrospectively collected data on patients who underwent primary TKA with tourniquet use throughout the duration of the procedure both with and without the use of TXA. The purpose of this study was to analyze the difference in blood loss, need for transfusions and complications between these three groups with varied use of TXA and tourniquets.

Methods

This was a retrospective cohort study including 290 patients, representing 320 individual operations, who underwent primary unilateral TKA. Cohorts of patients were identified from case logs of three surgeons within the same institution between 1/2013 and 2/2018 and were grouped based on the varied use of tranexamic acid and tourniquet duration. Patients charts were reviewed for complications for a 3-month follow-up period.

Three distinct groups were identified; in one group TXA was given in conjunction with the limited use of a pneumatic tourniquet. In this group the tourniquet was inflated just prior to cementation until component fixation and then deflated and patients were excluded if the tourniquet was left up for any other portions of the case. In another group TXA was also utilized and a tourniquet was used for the duration of the case until closure. In the third group a tourniquet was also employed throughout the case but without the use of TXA. Given the retrospective nature of the study in order to gain a cohort of patients in which TXA was not used, charts from 2013-2014 were reviewed; the surgeon's operative technique did not otherwise change over this time period. The two groups utilizing TXA were collected from 2017, representing the time point in which TXA was regularly used for all patients undergoing primary TKA.

Standard TXA dosing was 1gram IV prior to incision and 1gram IV prior to closure in patients with limited-use tourniquet. Three patients in the limited tourniquet group received only 1gram TXA for reasons not able to be identified on chart review. Patients in the full tourniquet group received 1gram IV prior to incision only.

Preoperative patient characteristics including age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) class, and presence of thromboembolic risk factors were collected retrospectively by chart review. Thromboembolic risk factors included history of malignancy, previous DVT or PE, family or personal history of clotting disorder, history of coronary artery stent placement or coronary artery bypass graft, and prior myocardial infarction or cerebrovascular accident. Patients without an ASA class listed in an available anesthesia report were assigned an ASA class

	TXA with Limited Tourniquet	Full Tourniquet with TXA	Full Tourniquet without TXA	p-value
Number of patients	67	129	96	
Gender	22 M/ 45 F	53 M/ 77 F	45 M/ 49 F	
Average ASA class	2.3 ± 0.49	2.27 ± 0.557	2.34 ± 0.55	0.605
Age	62.8 ± 7.8	65.2 ± 9.8	67.9 ± 7.8	0.002*
BMI	30.6 ± 6.6	30.5 ± 5.1	30.1 ± 4.7	0.792
Number of patients with thromboembolic risk factors	**17 (25%)**	**26 (20%)**	**17 (18%)**	

Table 1: Patient Demographics. *Post-hoc pairwise comparison between TXA with limited tourniquet and full tourniquet without TXA was p=0.002..

by two independent reviewers based on comorbidities. Preoperative and postoperative day one hemoglobin (Hgb) levels were also collected. Intraoperative characteristics including implant type, use of computer-navigated assistance, type of anesthetic (general v. spinal), operative time, tourniquet time and estimated blood loss were collected from the operative report. Any need for transfusion and the amount transfused were documented. Other complications within the follow-up period including arthrofibrosis requiring manipulation under anesthesia, incidence of DVT or PE, and any other wound or bleeding complications were extracted from chart review. Postoperative anticoagulation varied per surgeon discretion. Comparisons of multiple means were analyzed using one-way ANOVA, with post hoc pairwise comparisons utilizing a Tukey correction. Significance between two means was calculated using a 2-sample t test. Categorical variables are reported as frequencies. All analysis was completed using SPSS (IBM).

Results

A total of 320 procedures were included in this study. The patient demographics are shown in Table 1. The mean age was 65.5 years and average ASA rating was 2.3; there was no significant difference in average ASA rating between groups.

Among patients who received TXA operative length was significantly shorter in the full tourniquet group compared to those with limited tourniquet (86 v. 103 minutes, p<0.001). Average EBL in the limited tourniquet group was also significantly higher than in the full tourniquet group (123 v. 55 ml, p<.001). Given a high proportion of patients in the full tourniquet without TXA group that were missing documented operative length and EBL on chart review they were not included in this analysis. Tourniquet time varied significantly between all groups (p<0.001, Table 2) and averaged 25 minutes in the limited tourniquet group.

The average preoperative Hgb was 13.8 g/dl. Preoperative levels between the groups trended toward significance (p=0.50) with post-hoc pairwise comparison approaching significance between the TXA with limited tourniquet group and the full tourniquet without TXA group (13.6 v. 14.0 g/dl; p=0.53). Among all groups the mean decrease in Hgb preoperatively to POD 1 was 2.7 g/dl. Patients from the TXA with limited tourniquet group had a significantly lower drop in hemoglobin compared to either group in which the tourniquet was used for the duration of the case (p<0.001). Within the full tourniquet groups, those receiving TXA had a significantly lower reduction in Hgb (2.6 v. 3.2 g/dl, p<0.001). Postoperative Hgb was significantly lower in the full tourniquet without TXA group in post-hoc pairwise comparison with the TXA and limited tourniquet group (10.9 v. 11.4 g/dl, p=0.01).

No patients received a transfusion in the TXA and limited tourniquet group, while 2 patients (1.4%) in the TXA with full tourniquet group received transfusions, and 8 patients (7.8%) in the full tourniquet without TXA group received transfusions. The amount transfused was most commonly two units of packed red blood cells, with one patient in each of the full tourniquet groups receiving only one unit.

In the TXA with limited tourniquet group three patients underwent MUA within the follow-up period, one additionally had a wound revision done concomitantly for superficial wound dehiscence. Of note, all of the patients undergoing MUA had notable flexion contractures preoperatively. Additionally, one patient had a stitch abscess treated with oral antibiotics and another was given antibiotics for potential cellulitis. Within the TXA with full tourniquet group one patient underwent MUA twice (at 3 and 4 months postoperatively), and one patient with a history of severe burns returned 3 months postoperatively for skin grafting due to poor wound healing. Another patient on Coumadin underwent irrigation and drainage (I&D) and tibial polyethylene insert exchange POD 9 due to hemarthrosis and concern for infection, subsequently no evidence of wound infection was noted intra- or postoperatively. In the full tourniquet without TXA group one patient underwent I&D and tibial polyethylene insert exchange 3 months postoperatively for a deep wound infection and another had a washout one month postoperatively due to superficial wound infection. In addition, one patient with a history of idiopathic thrombocytopenic purpura developed a hemarthrosis, two patients received oral antibiotics for concerns for superficial infection, and three patients received topical clobetasol for presumed skin glue or suture reaction.

In the full tourniquet without

	TXA with Limited Tourniquet	Full Tourniquet with TXA	Full Tourniquet without TXA	p-value
Number of operations	76	141	103	
Tourniquet time (minutes)	24.6 ± 12.55	75.2 ± 30.27	60.4 ± 9.49	<0.001
Preoperative hemoglobin (g/dl)	13.6 ± 1.4	13.7 ± 1.38	14.0 ± 1.08	0.05*
Postoperative hemoglobin (g/dl)	11.4 ± 1.32	11.1 ± 1.23	10.9 ± 1.1	0.016**
Change in preoperative to POD 1 hemoglobin (g/dl)	2.2 ± 0.74	2.6 ± 0.90	3.2 ± 0.87	<0.001
Incidence of blood transfusions	0	2 (1.4%)	8 (7.8%)	
Incidence of DVT/PE	0	0	1 (1%)	
Incidence of arthrofibrosis requiring MUA	3 (3.9%)	1 (0.7%)	0	
Incidence of wound complications requiring reoperation	**1 (1.3%)**	**2 (1.4%)**	**2 (2%)**	

Table 2: Comparison of tourniquet times, blood loss and complications. * Post-hoc pairwise comparison between full tourniquet without TXA and TXA with limited tourniquet was trending towards significance with p=0.053. ** Post-hoc pairwise comparison between full tourniquet without TXA and TXA with limited tourniquet was p=0.011.

TXA group one patient was found to have a DVT POD 10. There was no other incidence of DVT, PE, or other thromboembolic event in any group within the follow-up period.

