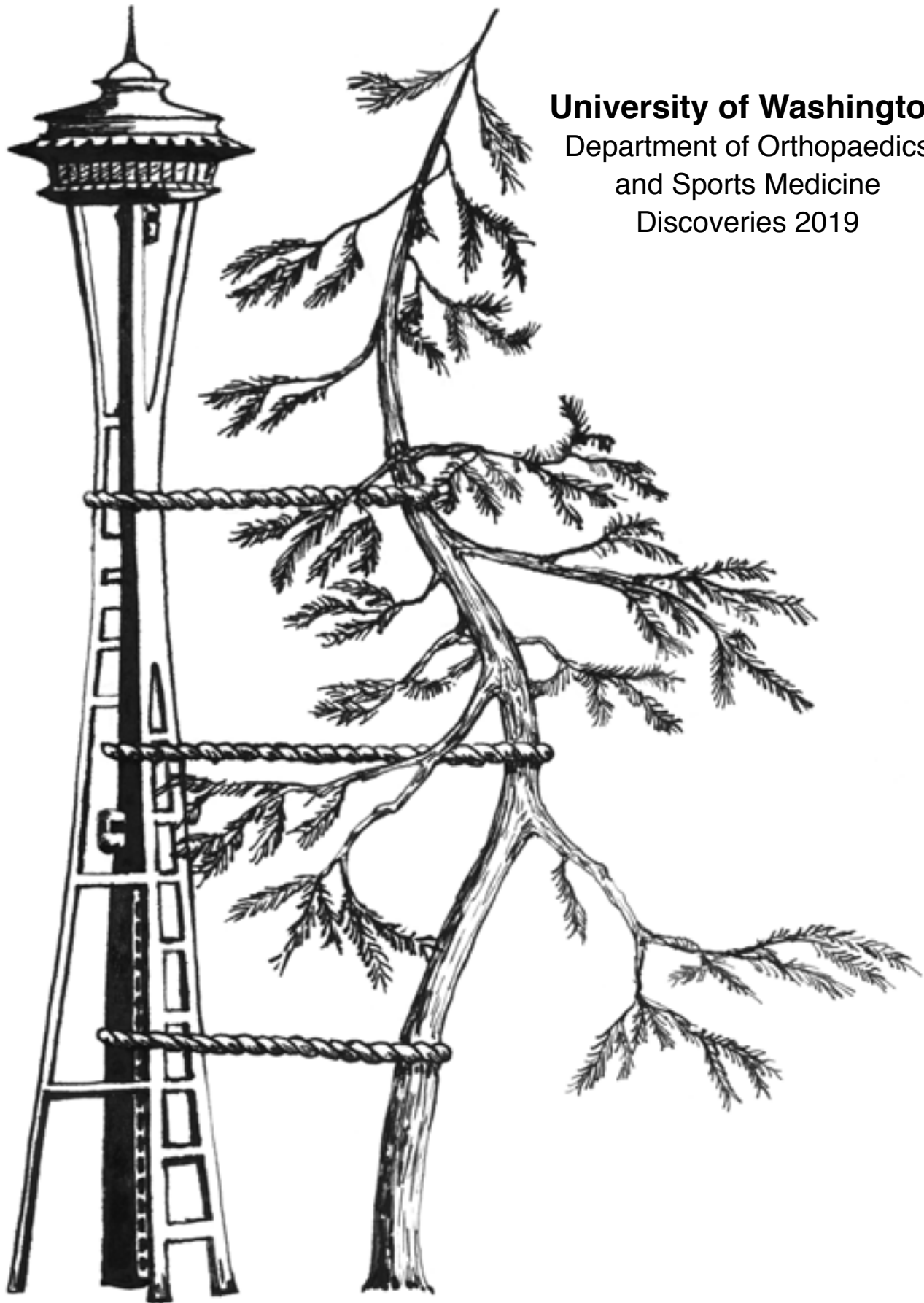


DISCOVERIES 2019

University of Washington Orthopaedics & Sports Medicine





University of Washington
Department of Orthopaedics
and Sports Medicine
Discoveries 2019

UW Medicine
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Front Cover Illustration: Cherry Blossoms on the Quad during Spring of 2017
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Foreword

Once again it is my privilege to present to you another excellent edition of our annual Discoveries departmental report. All of the credit for this annual summary of the Department goes to the contributors as well as to the Managing Editor Fred

rule”) that organizations and journals are placing on prior publication of even data that is labeled as preliminary, moving forward the emphasis of our Discoveries report will shift. While no longer publishing preliminary data or unpublished mature data, we will focus

on site and faculty updates as well as summaries of our research that has already been published or presented at national meetings. In future editions we also expect to summarize our clinical activity and clinical programs.

In this edition, in addition to updates on clinical and basic research, you will learn of the most recent developments at each of our hospitals, as well as a summary of the state of our residency from Dr. Chris Kweon and Dr. Doug Hanel.

As with any year in a large organization, we have had several new hires this year as well as the “formal” retirement of some of our critical long-standing faculty. Dr. Ted Wagner, after a long and illustrious career at Swedish Hospital, joined our Department in 2004 and after 15 years with us recently announced his retirement from his practice at the University of Washington Medical Center and the Bone and Joint Clinic. Dr. Wagner had previously stepped down from his practice at Seattle Children’s Hospital. During his time with UW Medicine, Dr. Wagner won a prestigious Resident Teaching Award and mentored some of our less experienced spine surgeons in the nuances of complex spine surgery.



Dr. Howard Chansky and Dr. Ted Wagner

Westerberg, and the three co-editors Drs. Chris Allan, Steve Kennedy and Will Lack.

When Discoveries was initiated by our former chair, Dr. Rick Matsen in 1991, it was in essence a local yearbook that summarized the clinical, operations and research activity of the department. Over the years it has evolved into a publication that is widely disseminated, available to both patients and the public, via the internet. No doubt that when posted on our departmental website, Discoveries is also indexed by the various ‘site crawlers’ such as those of Google. While “open publication” has many positives, it also brings to the fore difficult issues such as redundant publication and more importantly, the potential for others, including patients, to (mis)interpret and even act on preliminary results or results that have not undergone formal peer-review.

For these reasons and due to the increasing restrictions (the “Ingelfinger



Dr. David Eyre and his wife Sue Eyre



Dr. Jennifer Bauer, Dr. Ted Wagner, and Dr. Walter Kregel

Dr. Wagner has been an energetic proponent of international educational exchange and surgical collaboration. For decades he cared for Indonesian patients with spinal deformities, at times taking UW orthopaedic residents on these trips. He also trained several generations of Indonesian spine surgeons. Dr. Wagner has been doing similar educational exchange programs in Nepal and in 2015 joined a group named Clarion Global Response to set up a field hospital in Nepal after the devastating earthquake there. In recognition of his volunteer work overseas, Dr. Wagner was recently

announced as the 2019 recipient of the Blount International Humanitarian award from the Scoliosis Research Society. We had a well-attended and emotional farewell and celebration of Ted's career this April at the UW Waterfront Activities Center.

Also celebrated in April at the Waterfront Activities Center was the career of Dr. David Eyre who also announced his retirement this year. Dr. Eyre was recruited to the Department by Dr. Matsen in 1985. Dr. Eyre left Harvard to become our first holder of the Burgess Endowed Chair for Orthopaedic Investigation. David

focused his efforts on the biology of collagen and genetic disorders of the skeleton. His work has led to a better understanding of skeletal development as well as diseases of bone and cartilage. His work has had an impact on healthcare including the development of the Osteomark® NTx test that can measure activity and response to therapy in diseases such as metastatic cancer, Paget's disease and osteoporosis. Dr. Eyre holds over 50 patents, has received decades of continuous NIH funding and is a fellow in the American Academy for the Advancement of Science. In 2015 he was the UW Medicine Inventor of the Year, a remarkable achievement. Perhaps most importantly, David has always been generous with his time and has been a mentor to several generations of scientists and academic clinicians. He will be missed and it is hard to envision replacing him. It will be impossible for anyone to duplicate his sustained world-renowned excellence over three plus decades of work.

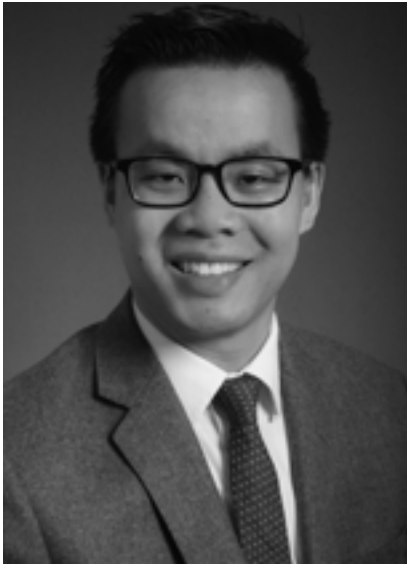
I am certain that with our team of dedicated editors and the continued enthusiasm of the faculty to contribute to Discoveries, you will find this and future editions to be every bit as informative and compelling as previous editions. Please do not hesitate to reach out to myself, Fred Westerberg, or any of the co-editors with questions and suggestions.



Dr. David Eyre and Dr. Ted Wagner

Howard A. Chansky, MD
Professor and Chair

New Faculty



Kenneth Chin, MD

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Kenneth Chin, MD is an orthopaedic surgeon who specializes in Foot & Ankle surgery and Sports Medicine at the University of Washington Medical Center and Northwest Hospital. He is a Clinical Assistant Professor in the Department of Orthopaedics and Sports Medicine. His area of focus is on minimally invasive and traditional surgeries of the ankle, foot, and knee, with a particular interest in the treatment of athletic ankle injuries.

Dr. Chin graduated from Case Western Reserve University School of Medicine in Cleveland, Ohio, which was followed by a residency in Orthopaedic Surgery at the University of Maryland/R. Adams Cowley Shock Trauma Center in Baltimore, Maryland. After residency, he completed two subspecialty fellowships in Foot & Ankle surgery at Mercy Medical Center and Sports Medicine at the University of Maryland.

Dr. Chin is an active member of the American Academy of Orthopaedic Surgeons and the American Orthopaedic Foot and Ankle Society.

He describes his patient care philosophy: "When patients come to see me, I believe in the utmost importance of taking the time to sit down with them and listen closely to their concerns. I strive to tailor treatment plans to the individual, whether that entails a surgical procedure or a more conservative approach. It is my strong belief there is no "one size fits all" approach when it comes to providing the best care for a patient."

In his free time, Dr. Chin enjoys mountain biking, skiing, and spending time with his wife, daughter, and chocolate lab Coco.



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Jared L. Harwood, MD, MBA, is an Assistant Professor in the Department of Orthopaedics and Sports Medicine. Dr. Harwood earned his MD from Georgetown University School of Medicine and completed his Orthopaedic Surgery residency and MBA at The Ohio State University.

Dr. Harwood specializes in the evaluation and treatment of bone and soft tissue tumors of the extremities and pelvis and is well versed in general Orthopaedic care. He believes that success in medicine can only be achieved through a partnership between patient and physician.

His clinical interests include limb-sparing tumor resections and reconstructions, targeted muscle re-innervation, prophylactic treatment of metastatic disease, and revision joint replacement.

His research interests include efficiency and sustainability of healthcare, opioid stewardship, process improvement, mentorship/leadership, communication, and outcomes in the treatment of metastatic disease.

"I believe that success in medicine can only be achieved through a partnership between patient and physician. I bring my knowledge, experience, and skills to the table but the patient's faith, hope, and desires also play an important role. My mother and wife are both nurses. They have taught me by example that people don't care how much you know, until they know how much you care. Serving my patients is what makes my profession enjoyable. No one comes to clinic or the operating room because they want to, but helping them through this difficult phase of life is a unique privilege."

New Faculty



William D. Lack, MD

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Dr. Lack is a specialist in orthopaedic trauma surgery with an interest in joint arthroplasty. He is an Assistant Professor in the Department of Orthopaedics and Sports Medicine practicing at Northwest Hospital and the VA Puget Sound Healthcare System.