Discussion

The results of this study suggest that TXA in combination with a limited tourniquet may be a reasonable approach to reduce blood loss in TKA and reduce rates of transfusion. Within our cohort, no patients with limited tourniquet and TXA required transfusion and the difference in preoperative to POD 1 blood loss was significantly reduced. Although intraoperative blood loss was higher, this is consistent with other studies that have demonstrated increased intraoperative [22] but reduced total blood loss with limited tourniquet use [20, 23]. The highest frequency of transfusions in our study was observed in the full tourniquet without TXA group (7.8%), though these patients were significantly older than the limited tourniquet and TXA group. Of note, their pre-operative Hgb trended towards being significantly higher than the TXA with limited tourniquet group (p=0.53), though their postoperative Hgb was significantly lower (p=0.01). Although the operative time was longer in those patients with limited tourniquet, they did have significantly shorter tourniquet times averaging 25 minutes. Longer tourniquet times have been identified in other studies as factors associated with increased rates of 30-day readmission and incidence of DVT, though neither of these findings were observed in our study [24, 25]. Due to limited sample size and the retrospective nature of the study it is difficult to compare wound complication rates, however there did not seem to be an increased frequency of wound complications in the limited tourniquet group. The highest frequency of superficial wound complications treated conservatively was observed in the full tourniquet without TXA group (6/103; 5.8%), which also had two incidences of reoperation for a superficial and deep wound infection.

Given the pro-coagulant effect of TXA, many other studies exploring TXA with TKA have excluded patients based on history of thromboembolic risk factors [13, 20, 26]. Patients with these risk factors were still eligible for TXA in our study and our findings did not demonstrate an increased incidence of DVT or PE in these patients. The overall incidence was low in all groups, with only one patient identified in the full tourniquet without TXA group. This is consistent with other studies which have not demonstrated an increased incidence of thromboembolic complications with TXA even in patients with a prior history of venous thromboembolism [27]. In another study, while patients with increased comorbidities (ASA class III and IV) and a history of thromboembolic risk factors did demonstrate an increased risk of thromboembolic complications, the use of TXA did not significantly alter this risk [28]. While further studies are needed to establish safety, preliminary results suggest that many patients that may benefit from TXA may be unnecessarily excluded in practice due to this concern.

Limitations of this study include it being retrospective in nature and the presence of confounders given three different surgeons with varying operative techniques and spanning different time periods. Additionally, the two groups utilizing TXA used different dosing strategies. Despite these limitations, we believe that our findings suggest that limited tourniquet use in combination with TXA is an effective strategy to decrease blood loss in TKA in a broad patient population, without an observed increased incidence of complications.

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Are We Obtaining Too Many Cervical CTs in Pediatric Trauma to Evaluate for a Subaxial Injury?

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Introduction

Improving quality, safety and value in the delivery of care has been designated as one of the central initiatives of the AAOS, AOA and POSNA[1,2]. This initiative involves delivering the highest quality of care while maintaining patient safety and minimizing cost. With its increased availability, CT has become commonplace in the evaluation for subaxial injuries, which is from C3 to C7, in the pediatric population. At our institution patients above the age of 10 are treated as adults and undergo a cervical CT as a screening tool for subaxial cervical injuries, despite CT being associated with approximately 10-30 times more radiation exposure and higher cost as compared to conventional XR[3,4]. Furthermore, multiple studies have shown the pediatric population to be an order of magnitude more sensitive to radiation than adults[5–7]. Most studies comparing CT and XR report their ability to detect an injury[8,9]. However, they do not evaluate whether this difference affects clinical management. Therefore, the purpose of this study is to determine whether the use of cervical CT as a screening tool alters clinical management, justifying its added cost and radiation exposure in the 10-12 year old population.

Methods

Study design and setting

This study is a retrospective chart review of all patients 10-12 years old who underwent a cervical CT that presented to a level 1 trauma center over a 10 year period.

Participants/study subjects

Inclusion criteria included patients 10-12 years old who had a traumatic event and underwent a cervical CT. It was felt that due to the initiation of physeal closure at the age of 12 among females that there may be a transition to more adult patterned injuries after this age. The decision to only evaluate subaxial injuries was made because C1 and C2 are included as part of the head CT. Therefore, the decision to obtain a cervical CT is only applicable to the subaxial spine. Both primary presentations and transfers were included in the study.

Description of experiment

The goal of the study is to evaluate the quality, safety and value of CT in our study's population. In order to evaluate the quality of care the incidence of injury along with treatment was recorded. Subsequently, we evaluated whether CT altered the patient's clinical course. Safety and value of care were assessed by comparing the cost and radiation exposure of cervical CT and XR.

Variables, outcome measures, data sources, and bias

The patients' history and physical exam were reviewed. Mechanism of injury, neurological status on arrival, presence of injury and cervical spine CT results were recorded.

Statistical analysis

Incidence was calculated as the fraction of subaxial cervical injuries from the total number of cervical spine CT exams obtained. With the assistance of a health physicist, we estimated the average effective radiation dose incurred by the patients from the CT. This in turn was compared to the radiation emitted by a standard 3 view cervical XR series at our institution.

Results

269 cervical CTs met our inclusion criteria. The patient demographics and mechanisms of injury can be found in Table 1. Out of all the cervical CTs evaluated, four patients had subaxial injuries, which amounted to 1.5% of CTs obtained. Three injuries were treated in a collar. One injury was a fracture dislocation in a patient with neurological deficits and was treated operatively. The amount of radiation emitted from a standard CT is 0.17 mSv and from a 3 view cervical XR 0.018 mSv. The effective radiation dose from a cervical CT in our patient population was 4.0 mSv. We were unable to estimate effective radiation from XR since very few of our patient population had undergone XR. The costs of a cervical CT and a 3-view XR at our institution are $1277 and $407 respectively.

Discussion

Pediatric patients are more susceptible to atlantoaxial injuries and incur a much lower incidence of subaxial injuries as compared to adults. This altered injury pattern is attributed to the larger ratio of the head to the body of the pediatric patient. Furthermore, the pediatric neck musculature is not as robust as that of adults, which leads to increased neck flexibility[10]. The culmination of all these factors leads to a more cranial center of rotation and creates a significant stress riser at the occipitocervical junction where there is a significant rigidity gradient. As the child approaches skeletal maturity, the injury pattern more closely resembles that of

Age		
	Mean	11.52
	STDev	0.88
Mechanism		
	MVC	61
	Car vs Ped	37
	Fall from Height	33
	Bike Accident	31
	Ground Level Fall	26
	ATV	13
	Direct Trauma	10
	Sports	10
	Fall off horse	7
	GSW	6
	Winter Sports	6
	Altercation	5
	Skateboard	5
	Other	19
	Total	269

Table 1: Patient demographics and mechanisms of injury.

an adult. This is reflected in a study by Leonard et al where they reported the cervical injury patterns in children under the age of 16. In their study they found that at the age of 10 the fraction of subaxial injuries exceeds that of the atlantoaxial injuries. However, they do not report the incidence of cervical injuries among all pediatric traumas in their paper[11].

CT is known to have a higher sensitivity as compared to XR when evaluating the cervical spine for injuries. In a meta-analysis comparing CT and XR for the evaluation of cervical spine injuries, it was found that CT had a pooled sensitivity of 98% as compared to 58% for XR[12]. However, this increased ability to detect injuries did not translate into a change in clinical management as evidenced by our current study. Moreover, it exposed the patients to a larger dose of radiation and increased costs of care.

Pediatric patients exhibit a higher radiosensitivity as compared to adults, with the thyroid being one of the most radiosensitive organs in the body. This increased sensitivity is attributed to the increased metabolic activity in the pediatric patient which makes their cells more susceptible to damage and mutations[5,13,14]. Furthermore, children are likely to live longer after their CT than adults and are therefore more likely to develop a radiation induced malignancy. A common misconception is that the decreased total radiation emitted during pediatric imaging translates into decreased radiation exposure to the pediatric patient. In fact, the pediatric patient's smaller size leads to a higher concentration of radiation exposure and effective dose despite an overall decreased quantity of radiation emitted[15].

The National Emergency X-ray Utilization Study (NEXUS) evaluated 3,065 pediatric patients where they found an incidence rate of cervical spine injuries among the pediatric population to be 0.98% as compared to 2.54% in the adult population[16]. The present study showed an incidence of injury of 1.5% among all cervical CTs ordered. Of the 4 injuries detected, 3 were treated with a collar and one treated operatively. At our institution, a patient under the age of 10 who presents after an injury with neck pain and a negative XR is treated with a collar. The patient then follows up after 2 weeks as an outpatient for a repeat exam and flexion extension XR[17–20]. The patient in our series who was treated operatively presented with a fracture dislocation and neurological deficits. In light of the displacement and significant compression deformity, it is likely that this injury would have been noticed on XR and resulted in more advanced imaging being obtained. Furthermore, the patient's neurological exam would have also prompted further imaging.

The concept of "As Low as Reasonably Attainable" (ALARA) is applied to medical procedures and interventions and is meant to describe that the amount of harm should be kept to the lowest amount necessary in order to achieve the needed outcome. This concept applies to our study by raising the question of whether all the CTs ordered are actually necessary in order to achieve proper patient care[21]. Multiple studies have shown that CTs are more sensitive than XR in detecting cervical injuries. In one study that included 20 patients who underwent both XR and CT it was found that XR had a false positive rate of 40% and false negative rate of 20% as compared to CT[22]. However, the increased ability of CT to detect an injury does not necessarily manifest into a change in clinical course as was shown in this current study. Furthermore, in the setting of neurological deficits or questionable ligamentous failure some would advocate an MRI as the study of choice as opposed to CT[23].

Michael Porter described value in healthcare as health outcomes achieved per dollar spent. He stresses that improving value leads to increased patient, provider, payer and supplier benefit while increasing the economic sustainability of the health system. When evaluating the clinical outcomes of using CT or XR to evaluate the subaxial spine in this study, it was found that in most cases the treatment did not differ. However, when evaluating the cost of CT versus XR, it was found that at our institution the CT costs over triple the amount of XR. Using the equation for value, one may claim that the value provided by using a CT as a screening tool for the detection of subaxial trauma delivers one third the value of using an XR. While this may imply that CT should not be used at all for screening of subaxial spine injury, that is not our conclusion. There are many modifying factors that may justify obtaining an initial CT, such as a high energy mechanism in an unexaminable patient or a patient with a large body habitus that does not lend itself to adequate XR. Therefore, our conclusion is that using CT as the initial imaging modality should not be routinely performed, but should be reserved for special circumstances at the care provider's discretion.

This study contains a number of limitations. The first limitation is the lack of cervical XR to serve as a control. In the one case that had surgical intervention, it was assumed that the neurological deficits would prompt further work up and that the injury would be detectable on XR. However, without actual XR we cannot make this claim with certainty. Another limitation is the possibility of a varying individual threshold among different care providers for ordering a CT. Furthermore, many of the patients were transfers that were initially managed by providers who were not accustomed to managing pediatric traumas. All these factors may skew the true incidence of subaxial cervical spine CTs. However, this would not change the fact that in this series in the presence of an injury, the CT did not alter patient management.

Conclusions

In our study we found the percentage of subaxial cervical injuries in patients 10-12 years old to be 1.5% of all patients obtaining cervical CT scans. Of the 4 injuries found, 1 was unstable. However, the unstable injury was a fracture dislocation with neurological deficits, which would likely be apparent on plain XR and would prompt obtaining a MRI due to the deficits. Even though CT has a higher sensitivity than XR, this did not translate into a change in clinical management of the patient. In light of the fact that CT is more than 3 times more expensive, while imparting 10-30 times the amount of radiation to a population of patients with increased radiation sensitivity and while not altering clinical management, we conclude that cervical CT is over-utilized in the 10-12 year old population.

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Preoperative Chlorhexidine Showers Can Lower the Skin Levels of Coagulase-Negative Staphylococcus But Not Propionibacterium

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Background

Propionibacterium and coagulase-negative Staphylococcus (CoNS) are the two most common bacteria involved in periprosthetic shoulder infections. These bacteria are found on and under the skin surface of healthy shoulders and can be inoculated into the deep tissues at the time of primary shoulder arthroplasty. Interventions aimed at decreasing skin bacterial load prior to surgery are intended to decrease the potential infection rate. Chlorhexidine washes the day prior to surgery are commonly employed in clinical practice, but their effectiveness in eliminating these bacteria has not been thoroughly tested. The objectives of this study were to answer two questions:

1. Do chlorhexidine washes the day prior to surgery effectively eliminate *Propionibacterium* and CoNS from the skin surface?
2. Are the results of preoperative skin cultures predictive of the results of cultures of the freshly incised dermal edge at surgery?

Methods

Twenty-nine patients (20 males, 9 females) with an average age of 63 ± 10 underwent primary shoulder arthroplasty between August 2017 and March 2018. Patients were instructed to shower with chlorhexidine (Hibiclens, Molylycke Health Care, Norcross, Georgia) the night before and the morning of surgery. Each patient had three skin swabs cultured: 1) one taken over the coracoid process at pre-operative clinic appointment (Clinic swab), 2) one from the same anatomic location immediately prior to skin preparation in the operating room (Pre-Prep swab), and 3) one taken from the incised dermal edge just after skin incision (Dermal swab). Culture results were reported semi-quantitatively as the Specimen Propi Value (SpPV) for *Propionibacterium* and Specimen CoNS Value (SpCV) for CoNS. The bacterial load of Propionibacterium and CoNS were compared for the clinic skin surface culture (Clinic SpPV/Clinic SpCV), the immediate preoperative skin surface culture (Pre-Prep SpPV/ Pre-Prep SpCV) (after the chlorhexidine showers), and the culture of the incised dermis (Dermal SpPV/Dermal SpCV).

Results

The mean (±SD) skin surface CoNS load decreased significantly from a Clinic SpCV of 0.7 ± 0.8 to a Pre-Prep SpCV of 0.1 ± 0.3 (p=0.024) after preoperative chlorhexidine showers. In 20 patients that had positive Clinic skin cultures for CoNS, the CoNS load decreased after the showers in 18 patients (90%).

The mean (±SD) skin surface *Propionibacterium* load did not decrease after preoperative chlorhexidine showers: the average Clinic SpPV was 1.0 ± 0.9 and average Pre-Prep SpPV was 1.3 ± 1.3 (p=0.435). In 24 patients that had positive Clinic skin cultures for *Propionibacterium*, the *Propionibacterium* load decreased after the showers in only 7 patients (29%).

Seven of 29 patients (24%) had positive Dermal cultures for *Propionibacterium*; only 1 of 29 patients (3%) had a positive Dermal culture for CoNS. All seven of the patients with a positive Dermal cultures for *Propionibacterium* had both positive Clinic swabs and positive Pre-Prep and had significantly higher Clinic SpPV (1.6±0.5 vs. 0.9±0.9, p=0.029) and Pre-Prep SpPV (2.4±1.3 vs. 1.0±1.1, p=0.012) than those with negative dermal cultures.

Conclusions

Preoperative skin showers with chlorhexidine are effective in decreasing CoNS load on the skin but are not effective in reducing *Propionibacterium* load on the skin. These results suggest that *Propionibacterium* from the dermal sebaceous glands can rapidly repopulate the skin surface after chlorhexidine showers. Shoulders with positive dermal wound cultures have higher loads of *Propionibacterium* on the skin surface than shoulders with negative dermal wound cultures.

University of Washington Medical Center and Northwest Hospital Orthopaedics

Chief, Howard A. Chansky, MD

At the University of Washington Medical Center, the focus continued to be on robust elective practices in shoulder, elbow, and hand surgery (Drs. Hsu, Warme, Matsen, Allan, Iannuzzi and Huang), sports (Drs. Hagen, Kweon and Gee), tumor (Drs. Davidson and Thompson), general orthopaedics and a small adult reconstruction program (Drs. Manner and Chansky).

At Northwest Hospital, the focus remains on geriatric fracture care (Drs. Clawson who retired from surgery but continues to build the "Strong Bones" program), total joint replacement (Drs. Fernando, Manner, Sassoon, Leopold and Chansky) and hand surgery (Drs. Kennedy and Beshlian). Dr. Manner's busy practice remained stable while the total joint volumes for Drs. Sassoon and Fernando continued to grow.

University of Washington Medical Center Surgery Pavilion

Dr. Nick Iannuzzi has joined the hand surgery practices of Drs. Allan and Huang at the UWMC. Nick continues to focus on the VA, but we are fortunate that he spends one day per week at the UWMC. Dr. Sarah Beshlian was named the Chief-of Staff Elect at NWH. She and Dr. Stephen Kennedy perform the majority of hand surgery at NWH.

Our SCCA and UWMC orthopaedic tumor service remains very busy and in this fall, will be joined by Dr. Jared Harwood. Dr. Harwood is currently in an orthopaedic oncology fellowship at Northwestern University.

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 of the shoulder via frequent publications and presentations around the country. Our sports service is anchored by Drs. Hagen, Gee and Kweon. Dr. Mia Hagen has quickly built a busy sports practice focusing on hip arthroscopy, a procedure which is becoming more popular but also in need of more research to define who will best benefit from the surgery. Dr. Hagen is also establishing a research program to study 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. We are very excited to have Dr. Viral Patel returning to our Department in September. Dr. Patel is a former much beloved and talented spine fellow who will be assuming leadership of the adult spine deformity practice at UWMC. Dr. Wagner and Connie Ly, PA, will work with Dr. Patel on caring for these complex patients.