Dr. Lack earned his bachelor's degree in biomedical engineering from the University of Iowa and his MD from Harvard Medical School in Boston. He completed his orthopaedic surgery residency at the University of Iowa. Afterwards, he completed a fellowship in orthopaedic trauma at Carolinas Medical Center.

For the first five years of his career, before joining the University of Washington, he developed his skills at Loyola University Medical Center just outside Chicago, becoming board certified during that time. At Loyola, he served as the director of clinical research in the orthopaedic department. He has published original research such as "Effect of Tranexamic Acid on Transfusion: A Randomized Clinical Trial in Acetabular Fracture Surgery", "Distal Nail Target and Alignment of Distal Tibia Fractures", and "Long Bone Union Accurately Predicted by Cortical Bridging within 4 Months".

Dr. Lack describes his patient care philosophy as follows: "I became a physician to serve those in need and I enjoy spending time answering questions and explaining treatment options. As an orthopaedic surgeon I believe it is best to make shared decisions with patients. By doing so, we can optimize care around a given patient's specific clinical problem and unique personal goals."



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Viral R. Patel, MD joined our department in 2018. He is an Acting Instructor here at the University of Washington Department of Orthopedics and Sports Medicine. His expertise lies in degenerative spine pathology, adult and pediatric spine deformity, and minimal invasive spine surgery.

Dr. Patel received his medical education at BJ Medical College, Gujarat University in Ahmedabad, India. Upon completion of his medical degree and residency, he joined their faculty serving as an Assistant Professor before joining the orthopaedic department of Baroda Medical College in the same capacity. In 2013, he left for the United States, joining the University of Washington to complete a spine surgery fellowship in our department. Afterwards, he completed two pediatric orthopaedic fellowships – one at Louisiana State University and another at University of Minnesota. And he completed another spine surgery fellowship, this time at the Twin Cities Spine Center from August 2017 to July 2018.

Dr. Patel has given presentations on the pathoanatomy of tuberculosis of the spine, spinal instrumentation in tuberculosis of the spine, multidrug resistance of tuberculosis of the spine, as well as postoperative deep wound infections. His research projects include results of spinal instrumentation in tuberculosis of spine, results of lumbopelvic fixation of sacral fracture with spinopelvic dissociation, and a comparison of radiologic outcomes in patients with adolescent idiopathic scoliosis using conventional rod contouring vs. preoperative surgical mapping and patient specific rods.

New Faculty



Florence Unno, MD

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Florence Unno, MD joined the UW as an Acting Assistant Professor on January 1, 2019. She is based at Northwest Hospital and specializes in fracture surgery. Dr. Unno received her undergraduate education from the Sorbonne University in Paris, France and her graduate degree from Institut d'Etudes Politiques de Paris (aka Sciences Po). Her medical degree is from the University of Geneva Medical School in Switzerland. After completing her orthopaedic surgery residency at the Geneva University Hospital, she practiced as a junior attending surgeon at the Bellinzona Hospital in Ticino, Switzerland. Given her special interest in trauma and fracture surgery, she completed a year-long fellowship in orthopaedic traumatology at the University of British Columbia in Vancouver. She sought further experience as an AO Trauma Fellow at Sunnybrook Hospital, Toronto, Canada and as a Visiting Scientist in our trauma department at Harborview. More recently, she completed a fellowship with Dr. Keith Mayo focusing on hip preservation, at the Hansjörg Wyss Hip and Pelvis Center, Swedish Medical Group. She has been active in the trauma community as faculty with AO Switzerland and now with AO North America.

Dr. Unno is active with IGOT (The Institute for Global Orthopaedics and Traumatology), an organization whose goal is to promote and train local surgeons in developing countries through teaching and research.

Her current research projects include studies involving understanding the difference between different radiographic views on the morphology of the acetabulum, and a series of diverse anatomic studies of hip anatomy.



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Haitao Zhou, MD is an orthopaedic physician and a faculty member of the Department of Orthopaedics and Sports Medicine. He is based at Harborview Medical Center and specializes in spinal surgery.

Dr. Haitao Zhou earned his Bachelor of Medicine in Beijing, China in 1995. He completed his internship and his residency at Beijing Medical University Third Hospital. He was an attending in spine surgery at the Department of Orthopaedic Surgery, Peking University Third Hospital, Beijing, China. In 2005, he joined the Medical College of Georgia as a postdoctoral fellow, where he later completed his American orthopaedic residency. In 2015, he started fellowship training in spinal surgery at Harborview Medical Center. Afterwards, he joined our department as Acting Instructor before being promoted to Assistant Professor.

His published work includes articles such as "Cable-Strengthened C2 Pedicle Screw Fixation in the Treatment of Congenital C2-3 Fusion, Atlas Occipitalization, and Atlantoaxial Dislocation", "Does atlantoaxial dislocation influence the subaxial cervical spine?", and "Novel Surgical Classification and Treatment Strategy for Atlantoaxial Dislocations".

In the future, he will continue to research new methods for surgical intervention for adult orthopaedic deformities. When it comes to his patients, Dr. Haitao Zhou values open communication. "I believe all patients should be treated by their doctors as if they were a family member. I believe that spending time communicating to the patient can solve more issues than we thought."

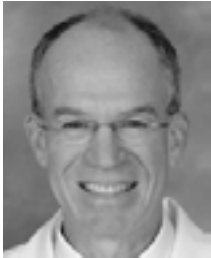
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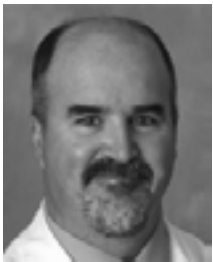
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Acting Instructor

Claire Watson, PhD

Visiting Lecturers

2019 LeCocq Lectureship

April 25-26, 2019



(Left to right) Carlo Bellabarba, MD, Paul A. Anderson, MD, Stephen K. Benirschke, MD, and Howard Chansky, MD

We were happy to host Dr. Paul A. Anderson as our guest lecturer for the 2019 LeCocq Lectureship. On Thursday April 25th, he gave a presentation on “The Use of 3D Printing in Orthopaedic Surgery.” At the 55th Annual John F. LeCocq Dinner that evening, he gave the featured lecture on “Quality Improvement: A Call to Arms.” The following day he gave his final talk “Bone Health Optimization for the Orthopaedic Surgeon”.

Dr. Anderson is a board-certified orthopaedic spine surgeon with special interest in spine trauma, tumors, cervical spine, and geriatric spinal diseases. He is an internationally recognized expert in the field of orthopaedic spinal surgery and currently holds academic positions as Professor of Orthopedic Surgery and Adjunct Professor in Neurological Surgery and Biomedical Engineering at the University of Wisconsin. Previously he was an Associate Professor of Orthopedic Surgery at the University of Washington and also worked in private practice in Seattle. He has served as President of the Cervical Spine Research Society and President of the Lumbar Spine Research Society and has held various positions in a number of spinal and orthopaedic societies. He has served as a member as well as Chairman of the AAOS Biomedical Engineering Committee, Co-Chair of ASTM 04.25, and Clinical Chair of ASTM F04. Most recently, he chairs the “Own the Bone” Steering Committee of the American Orthopaedic Association which aims to educate medical practitioners and patients on the importance of bone health and promote fracture liaison services. Dr. Anderson earned his undergraduate and Master’s degrees from The University of Michigan in Chemical Engineering. He completed medical school and orthopaedic residency at Wayne State University and a clinical spine fellowship with Dr. Henry H. Bohlman (Case Western Reserve University, Cleveland).



Visiting Lecturers

2019 Resident Research Day

June 21, 2019

On June 21, 2019 we were happy to host Dr. William Levine as the guest lecturer for our Resident Research Day. Held in conjunction with our Resident Graduation, Dr. Levine lectured on “Surgical Education in 2019 – It’s not as easy as it used to be” and “One size does not fit all – Use the right prosthesis for the right pathology!”

William N. Levine, MD is a nationally and globally renowned specialist in arthroscopic and open shoulder, elbow, and knee surgery, and sports medicine. He is Chair of the Department of Orthopedic Surgery at Columbia University’s College of Physicians and Surgeons, where he holds the Frank E. Stinchfield Professorship in Orthopedic Surgery, and serves as Chief of the Orthopedics Service at New York-Presbyterian/Columbia University Medical Center. Dr. Levine previously served the Department as Vice Chairman for Education, Residency and Fellowship Director, Chief of the Shoulder Service, and Co-Director of the Center for Shoulder, Elbow and Sports Medicine.

As Head Team Physician for Columbia University, Dr. Levine is responsible for providing care for 31 Columbia intercollegiate athletic teams. Under his guidance, the department’s surgeons also function as Team Physicians for the New York Yankees, Major League Soccer’s (MLS) New York City Football Club, the Rockland Boulders, Fordham University, City College of New York, as well as over 25 high schools. Dr. Levine is a consultant for the National Hockey League Players’ Association and chairs the Shoulder and Elbow subcommittee for the National Football League. As a former teaching tennis professional and the starting goalie for Stanford University’s club hockey team, Dr. Levine is passionate about sports medicine and dedicated to patient care. He has been named a “Top Doctor in Sports Medicine” by Castle



Connolly and New York Magazine, and one of the top 25 shoulder surgeons in the United States by Orthopedics This Week.

Dr. Levine is a past member of the Executive Committee of the American Orthopedic Association, the world’s first orthopedic association and the organization that was primarily responsible for the development of orthopedics as a discipline separate from general surgery. He also served on the Board of Directors of the American Board of Orthopedic Surgery, the governing body that oversees licensure and training of orthopedic surgeons. Dr. Levine assumed the role as Editor-in-Chief for the Journal of the American Academy of Orthopedic Surgeons in January 2016. He also received the prestigious American Shoulder and Elbow Surgeon’s Traveling Fellowship. Dr. Levine is a member of all the field’s major professional societies, including the American Orthopaedic Society for Sports Medicine, and the Herodicus Society. He has made substantial contributions to research, having published more than 150 peer-reviewed articles, written over 50 book chapters, edited 11 textbooks, and given over 200 scientific presentations in the United States and abroad. He holds multiple patents and research grants.

A native of Fargo, North Dakota, he received a BA in Human Biology from Stanford and his Doctor of Medicine degree from Case Western Reserve. He was a resident in orthopedic surgery at New England Medical Center, and held fellowships at Columbia-Presbyterian Medical Center in Shoulder Surgery and the University of Maryland in Sports Medicine. He joined Columbia’s Department of Orthopedic Surgery in 1998, became Residency Director in 2002, and in 2006 was awarded the Charles S. Neer, MD Teacher of the Year Award for his enthusiasm, passion and dedication to resident education. He lives in Manhattan with his wife and two daughters.

Foot Function in Identical and Non-Identical Twins

Scott Telfer, EngD, Joseph J. Bigham, and Amanda S.M. Sudduth

Introduction

Determining genetic and environmental risk factors for musculoskeletal conditions is challenging due to the large number of factors that could potentially play a role. Twins and twin study designs have the powerful advantage that they inherently control for the effects of genetics and, at least to some extent, environment during childhood and adolescence. These types of studies present a unique opportunity to investigate the influence of different external factors on the development of musculoskeletal disorders (Goldberg et al., 2005), and have successfully provided insights into a number of conditions.

There is little information in the literature about how similar foot function is between co-twins. In this study, we aimed to determine the levels of variability in foot function, measured as the forces under the feet (plantar pressures), between identical and non-identical twins. We hypothesized that the foot function of identical twins would display more similar pressures than non-identical twins. If plantar pressures for paired feet from identical twins are found to be more similar than non-identical twins, it may provide a clear path to investigate biomechanical risk factors for the development of foot and ankle disorders using twin study designs.

Methods

This research was approved by the University of Washington Institutional Review Board and all participants provided written, informed consent. Twin pairs were recruited from the Washington State Twin Registry. Potential participants were considered ineligible for inclusion if they had a recent (<1 year) lower limb surgery, or a neurological, metabolic, or musculoskeletal condition considered likely to impair ambulation. Twin pairs were also required to be the same sex and BMI (within 3 kg/m²).