We are all supported by our advanced practice providers who provide amazing care to our orthopaedic inpatients. Janice Olivo, PA and Kirsten Dahlberg, RN, FNP-BC and Katie Moore, ARNP who help with the care of our patients at UWMC and NWH. These three also contributed to improved patient satisfaction scores. In addition, they directly help with morale of both our resident physicians and patient's families. 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 administrative and research interests. Our physician assistants are listed with the rest of the faculty on page 11.

There is nothing static in a department of over 75 faculty. While we have new faculty joining us for the tumor and spine services, we also have faculty who are departing. On behalf of the Department, I extend best wishes to Dr. Darin Davidson, Dr. Adam Sassoon and Kirsten Dahlberg, RN, FNP-BC who will be departing at various points during this upcoming summer.

I am grateful for Dr. Darin Davidson's thoughtful care of very complex orthopaedic cancer patients over the previous 6 years. Darin also helped modernize and expand our

Northwest Hospital

orthopaedic tumor fellowship and enhanced the education of our trainees. I wish Dr. Davidson the best in his future endeavors.

Dr. Adam Sassoon has been an excellent partner who was also a productive researcher. He quickly made a name for himself caring for very challenging joint replacement and combined joint replacement-trauma cases. “No” is not an oft-used word by Dr. Sassoon. We will miss his willingness to work hard and take on the cases that others in the community referred to UW Medicine. Dr. Sassoon and his family will be moving “home” to the Santa Monica area to take a position with UCLA.

Some changes are only positive, and promotions certainly fall into that category. This year Dr. Gee was promoted to Associate Professor, and Dr. Warme to Professor. Since his arrival six years ago, Dr. Gee has built a very busy practice, assumed leadership of surgical care of our Husky athletes, and succeeded both academically and clinically. He has also developed a local and national reputation as an expert on the care of athletic injuries. Dr. Warme truly revolutionized our residency training program by developing and leading our Arthroscopic Boot Camp. Visiting faculty have told us that they have not seen such an elaborate training course anywhere else in the country. No doubt that this is a primary driver of the decision so many of our residents make to pursue a career as sport surgeons. Dr. Warme is also an expert on the care of diseases of the shoulder and has pioneered a commonly used treatment of dislocated sternoclavicular joints. Congratulations to both Dr. Warme and Dr. Gee for these well-deserved promotions.

Congratulations are also in order for Dr. Carlo Bellabarba, Chief of Orthopaedics at Harborview Medical Center. Carlo is an internationally renowned spine surgeon who was recently selected as the holder of the Hansjörg Wyss Endowed Chair. Starting this September, Dr. Bellabarba will be assuming a limited but important role in mentoring Dr. Viral Patel as he builds an academic spine program at UWMC.

Finally, Northwest Hospital and Medical Center and the University of Washington Medical Center announced that they will legally merge as of January 1, 2020. This “one hospital on two campuses” model should bring cost-savings and operational efficiencies to our practice. More details to follow as this important development evolves over the next 12-18 months.

Seattle Children's Hospital Orthopaedics

Chief, Suzanne M. Yandow, MD

Pediatric orthopedic surgery remains one of the largest divisions of care at Seattle Children's Hospital. Last year our outpatient volumes exceeded 40,000 visits with over 2,400 surgeries. The surgical group expanded with two additional surgeons (Dr. Jen Bauer and Dr. Todd Blumberg), and a new pediatric orthopedic sports medicine specialist, Dr. Kyle Nagle. In addition Dr. Matt Thompson joined the musculoskeletal surgical oncology team sharing his time at UW, SCCA and SCH. Faculty expansion increases expertise and allows rapid access to care. The planned expansion of the SCH campus will include new OR suites and the opening of the SCH Everett outpatient clinic will bring our care closer to home for many patients and families.

This year, May 19, 2018 marks the 50 year anniversary of the annual Lynn Taylor Staheli conference. Held at Seattle Children's Hospital, this conference provides pediatric musculoskeletal disease and trauma education and treatment updates for primary care providers. Record attendance speaks to its importance and growth in popularity for our community.

Dr. Staheli was also recognized for his humanitarian efforts globally and received the Pediatric Orthopedic Society of North America (POSNA) Humanitarian Award. Likewise, Seattle Children's Hospital honored him by establishing the Lynn Taylor Staheli Humanitarian Award. This recognizes his success as a worldwide educator in both pediatric orthopedics with the "POA—Pediatric Orthopedic Academy" and "Global Help". These provide open access, free of charge education in all domains of pediatric surgery and pediatric orthopedics.

Seattle Children's Hospital

Foot and Ankle

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. The program had over 6500 visits in 2016 for foot and ankle concerns. Our volume has increased by over 20% since 2015. An AEF (Academic Enrichment Fund) grant-funded project on idiopathic toe walking is undergoing final data analysis. Our results show poor efficacy of non-operative treatment modalities and these data will change the paradigm of management of this condition. This is a single example of many research studies improving the care of children's foot and ankle deformities. In 2017 our clubfoot program cared for over 500 idiopathic or syndromic clubfoot patients, including 117 new patients. Dr. Sousa and Dr. Jinguji are also members of our clubfoot team. We have hosted four international pediatric orthopedic surgeons in the last year who have each come for weeks to months to increase their knowledge of the high level pediatric foot care that we provide at Seattle Children's Hospital.

Limb Reconstruction

The multi-disciplinary limb reconstruction team led by Dr. Bouchard has grown substantially. Patients mostly have congenital, post-traumatic, post-infections or skeletal dysplasia-related deformities. Ages range from infants to young adults and patients hail from Alaska, Colorado, Idaho and across the state of Washington. In the spring, Dr. Bouchard will be training on a European lengthening implant, the Fitbone. Currently, there are only two centers in the U.S. providing this option.

Spine

The Seattle Children's Spine Program this year has gone through some momentous changes. Dr. Ted Wagner, who has been one of the foundations of spine deformity surgery in the Seattle Area since the 1980's, announced his retirement from the Children's Staff, and is focusing on supporting the University of Washington adult Spine service. A four-year search for new partners to expand and carry on the Spine Surgery program culminated this fall in the hiring of two young outstanding academic pediatric orthopedic surgeons. Dr. Jennifer Bauer and Dr. Todd Blumberg will complement Dr. White who is focusing on treatment of early onset scoliosis and spine deformities associated with skeletal dysplasias. Drs. Bauer and Blumberg will assume the practice of Dr. Krengel who is transitioning to a mentorship and pediatric trauma role. This is an exciting time for the program, injecting new levels of enthusiasm and innovation. Dr. Blumberg returns after his residency

at the University of Washington, and has recently completed his pediatric orthopedic fellowship at Children's Hospital of Philadelphia. He has major interest in both pediatric spine deformities and hip problems in children, as well as pediatric trauma. Dr. Bauer completed her orthopedic residency at Vanderbilt University, and her pediatric orthopedics spinal deformity fellowship at A.I. Dupont. Her interest is complex pediatric spinal deformity. She also serves as the physician lead for the reduction of surgical site infections at SCH. The department continues to have a multi-specialty program collaborating with neurosurgery, pulmonary and anesthesia. Spine conditions treated include skeletal dysplasias, neurologic and muscular disorders, sports injuries, low back pain, and musculoskeletal tumors.

Sports

The Seattle Children's Sports Medicine Program is composed of two sports orthopedic surgeons, seven sports medicine trained pediatricians, physician assistants, certified athletic trainers, and sports physical therapists. Our mission is to:

- Provide excellent care to the whole athlete, as a collaborative team, serving all children, adolescents and young adults in play and sport, including those of diverse populations of all abilities.
- Perpetuate a scope of care that embodies a dedication to injury prevention, treatment, rehabilitation, and performance development.
- Serve the Pacific Northwest through cutting-edge research and advocacy in education and outreach

With two full-time sports surgeons, the department has seen an increase in the number of arthroscopy surgeries, particularly for ACL tears, patellar instability, and shoulder instability. We initiated collection of patient-reported outcome measures to address the demands of evidence-based medicine. We now have a cloud-based and tablet-friendly platform to allow sports medicine providers to gain valuable data for providing optimal care and developing evidence-based protocols for treating patients with knee, shoulder, and elbow conditions. Our newest sports faculty addition is Dr. Kyle Nagle. He is a board certified pediatrician and fellowship trained sports medicine physician. He brings experience in pediatric fellowship direction, care of pediatric sports injuries, and non-operative fractures. He will also lead our community outreach in promotion of physical activity in children and families from across the western region.