Participants attended a single laboratory visit during which they underwent a clinical and biomechanical

assessment. Demographic details were recorded, then participants underwent a barefoot plantar pressure assessment using a plantar pressure measurement plate. First, they were asked to stand on the plate in a relaxed pose, feet shoulder width apart, looking straight ahead, and with their weight equally distributed across both feet. Plantar pressures under both feet were recorded for 30 seconds. Following this, a dynamic assessment was performed where the participants were instructed to walk over the pressure plate, and 10 steps were recorded for each foot.

Data processing and analysis

For the static and dynamic trials, an average trial was generated for each foot by aligning the ten collected trials using a linear translational and rotational process and averaging the results for each timepoint at the pixel (individual sensor) level. Once this was complete, the average trials for each foot were aligned across all feet using the same process, with additional degrees of freedom added to this registration phase to allow scaling of the pressure image, allowing different sizes of feet to be registered. This provided 40 dynamic pressure datasets (one for each foot) that were spatially aligned.

Statistical parametric mapping (SPM), (Patady and Goulermas, 2008) was performed to determine the z-statistic across the measurements at the sensor level at each timepoint for both the identical and non-identical twin groups. A paired analysis was used with each individual acting as the comparator for their co-twin, i.e., for each twin pair, the right foot of twin A was compared to the right foot of twin B.

Results

Five pairs of identical and five pairs of non-identical twins were recruited (20 individuals / 40 feet total). Overall, results from the statistical parametric modeling analysis showed that identical co-twins had lower variability between their dynamic pressure distributions. For ease of visualization, Figure 1 presents mean z-statistic results at the sensor level for the dynamic trials for

each 20% of stance phase. Similarly, for the static measurements, variation was found to be lower in the monozygotic pairs than the dizygotic pairs, with mean z-statistics of 1.15 and 1.26 respectively.

Discussion

This study found that plantar pressure measurements of twin pairs showed greater similarities for monozygotic twins compared to dizygotic twins. Previous work on twins and musculoskeletal disorders has focused on estimating the heritability (the role of genetics) of different conditions. Here, our primary aim was to determine the biomechanical similarities in foot function between different types of twins, and we showed that identical twins had less variation in static and dynamic pressure distributions than non-identical twins.

We used plantar pressure measurements to assess foot function in the study participants. This has been shown to provide a range of insights into foot biomechanics (Telfer and Bigham, 2019), however other techniques, for example, multisegment foot models for kinematic and kinetic analyses (Al-Munajjed et al., 2016), could provide further information on differences in foot function and may be explored in the future.

The mechanism by which monozygotic twins develop similar plantar pressures is almost certainly primarily genetic in origin. There is existing evidence in the literature of genes that are strongly associated with musculoskeletal factors such as power generation in athletic performance, bone density, and shape. Further research is required to identify if particular genes are associated with foot function.

Little attention has been paid to the role of biomechanics in twin studies that have investigated risk factors for musculoskeletal conditions. The present study provides strong evidence that levels of similarity in foot function varies between twin types, supporting the use of twin study designs to help

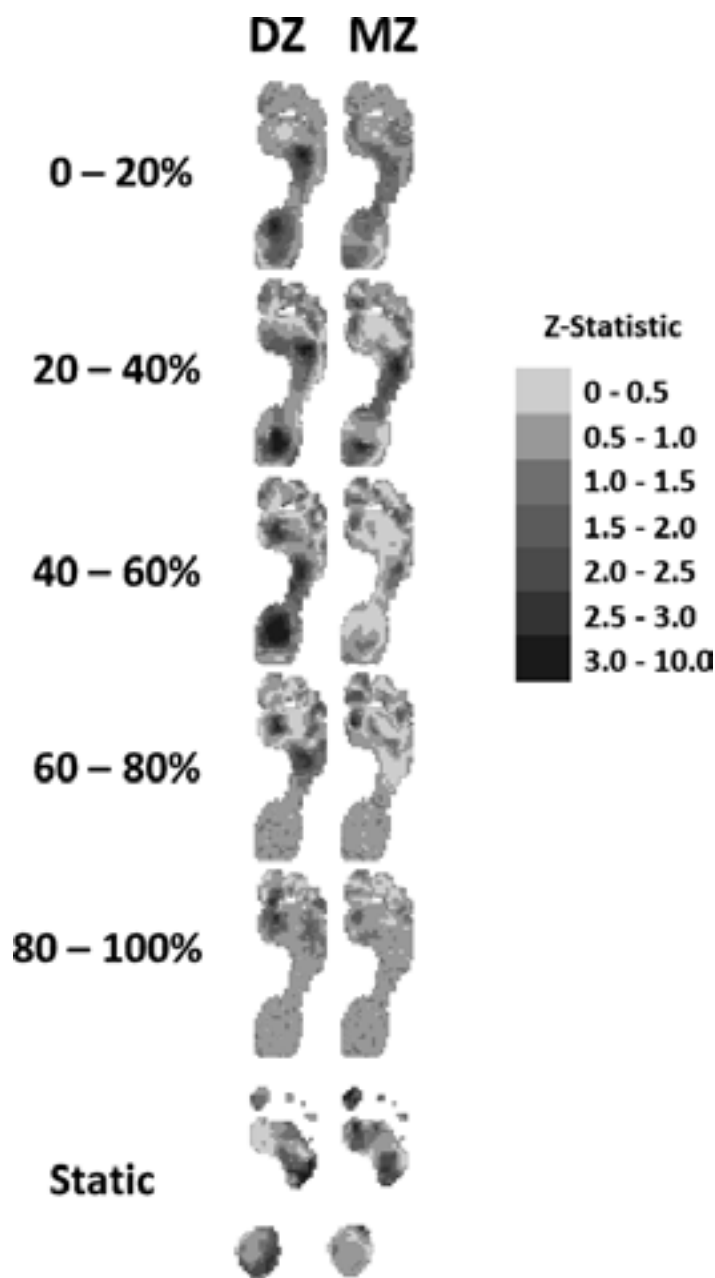


Figure 1: Visualizations of sensor level z-statistics for twin groups. Each row represents 20% of stance phase. DZ: Dizygotic group; MZ: monozygotic group.

identify biomechanical risk factors for musculoskeletal injury and disease.

Acknowledgements

The authors would like to acknowledge the Washington State Twin Registry (<https://wstwinregistry.org/>) for their support.