Now in its tenth year, the Athletic Training Program has emerged as the regional leader in providing on-site healthcare for young athletes and is one of the largest of its kind in the country. Beginning in 2008 with just one district and seven schools, we have expanded into 20 different school districts covering 38 high schools and over 150 different community organizations in the Western Washington region. 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. This group provided over 33,000 assessments including over 550 concussions and close to 82,000 treatments to young athletes.

Skeletal Health

The Skeletal Health and Dysplasia Program at Seattle Children's Hospital is internationally recognized for our expertise in the clinical care of children with genetic bone disorders and metabolic bone disease. Our skeletal dysplasia registry continues to grow, and is now a nationally and internationally recognized program. The Skeletal Dysplasia Management Consortium (SDMC) was held in Seattle, this year with a focus on "Best Practices in the Care of Type II Collagen Disorders". In the community, our group actively supports and collaborates with both the national and regional leadership of Little People of America (LPA), as well as the leadership of the National MPS (Mucopolysaccharidosis) Society and the Osteogenesis Imperfecta Foundation (OIF).

Neuromuscular

Neuromuscular care at Seattle Children's Hospital continues to grow in collaboration with our many partners. Neuromuscular diseases such as cerebral palsy, spina bifida, and muscular dystrophy continue to be taken care of by the pediatric orthopedic surgeons across our subspecialties. We continue to partner with rehabilitation medicine, physical therapy, orthotics and occupational therapy to deliver comprehensive state of the art care to these patients. We have many combined clinics including an Orthopedic/ Rehabilitation medicine clinic as well as a surgical tone management clinic. The current concept for the management of musculoskeletal deformities is Single Event Multilevel Surgery (SEMLS). SEMLS attempts to have a diagnostic matrix of all the deformities within a child's lower extremities that affect the gait and perform all those procedures at a single operation. We have received several generous donations and with these donations we look forward to building and staffing a motion analysis laboratory and expanding research in cerebral palsy. This lab will allow for complex modeling of children's gait to better understand the kinetics and kinematics of gait and thereby optimize the surgical plan for these patients.

Bone Tumor

At Seattle Children's Hospital, the Pediatric bone and soft tissue tumor service cares for patients with benign and malignant bone and soft tissue tumors as well as cancer-related orthopedic conditions. As a part of a multidisciplinary team of collaborative physicians and surgeons we provide a comprehensive and patient-centered approach to aggressive cancer treatment while striving to preserve function utilizing the latest techniques in limb salvage surgery as well as vascular malformation and benign tumors. New research includes Dr. Lindberg's continued collaboration with the Interventional Radiology Department and the Vascular Anomalies group in the study of preoperative glue embolization and surgical resection in the treatment of vascular malformations. Dr. Thompson has recently published a study on accuracy of sarcoma resection using pre-op MRI. Dr. Yandow's research on bone marrow aspiration and treatment of bone cyst continues to improve the treatment and care of benign bone tumors.

Trauma

Fracture care continues to be a significant segment of activity for the Pediatric Orthopedic and Sports Medicine Division. Once again, the

number of surgically managed fracture cases increased over the prior year, with 560 operative cases performed, a roughly 15% increase. The fracture service, with its dedicated AM trauma room instituted last year, has proven effective in managing these cases to the benefit of both patient and surgeon.

Hand

We continue to be involved in the national CoULD (Congenital Upper Limb Difference) registry as one of the leading sites for enrollment. This is leading to several national projects as well as a local project to try to help improve response rates for follow-up data on our patients. The upper limb group has also been involved in 3 other research projects this past year with one evaluating anesthesia technique for trigger thumb surgery and a review of finger trauma in the emergency room which has led to a poster presentation at ASSH as well as 2 regional podium presentations. Lastly, in a combined effort with the adolescent medicine team, we are investigating the use of biofeedback to treat chronic wrist pain in adolescents. Through research, social support and medical treatment, we continue to strive to improve our patients lives.

Outreach

Our Mill Creek site is undergoing a significant expansion and will be relocating to Everett. Pediatric orthopedics will be very well represented at the new facility. Our outreach and satellite clinics work hard to serve both the needs of the community and primary care teams while also trying to integrate with existing orthopedic providers within the region. Our goal is always the same: To provide the best pediatric orthopedic care possible while minimizing travel and hardship for patients and their families.

Harborview Medical Center Orthopaedics

Chief, Carlo Bellabarba, MDCM

Departmental Promotions

2017-18 saw the well-deserved promotions of Lisa Taitsman, MD, MPH to Professor, Reza Firoozabadi, MD to Associate Professor and Haitao Zhou, MD to Assistant Professor in the Department of Orthopaedics and Sports Medicine.

Medical Center

Seattle's explosive growth over the past several years has clearly been felt at Harborview, with the hospital now running at full capacity (and beyond) year-round. Level-1 trauma care and treatment of our underserved population continue to co-exist with robust elective practices, particularly in foot and ankle, hand and spine surgery.

Clinical Care

The 2017-18 year to date has seen continued stability in terms of orthopaedic faculty and surgical volumes. The case mix index, a measure of the complexity of the patients treated by the orthopaedic service at Harborview, continues to climb on a yearly basis, emphasizing the importance of Harborview as a source of experienced, specialized care in the treatment of musculoskeletal conditions within our region.

Research and Education

With the assistance of research coordinator Julie Agel, MA, the Harborview orthopaedic faculty continue to conduct a variety of prospective and multi-center research studies, and have contributed over 100 peer-reviewed publications in their respective areas of expertise to the orthopaedic literature over the course of 2017-18.

Harborview remains the largest component of the University of Washington Department of Orthopaedics' teaching program, replete with fellows, residents, medical students and advanced practice providers who benefit from the high complexity and volume of patients to learn from our faculty. Harborview orthopaedics also continues to host dozens of visitors who travel from throughout the globe year-round to immerse themselves in the Harborview orthopaedic experience first-hand.

Harborview Medical Center Ninth and Jefferson Building

Lisa Taitsman, MD, Professor, Reza Firoozabadi, MD, MA, Associate Professor, and Haitao Zhou, MD, Assistant Professor.

VA Puget Sound Orthopaedics

Chief, Albert O. Gee, MD

The Puget Sound Veteran's Administration (VA) Medical Center continues to be a tertiary referral center for orthopaedic surgical care in the Northwest United States. We honor the long tradition of those surgeons who have come before us in striving to provide the highest level of care to our Veterans, while training the next generation of surgeons and advancing the science musculoskeletal medicine through research.

The faculty base remains unchanged and includes Drs. Chansky, Sangeorzan, Iannuzzi and myself. Amongst the four of us, we cover the subspecialty areas of Hip and Knee arthroplasty, Foot and Ankle surgery, Hand and Upper Extremity surgery and Shoulder and Sports Medicine, respectively. Dr. Fred Huang continues to provide per-diem general orthopaedic surgery care on a monthly basis and we are grateful to him for doing this for so many years now.

Our team has been together for over 3 years and we are looking forward to expanding with the addition of two new surgeons in the near future.

Dr. Will Lack, who will be coming to us from Loyola University in Chicago, will bring expertise in Trauma care and Dr. Jared Harwood, who is completing his fellowship currently at the University of Chicago, will bring Oncologic surgical specialty to our VA. We are all excited to have them joining us soon and we are confident they will further elevate the care that we are able to provide.

We have the privilege of working with a large team of trainees which includes 2 Chief Residents, a PGY-4, PGY-3 and PGY-2 level residents as well as rotating medical students. They work hard to cover a busy and diverse service and we are ever grateful to them for their service.

We have been fortunate to have an incredibly stable physician extender team which includes: Dustin Higbee, PA-C, Steve Casowitz, PA-C, Amy Katzenmeyer, NP, and Renato Rafi, PA-C and Annette Testa, LPN. We added a new PA this year, Martin Hendricks, PA-C. These providers help both in the operating room and in clinic and are the cornerstone of access at our VA.

VA Puget Sound Health Care System - Seattle Division

Perhaps the most important members of our team are our nurse coordinators Monette Foltan, RN and Katherine German, RN who schedule and manage all the complexities of our surgical schedule. And we are always grateful to our administrative assistant, Cindy Lostoski and our service line manager, Diane Diggins, who handle essentially everything else and keep us all in line.

The work of Dr. Sangeorzan and his research lab, supported by Dr. Bill Ledoux, PhD, remains at the forefront in the study of lower extremity and foot biomechanics. Their Center of Excellence in Limb Loss Prevention and Prosthetic Engineering continues its impressive record of scientific discovery and uninterrupted extramural funding support.

I am happy to report that the Puget Sound VA Orthopaedic Surgery Service remains strong and busy as we continue to strive for highest standards in clinical care, education and research in the service and care of America's Veterans.