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Bacteria and Shoulder Joint Replacement

Frederick A. Matsen III, MD

It is now well recognized that Cutibacterium (Propionibacterium) are the most common organisms cultured from deep tissue and explant specimens harvested at the surgical revision of a failed arthroplasty, especially in those cases revised for pain and stiffness without clinical evidence of inflammation.

It is also well recognized that the most likely source of these organisms is the sebaceous glands and hair follicles of the skin that is incised when a shoulder replacement is performed, particularly in young, healthy male patients.

Finally, it is generally accepted that the usual surgical skin preparation and preoperative antibiotics are ineffective in lowering the amount of these organisms in the skin and in reducing the risk of Cutibacterium entering the wound at surgery.

Several questions remain unanswered.

(1) Why do Cutibacterium cause problems in some shoulders but not in others?

(2) Why does it often take months or years before the symptoms related to the Cutibacterium become evident?

(3) What can be done to prevent clinical problems associated with the presence of Cutibacterium in shoulder arthroplasty?

(4) How can the presence of Cutibacterium in a failed arthroplasty be diagnosed while the patient is still in operating room (i.e. in time to adjust the surgical plan accordingly)?

(5) What is the best medical and surgical treatment for a failed shoulder arthroplasty?

We've asked orthopaedist/artist Steve Lippitt to help us shed some light on some of these unknowns.

Most shoulder implants have bodies made of titanium, a metal that can provide a foundation for a biofilm (a film on the metal that includes bacteria, proteins, and carbohydrates) (Figure 1).

Cutibacterium prefer a "low oxygen" or anaerobic environment, such as that found on the inside of the humerus

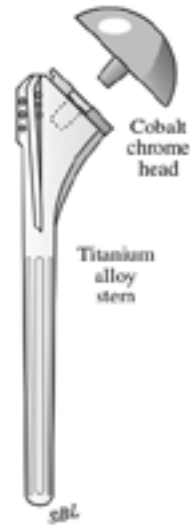


Figure 1: Shoulder Implant



Figure 4: Body's defense system



Figure 2: Inside of the humerus

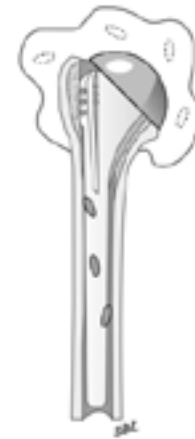


Figure 5: Inside of the Humerus plus a titanium implant body

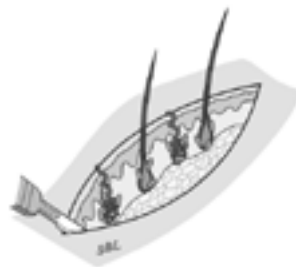


Figure 3: Surgical skin incision

(Figure 2).

Cutibacterium can enter the wound at the time of the surgical skin incision (Figure 3).

Those bacteria that enter the joint are free floating or "planktonic". Because the joint has a rich blood supply, these are usually cleaned up by the body's defense system in the oxygen-rich environment (Figure 4).

Despite all precautions, some Cutibacterium may find their way into the humeral canal where they find an attractive environment in which to form

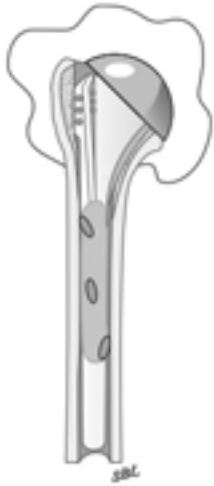


Figure 6: Semi-dormant state



Figure 7: Sleeping Beauty



Figure 8: Rip Van Winkle

a biofilm: the anaerobic inside of the humerus plus a titanium implant body (Figure 5).

Here the Cutibacterium in the biofilm enter a semi-dormant state of slow growth and great resistance to antibiotic therapy (Figure 6), reminding one of Sleeping Beauty (Figure 7) or Rip Van Winkle (Figure 8).

During this “honeymoon” period, the Cutibacteria in the biofilm can slowly multiply, but, because they do not have contact with the joint, symptoms of pain

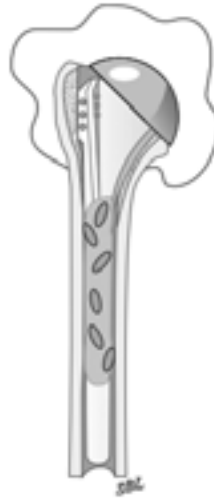


Figure 9: Multiplication of Cutibacteria

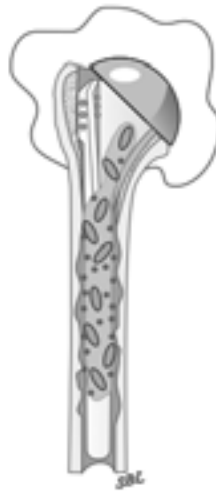


Figure 10: Further multiplication of Cutibacteria

and stiffness are not apparent (Figures 9 & 10).

After a period of months, years or even decades, some bone resorption can occur, releasing Cutibacterium into the joint where they can give rise to pain and stiffness without the usual characteristics of inflammation. Because the number of bacteria in the joint are small, the chance of recovering them with a joint aspiration is low. Instead, identifying these bacteria requires culturing deep tissue specimens and the implants removed at revision surgery (Figure 11).

In some cases, bone resorption takes place to the extent that the



Figure 11: Identifying bacteria requires culturing deep tissue specimens and the implants removed at revision surgery

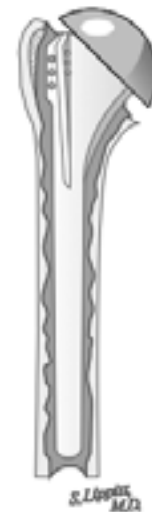


Figure 12: Bone resorption

humeral component can become loose (Figures 12, 13, and 14).

The story above may seem like a “fairy tale” and is not yet robustly supported by sound research. However, this model suggests possible answers to some of our questions:

(1) Why do Cutibacterium cause problems in some shoulders but not in others? Some patients (female patients and older males) may have low levels of Cutibacterium in their sebaceous glands. Some patients may be better than others in terms of “cleaning up” bacteria introduced at surgery.

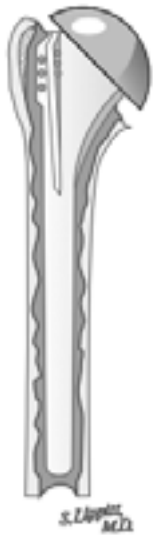


Figure 13: Bone resorption



Figure 14: Bone resorption

(2) Why does it often take months or years before the symptoms related to the *Cutibacterium* become evident? Bacteria in biofilms grow very slowly, taking a long interval between the time of the index surgery and the time that the patient presents to the surgeon with a painful stiff joint.

(3) What can be done to prevent clinical problems associated with the presence of *Cutibacterium* in shoulder arthroplasty? Our best guess at this point is copious irrigation of the wound,

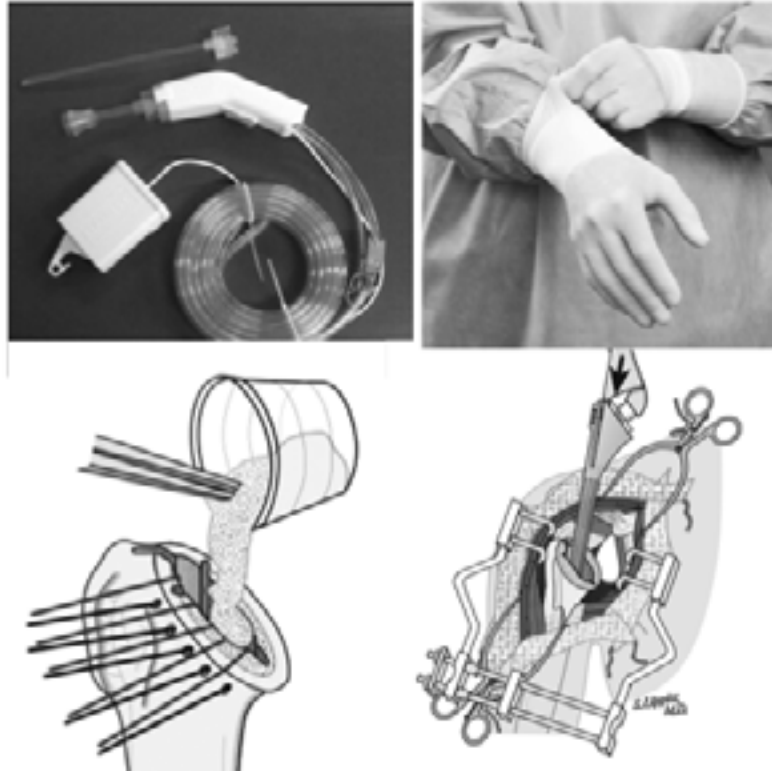


Figure 15: Irrigation of the wound, use of new gloves when handling the implant, placing antibiotics in the humeral canal prior to the placement of the prosthesis, and avoiding contact of the prosthesis with the skin edge

use of new gloves when handling the implant, placing antibiotics in the humeral canal prior to the placement of the prosthesis, and avoiding contact of the prosthesis with the skin edge (Figure 15).

(4) How can the presence of *Cutibacterium* in a failed arthroplasty be diagnosed while the patient is still in operating room (i.e. in time to adjust the surgical plan accordingly)? The best we have so far is to seek preoperative and intraoperative clues: young, lean, male patients, exogenous testosterone, a “honeymoon” period with the onset of symptoms without other explanation, and the intraoperative finding of synovitis. Tests of blood or joint fluid can be helpful when inflammation is present, but are less useful in the usual “stealth” presentation of *Cutibacterium*.

(5) What is the best medical and surgical treatment for a failed shoulder arthroplasty? Our preference is to manage suspicious cases with a primary prosthesis exchange and immediate intravenous antibiotics that are continued until multiple tissue and explant cultures have been observed

for three weeks. The story above needs to be tested by many observations of many cases by many observers. It should be considered a “rough draft” ripe for editing and revision based on good clinical research.

Notes

A version of this article can be found online: <http://shoulderarthritis.blogspot.com/2019/03/cutibacterium-and-shoulder-joint.html>

Non-Enzymatic Glycation of Collagen is Not Random but Highly Site-Specific

David M. Hudson, PhD, Marilyn J. Archer, BS, and David R. Eyre, PhD

Introduction

The stochastic addition of sugar molecules to collagen, a process called protein glycation, is thought to contribute to musculoskeletal complications that are commonly associated with aging and diabetes, such as limited joint mobility, increased risk of injury and the impaired ability to heal [1]. How exactly such random glycation result in impaired tissues is still poorly understood. Because of the slow turnover rate of most fibrillar collagens, they are more susceptible to accumulate glycation and subsequent advanced glycation end-product (AGE) cross-links. Among the many known cross-links in fibrillar collagens, perhaps the least understood but most speculative pathologically are the AGE cross-links. Normal enzymatic lysyl oxidase-mediated cross-links between individual collagen molecules in a fibril are essential for the strength and integrity of tendons and most musculoskeletal tissues. On the other hand, non-enzymatic glycation is thought to arbitrarily accumulate on aging tissue collagens with the potential to form abnormal intermolecular cross-links, which are believed to contribute to tissue stiffening and fragility. Identification of AGE cross-links in collagen has been impeded by the highly repetitive structure of the helical domain from the type I collagen molecule. Consequently, AGEs have only been detected in collagens using whole tissue hydrolysates. Despite decades of research and thousands of publications on AGEs, experimental evidence for any specific molecular sites of glycation in collagen has been limited. Using targeted mass spectrometry, we recently identified elevated fructosyl-hydroxylysine glycation at each of the helical domain cross-linking sites of type I collagen from diabetic mouse tendon [2]. Here we expand on our previous research and reveal that these non-enzymatic protein glycation are not stochastic in nature, as previously thought, but have