Departmental Seed Grant Program

Vice Chair of Research, Ted S. Gross, PhD

Under the leadership of Dr. Chansky, our Departmental Seed Grant Program was initiated in 2016. Our goals for this first round of funding were two-fold: 1) stimulate new academic collaborations within the Department, and 2) enable the collection of preliminary data that would guide new extramural grant applications. We received 20 applications and, based upon blind peer review, 11 projects were selected for funding with an average budget of nearly $27,000. The diversity of funded projects (ranging from development of new *in vivo* models to explore a variety of bone biology pathologies, to using gaming technology to assess musculoskeletal function, to assessing patient reported outcomes following pelvis and acetabular fracture) reflected the breadth of curiosity and expertise in our Department.

By any metric, the first round of funding has been an outstanding success. Five new NIH and two new OREF proposals were submitted based on data generated from Seed Grants. Additionally, two more NIH submissions are anticipated by the end of 2018. Three new *in vivo* models have been developed, each of which holds potential for use in future extramural applications. To date, we are aware of two manuscripts (with 4 more in review or planned) and eight abstracts (including both AAOS and ORS) that have arisen from Seed Grants. Special acknowledgement should be extended to PIs that have already successfully received extramural funding using data from their Seed Grants:

Amy Cizik, PhD (Co-PI: Conor Kleweno, MD)
OREF, 'Validation for Patient Reported Outcome Measures for Pelvic and Acetabular Fractures Following Traumatic Injury'
Total Costs: $150,000

Chris Kweon, MD (Co-Inv: Albert Gee, MD, Scott Telfer, PhD)
Pac 12, 'Injury Prevention: Simple Motion Capture Technology for Readiness of Return to Sport Assessment and Injury Risk Prevention'
Total Costs: $85,000

Scott Telfer, PhD
NIH R21AR072216, 'Instrumented Footwear to Measure Planter Tissue Properties'
Total Costs: $242,000

Finally, special congratulations are extended to one of our Seed Grant PIs, Ron Kwon, PhD, on his successful promotion to Associate Professor.

We anticipate that additional progress will continue from the first round of Seed Grants as projects mature and look forward to receiving new proposals for our second round of Seed Grant funding later this year.

Ronald Y. Kwon, PhD, Associate Professor

Graduating Residents

Kariline Bringe, MD

After residency, Kariline will move to Roanoke, VA where she will complete a fellowship in joint reconstruction at the Carilion Clinic. Upon completion of her fellowship, she will likely return to the Midwest to start her career.

David Ibrahim, MD

After residency, David will be completing a fellowship in Adult Hip and Knee Reconstruction at Florida Orthopedic Institute in Tampa, Florida. Following completion of his fellowship, he plans to return to the West Coast.

Romie Gibly, MD, PhD

Romie, his wife Erin, and their sons Smith and Leo will be moving to Denver, Colorado where he will be completing a fellowship in Pediatric Orthopaedic Surgery at the University of Colorado and Children's Hospital Colorado. After fellowship, they are hoping to return to the Pacific Northwest.

Colin Kennedy, MD

After residency, Colin and his wife, Alexandra, will move to San Diego where he will complete a Hand and Microvascular Surgery Fellowship at University of California San Diego. Upon completion of fellowship, Colin will practice in the United States Air Force. He and Alexandra eventually plan to return to the Pacific Northwest.

Graduating Residents

Lauren MacTaggart, MD

After residency, Lauren, her husband Kyle, and their dog Luna will be heading east to Philadelphia. Lauren will complete a fellowship in Hand and Upper Extremity with the Philadelphia Hand to Shoulder Center. After fellowship, they plan to settle back in the Pacific Northwest.

Adam Sangeorzan, MD

Adam will be completing a Fellowship in Foot and Ankle Surgery at Brigham and Women's Hospital in Boston. He plans to return to the Pacific Northwest afterwards to continue his career.

Stuart Michnick, MD

After residency, Stuart, his wife Amber and their daughter Aria will be moving to Baltimore where he will complete a fellowship in foot and ankle surgery. After fellowship, they will be pursuing practice opportunities closer to their home state of Texas.

Alan Swenson, MD

After residency Alan will be moving to Cincinnati where he will complete a fellowship in hand and microvascular surgery at the Mary S. Stern Fellowship for Hand Surgery. After fellowship he will be moving home to Anchorage, Alaska where he will practice as a hand and upper extremity surgeon.

Incoming Residents - R2s

Sagar Chawla, MD, MPH

From Des Moines, Iowa, Sagar attended Iowa State University. Upon graduation, he attended Mayo Clinic School of Medicine and earned a Masters in Public Health at Johns Hopkins Bloomberg School of Public Health. His areas of interest include hand, trauma, global surgery, and outcomes research. He enjoys hiking, kayaking, and cooking.

Corey Schiffman, MD

From Oak Park, Illinois, Corey completed his undergraduate degree at The University of Michigan. Upon graduation, he went to medical school at Loyola University Chicago. His areas of interest include sports medicine, shoulder and elbow, and trauma. Outside of work, his interests include running while listening to music and eating with family and friends.

William Hannay, MD

Will Hannay comes from Grand Rapids, Michigan. He attended Grand Valley State University and later obtained his medical degree from the University of Miami (FL). His orthopaedic interests include trauma, upper extremity, and reconstruction. He enjoys hiking, camping, snowboarding, and fly fishing.

Sara Shin, MD

Sara comes from Gig Harbor, WA and attended the University of Washington. She earned her medical degree at Drexel University College of Medicine. Her areas of orthopaedic interest include hand and trauma. Outside of work she enjoys trail running, snow shoeing, mountain climbing, traveling, and spending time with family.

Incoming Residents - R2s

Ryan Stancil, MD, MPH

Ryan Stancil was raised in Lake Forest, California. He studied neuroscience at UCLA for his undergraduate degree followed by medicine at Drexel University. He practiced diving medicine in the US Navy prior to entering orthopaedic residency. He is interested in adult reconstruction and trauma. He enjoys boating, cooking, hiking and skiing for fun.

Cathy Vu, MD, MPH

Cathy hails from Atlanta, Georgia and went to Princeton University for her undergraduate degree. She returned to Atlanta to obtain her medical and master of public health degrees from Emory University School of Medicine. Her interests include traveling, finding new coffee/bubble tea spots, and running down hiking trails.

Mario Taylor, MD

Mario, born on the beautiful island of Jamaica, grew up in Westchester, NY before attending Virginia Tech for undergrad. He then obtained his medical degree from Howard Uni. College of Medicine before joining the UW Dept. of Orthopaedics resident family.

Jacob Wilkerson, MD

Jake Wilkerson comes from Houston, Texas with interests in trauma and arthroplasty. He attended Texas A&M University, later going to medical school at University of Texas-Houston. He enjoys fly fishing, skiing, and spending time with his wife and dog.

Incoming Residents - R1s

Shaun Chang, MD

Born and raised in Honolulu, Hawaii, Shaun is an alumnus of Punahou School and earned his BS from Boston University before graduating from the University of Hawaii's John A. Burns School of Medicine. He enjoys running, hiking, the beach, music, football, and cooking. Shaun's areas of interest are trauma and sports medicine.

Ekamjeet Dhillon, MD

Ekam grew up in Palatine, Illinois and pursued his undergraduate degree at Loyola University Chicago. He later obtained his medical degree at the Northwestern University Feinberg School of Medicine. His areas of interest include spine, hand, sport, and global health. Outside of work, he enjoys soccer, views, boats, traveling, and music.

William Crutcher, MD

Billy grew up in Seattle and attended Boston College for his undergraduate studies. He then earned his medical degree from Thomas Jefferson University in Philadelphia. His areas of interest include sports, joints, and trauma. In his spare time, he enjoys skiing, basketball, and hanging out with friends and family.

Alexander Higgins, DO

Alex was born in Pittsburgh, PA. He attended Saint Michael's College in Colchester, Vermont, graduating with a BA in Psychology. He received his medical education at A.T. Still University–School of Osteopathic Medicine in Arizona. While there, he served as a representative in a medical jeopardy competition against local university students.

Incoming Residents - R1s

Madeleine Jackson, MD

Madeleine comes from Santa Barbara, California and attended Princeton University. She earned her medical degree from UC San Diego. Her areas of interests include pediatric orthopaedics and orthopaedic oncology. Outside of work she enjoys hiking, traveling, woodworking and baking the perfect loaf of bread.

Zakkary Walterscheid, MD

Zakk is from Albuquerque, New Mexico. In 2013, he graduated with a BS in Bioengineering from University of California, San Diego. In 2018, he graduated with his medical degree from Virginia Tech Carilion School of Medicine. While in medical school, he published research on the use of tranexamic acid in total joint and orthopaedic trauma surgery.

Taleef Khan, MD, MBA

Taleef is from Creve Coeur, Missouri and attended Washington University in Saint Louis. He obtained both his MD and MBA from Washington University's School of Medicine and the Olin Business School. His areas of interest are spine and joint reconstruction. Outside of work, he enjoys playing basketball and trying out new restaurants.

Jie (Jay) Yao, MD

Jay comes from Austin, Texas and attended Rice University where he completed his undergraduate degree. Upon graduation, he attended medical school at the University of Texas Southwestern Medical Center in Dallas, Texas. He enjoys spending time with his wife and dog, musical instruments, board games, and basketball.

ACEs and Fellows

Clay A. Carmody, MD
Foot & Ankle

Devin S. Ganesh, MD
Shoulder & Elbow

Andrew Gupta, MD
Pediatrics

Christina W. C. Cheng, MD
Spine

David Gendelberg, MD
Spine

Richard "Trey" W. Gurich, Jr, MD
Oncology

David M. Donohue, MD
Trauma

Joshua Gordon, MD
Hand

Garin G. Hecht, MD
Trauma

Michael Galvez, MD
Hand

Courtney M. Grimsrud, MD
Foot & Ankle

Megan Kuba, MD
Pediatrics

ACEs and Fellows

Justin F. Lucas, MD, MS
Trauma

Amy L. Ravindra, MD
Shoulder & Elbow

Travis J. Wilson, MD
Foot & Ankle

Gabriel J. Pavey, MD
Oncology

Michael T. Talerico, MD
Trauma

Adnan Prsic, MD
Hand

Anthony Vu, MD
Hand

Sara M. Putnam, MD
Trauma

Nathan A. Wigner, MD, PhD
Spine

Research Grants

National Institutes Of Health

Collagen Assembly in Intervertebral disc
Russell J. Fernandes, MSc, PhD
David M. Hudson, PhD

Collagen Cross-Linking in Skeletal Aging and Diseases
David R. Eyre, PhD
David M. Hudson, PhD
Russell J. Fernandes, MSc, PhD
Jiann-Jiu Wu, PhD

Identifying Osteoporosis Genes by Whole Genome Sequencing and Functional Validation in Zebrafish
Ronald Y. Kwon, PhD

Instrumented Footwear to Measure Plantar Tissue Properties
Scott Telfer, EngD
Peter R. Cavanagh, PhD, DSc
William R. Ledoux II, PhD

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
Leah E. Worton, PhD

Neuroskeletal Systems Biology in Zebrafish
Ronald Y. Kwon, PhD

Pathogenesis of Novel Forms of Osteogenesis Imperfecta (Project 3: Collagen Post-translational Modification and Cross-linking)
David R. Eyre, PhD
David M. Hudson, PhD
Russell J. Fernandes, MSc, 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

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 J. Bransford, MD

American Shoulder and Elbow Surgeons

ASES 2017 Fellowship Program Grant
Winston J. Warme, MD

Acumed

Acumed Grant 2017
Jerry I. Huang, MD

Arthrex, Inc.

Arthrex Fellowship Educational Grant
Winston J. Warme, MD

Baylor College Of Medicine

Pathogenesis of Novel Forms of Osteogenesis Imperfecta
David R. Eyre, PhD
David M. Hudson, PhD
Russell J. Fernandes, MSc, PhD

Research Grants

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

Conventus Orthopaedics, Inc.

Conventus CAGE™ PH for use in Proximal Humerus Fracture Fixation
Jonah Hebert-Davies, MD

Foundation for Orthopedic Trauma

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

Histogenics Corporation

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

Integra LifeSciences Corporation

A Post-Market, Prospective, Non-Randomized, Multi-Center, Open-Label Clinical Evaluation of the Integra® Cadence™ Total Ankle System in Primary Ankle Joint Replacement
Michael E. Brage, MD

Integra Grant
Jerry I. Huang, 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, MD
Bruce J. Sangeorzan, MD
Conor P. Kleweno, MD
Daphne M. Beingessner, MD
David P. Barei, MD
Lisa A. Taitsman, MD
M. Bradford Henley, MD
Michael Brage, MD
Robert P. Dunbar, MD
Sean E. Nork, MD
Stephen K. Benirschke, MD

A Retrospective Study of Early Mechanical Stabilization and Bleeding in Disruption of the Pelvic Ring (PilotBIND)
Conor P. Kleweno, MD

Complications and Safety of Blood Clot Prevention Medicines Used in Orthopedic Trauma Patients
Reza Firoozabadi, MD, MA

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

Supplemental Perioperative Oxygen to Reduce Surgical Site Infection After High Energy Fracture Surgery
Armagan H. C. Dagal, MD
Bruce J. Sangeorzan, MD
Conor P. Kleweno, MD
Daphne M. Beingessner, MD
David P. Barei, MD
Douglas G. Smith, MD
Lisa A. Taitsman, MD
M. Bradford Henley, MD
Reza Firoozabadi, MD, MA
Robert P. Dunbar, MD
Sean E. Nork, MD
Stephen K. Benirschke, MD

The Major Extremity Trauma Research Consortium
Reza Firoozabadi, MD, MA

Medical University Of South Carolina

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

Research Grants

Omega Medical Grants Association, LLC

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

Omega Trauma Fellowship
David P. Barei, MD

Orthopaedic Research and Education Foundation

Validation for Patient Reported Outcome Measures for Pelvic and Acetabular Fractures following Traumatic Injury
Amy Cizik, PhD, MPH
Conor P. Kleweno, MD
Dagmar Amtmann, PhD

Orthopaedic Trauma Association

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

An Imaging Framework for Clinically Testing new Treatments to Prevent Post-Traumatic
Conor P. Kleweno, MD

COTA Trauma Fellowship
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 Y. Kweon, MD
Scott Telfer, EngD
Albert O. Gee, MD

Synthes USA

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

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

University of Pittsburgh

Surgical Timing and Rehabilitation (STaR) for Multiple Ligament Knee Injuries (MLKs): A Multicenter Integrated Clinical Trial
Albert O. Gee, MD
Amy Cizik, PhD, MPH
Christopher Y. Kweon, MD

US Army Research Office

Patient Enrollment
Reza Firoozabadi, MD, MA

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 2017-2018

A list of publications authored by our faculty from January 2017 to May 2018. Our faculty members names are in **bold type**.

1. Abola MV, Teplensky JR, Cooperman DR, **Bauer JM**, Liu RW. Pelvic Incidence Is Associated With Sacral Curvature, Sacroiliac Joint Angulation, And Sacral Ala Width. Spine (Phila Pa 1976). 2018 Apr 12.

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Sigvard T. Hansen, Jr., MD ★★★★★
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Hugh E. Toomey, MD ★★

1970
John C. Brown, MD ★
John M. Coletti, Jr., MD ★
Malcolm B. Madenwald, MD ★
Michael T. Phillips, MD ★
Robert D. Schrock, Jr., MD

1971
Franklin G. Alvine, MD ★★★
Bruce E. Bradley, Jr., MD ★
Nils Fauchald, Jr., MD
Louis A. Roser, MD ★
Jerome H. Zechmann, MD

1972
Thomas L. Gritzka, MD ★
Donald D. Hubbard, MD ★
David J. LaGasse, MD ★
David R. Nank, MD ★★
John A. Neufeld, MD ★

1973
Frederick J. Davis, MD ★
Larry D. Hull, MD ★
Theodore A. Wagner, MD ★★★★
Robert P. Watkins, Jr., MD ★

1974
Samuel R. Baker, MD ★★
Richard A. Dimond, MD ★★
Ronald B.H. Sandler, MD ★★
Robert A. Winquist, MD ★★★★★★★

1975
William M. Backlund, MD, PS ★
Thomas M. Green, MD ★★★★
Gunter Knittel, MD
Frederick A. Matsen III, MD ★★★★★★★
Larry R. Pedegana, MD ★
Donald L. Plowman, MD ★★★

1976
John F. Burns, MD ★
Douglas T. Davidson III, MD ★
Douglas K. Kehl, MD
Peter Melcher, MD
Richard A. Zorn, MD ★

1977
Carl A. Andrews, MD ★
Steven T. Bramwell, MD
Larry D. Iversen, MD ★
Mark C. Olson, MD ★
Geoffrey W. Sheridan, MD ★★

1978
John W. Brantigan, MD
Gary J. Clancey, MD ★★★★
William Oppenheim, MD ★★
Arnold G. Peterson, MD ★★★
Robert J. Strukel, MD
Richard S. Westbrook, MD ★

1979
Allan W. Bach, MD ★★★★
Gregory M. Engel, MD ★
Jonathan L. Knight, MD ★★
Richard L. Semon, MD ★★★

1980
John M. Hendrickson, MD ★★
Stuart R. Hutchinson, MD ★
Douglas G. Norquist, MD ★
Michael A. Sousa, MD ★★★★★
Carol C. Teitz, MD ★★

1981
John M. Clark, Jr., MD, PhD ★★
Dennis J. Kvidera, MD ★
Martin S. Tullus, MD ★★★★
Robert G. Veith, MD ★★★★★★

1982
William D. Burman, MD
Richard M. Kirby, MD ★★★★★
Steven S. Ratcliffe, MD ★★
John L. Thayer, MD ★★★★

1983
Robert M. Berry, MD ★★
Edward L. Farrar III, MD ★★★
Keith A. Mayo, MD ★★★★★★
Elizabeth Anne Ouellette, MD ★
Henry K. Yee, MD ★
Joseph D. Zuckerman, MD ★★★

1984
Jeffrey W. Akeson, MD ★★
Thomas J. Fischer, MD ★★★★★
Jeffrey C. Parker, MD ★
Kevin P. Schoenfelder, MD ★
Marc F. Swiontkowski, MD ★★★★★★

1985
Paul J. Abbott, MD ★
William P. Barrett, MD ★★★★
Richard J. Barry, MD ★
Daniel L. Flugstad, MD ★★
Jeffrey N. Hansen, MD ★★

1986
Gary Bergman, MD ★★★★
Lawrence E. Holland, MD ★
Carleton A. Keck, Jr., MD ★★
Michael E. Morris, MD ★★★

1987
Craig T. Arntz, MD ★★
Herbert R. Clark, MD ★
Michael K. Gannon, MD ★
Steven L. Reed, MD ★

1988
Jonathan L. Franklin, MD ★★★★
Michael A. Thorpe, MD ★★★★
Richard V. Williamson, MD ★

1989
James P. Crutcher, MD ★★★★
Nancy J. Ensley, MD
Martin G. Mankey, MD ★★★★
Lawrence V. Page, DO ★★★
Steve C. Thomas, MD ★★★

1990
J. Roberto R. Carreon, MD
Ken Fujii, MD ★
David M. Kieras, MD ★
Walter F. Krengel III, MD ★★★
Jay A. Winzenried, MD ★★

1991
David H. Bishop, MD ★
Tim P. Lovell, MD ★
Mark E. Murphy, MD, PhD ★★
Mark Remington, MD ★★
Kit M. Song, MD

1992
Eli Powell, MD ★
Curt Rodin, MD
Michael Sailer, MD ★★
Jeff Stickney, MD ★★
Don Striplin, MD ★
John D. West, MD ★

1993
Susan R. Cero, MD ★★★★★
Philip J. Kregor, MD ★
Lyle S. Sorensen, MD ★★★★★★★
J. Eric Vanderhooft, MD ★★★

1994
Eric Bowton, MD ★
Sohail K. Mirza, MD ★★★★
William Obremskey, MD ★★★★
Jim Vahey, MD ★★★★
Brodie Wood, MD ★★★★★

1995
Timothy Beals, MD ★★★
Todd Clarke, MD ★★★
Scott Hormel, MD ★★
Ron Kristensen, MD ★★★
William J. Mills III, MD ★★

1996
Vernon Cooley, MD ★★
David Deneka, MD ★★★
Peter Mitchell, MD ★★
Peter T. Simonian, MD ★★★★★
William Wagner, MD ★★★

1997
L. Anthony Agtarap, MD ★
Mohammad Diab, MD
David Levinsohn, MD ★
Daniel Stechschulte, Jr., MD, PhD ★★★★★
Randall W. Viola, MD

1998
David Belfie, MD ★
Jay Crary, MD ★★★★★
Oriente DiTano, MD ★
Don Ericksen, MD ★★★★★
Colin Poole, MD ★

1999
Craig Boatright, MD
Thomas D. Chi, MD ★
Jeffrey Garr, MD ★
John Michelotti, MD ★
Julie A. Switzer, MD ★

2000
Joel Hoekema, MD ★★★
Daniel Jones, MD ★
Cara Beth Lee, MD ★
Patrick McNair, MD
Brett Quigley, MD ★

2001
Richard Bransford, MD ★
Matthew Camuso, MD
Frederick Huang, MD ★★★★★
Michael Metcalf, MD ★★★★
Eric Novack, MD

2002
Timothy DuMontier, MD ★
Scott Hacker, MD ★
Timothy Rapp, MD ★
William Sims, MD ★
Carla Smith, MD ★★

2003
Ben DuBois, MD ★★★★★
Andy Howlett, MD ★
Guy Schmidt, MD ★
Brian Shafer, MD ★
Emma Woodhouse, MD ★

2004
Jon Braman, MD ★
Alexis Falicov, MD ★
Thea W. Khan-Farooqi, MD
Mike McAdam, MD ★
Jason H. Thompson, MD ★

2005
Anthony Buoncristiani, MD ★
Waqqar Khan-Farooqi, MD
Wren McCallister, MD
Timothy O'Mara, MD ★★★
David W. Stevens, MD ★

2006
Stacey Donion, MD
Eric Klineberg, MD ★
Bill Montgomery, MD ★
Heidi Shors, MD ★★
Mel Wahl, MD ★
Burt Yaszay, MD ★

2007
Jamie Antoine, MD ★
Jeremiah Clinton, MD ★
Mary Cunningham, MD ★
Evan Ellis, MD ★
Joseph Lynch, MD ★
Allison MacLennan, MD ★

2008
Drew Fehsenfeld, MD ★★
Mark Freeborn, MD ★★★
Christopher Howe, MD ★
John Howlett, MD ★
Michael Lee, MD ★
Gregg Nicandri, MD ★

2009
Rajshri Maheshwari Bolson, MD ★
Jason King, MD ★
Annie Links, MD ★
Soren Olson, MD ★
Karen Perser, MD ★
Scott Ruhlman, MD ★
Addison Stone, MD ★
Jason Wilcox, MD ★

2010
Sean Amann, MD ★
Jeremy Bauer, MD ★
Aric Christal, MD ★
Wendy Emerson, MD ★
Michael Hwang, MD ★
Lee Pace, MD ★
Christopher Wolf, MD ★
Vinko Zlomislic, MD ★

2011
Aaron Chamberlain, MD ★
Brian Daines, MD ★
Cory Lamblin, MD ★
Edward Moon, MD ★
Derek Rains, MD ★
Peter Scheffel, MD ★
Christian Sybrowsky, MD ★
Brett Wiater, MD ★

2012
Benjamin Amis, MD ★
Adam Bakker, MD ★
Gregory Blaisdell, MD ★
Joshua Lindsey, MD ★
Grant Lohse, MD ★
Matthew Lyons, MD ★
Andrew Merritt, MD ★
Nels Sampatacos, MD ★

2013
Kyle Chun, MD ★
Elizabeth Dailey, MD ★
Andrew Ghatan, MD ★
Brian Gilmer, MD ★
Jennifer Hagen, MD ★
Mark Miller, MD ★
David Patterson, MD ★
Emily Squyer, MD ★

2014
Sid Baucom, MD
Nathan Coleman, MD
Jacques Hacquebord, MD
Nicholas Iannuzzi, MD ★
Paul Kim, MD
Ted Sousa, MD ★
Nicholas Wegner, MD
David Zeltser, MD ★

2015
Timothy Alton, MD ★
Kenneth Gundle, MD ★
Daniel Holtzman, MD ★
Amanda Roof Larson, MD ★
Paige Mallette, MD
Courtney O'Donnell, MD
Daniel Patton, MD ★
Laura Stoll, MD ★

2016
Todd Blumberg, MD ★
Akash Gupta, MD
Sean Haloman, MD ★
Emily Harnden, MD ★
Clifford Hou, MD
Dayne Mickelson, MD ★
Jessica Telleria, MD ★

2017
Ahmad Bayomy, MD ★
Christopher Domes, MD
Kevin Hug, MD ★
Alexander Lauder, MD ★
Calvin Schlepp, MD ★
Shawn Schoch, MD
Neil Tarabadkar, MD
Sara Shippee Wallace, MD ★

2018
Kariline Bringe, MD
Romie Gibly, MD
David Ibrahim, MD
Colin Kennedy, MD
Lauren MacTaggart, MD
Stuart Michnick, MD
Adam Sangeorzan, MD
Alan Swenson, MD

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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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α1(I) FLPQPPQEKSQDGGRYY (C-
α2(I) QYSDKGVSSGPGPMGLM (N-
Non-Glycated Helical Lysines
Sequence