Rat tail tendon collagen extractability

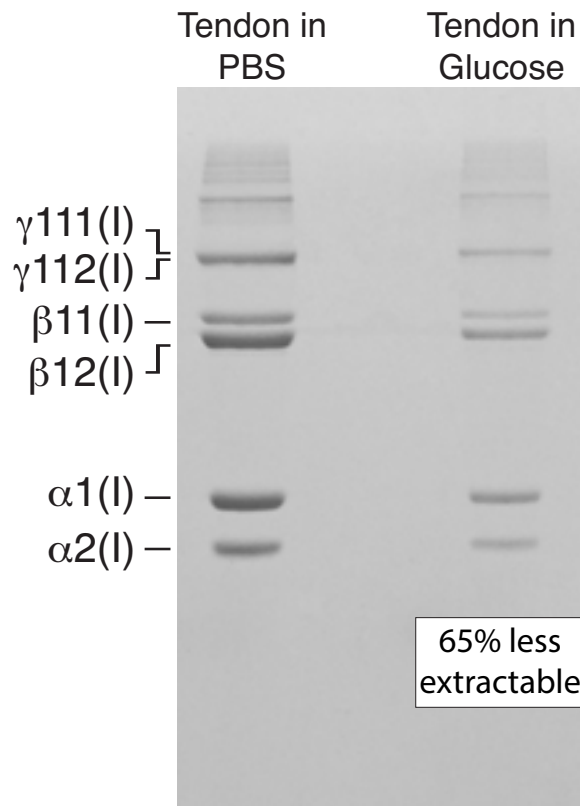


Figure 1: Collagen extractability is reduced in rat tail tendon after in vitro glycation. Rat tail tendon was incubated with and without 25 mM D-glucose in PBS at 37°C for 30 days. Densitometry of collagen α -chains from a stained 6% SDS-PAGE revealed that total collagen (normalized to dry weight) from rat tail tendon was 65% less extractable after in vitro glycation with reducing sugar (D-glucose) compared to incubation in PBS.

site-specific targets in type I collagen.

Methods

Animal tendons: Adult laboratory rats (*Rattus norvegicus domesticus*) were obtained from previously published studies.

Sugar incubation: Whole rat tendons (50 mg/mL) were incubated *in vitro* with reducing sugar (e.g. 25 mM D-glucose or 50 mM isotopic D-($^{13}\text{C}_6$) glucose) in 50 mM PBS, pH 7.4 at 37°C.

Collagen isolation: Intact type I collagen was solubilised from rat tail tendons by acid extraction in 3% acetic acid for 24h at 4°C and heat denaturation for 2 minutes at 100°C in Laemmli buffer.

Mass spectral analysis:

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

Results

Sugar incubations of whole rat tail tendon were performed to establish a rapid in vitro glycation system for collagenous tissues. Differences in type I collagen extractability between tendons incubated in PBS and PBS with D-glucose supported an effect by glucose on intermolecular cross-linking in tendon collagens. Densitometry of stained collagen chains (α , β , γ)

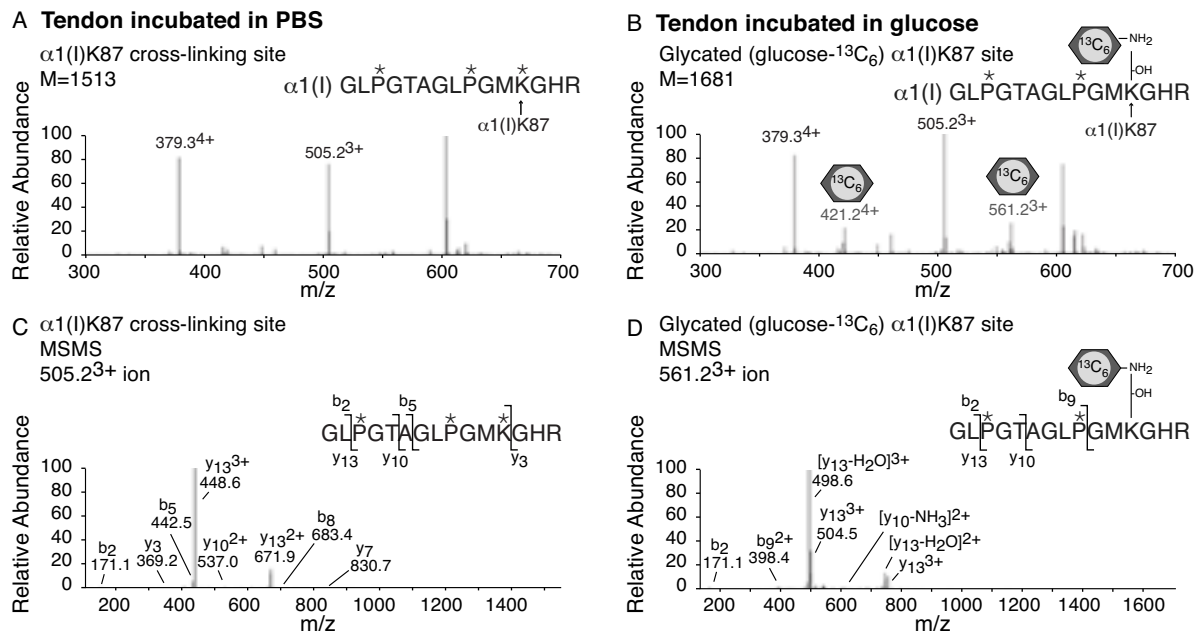


Figure 2: Site-specific glycation confirmed by *In vitro* incubation with $^{13}\text{C}_6$ -glucose. Rat tail tendon was incubated with and without 50 mM D- $(^{13}\text{C}_6)$ glucose in PBS at 37°C for 15 days. (A) LC-MS profiles of *in-gel* trypsin digestions of the helical cross-linking lysine $\alpha 1(\text{I})\text{K87}$ tryptic peptide after PBS incubation. (B) A distinct +168Da mass addition on $\alpha 1(\text{I})\text{K87}$ was present after D- $(^{13}\text{C}_6)$ glucose incubation (20%). (C, D) MS/MS was used to fingerprint these peptides. Hexagon indicates $^{13}\text{C}_6$ -fructosyl; K* indicates Hyl; P* indicates 4Hyp.

from SDS-PAGE with sample loads normalized to the dry weight of tendon revealed that total collagen was less extractable in rat tail tendons incubated with glucose (65% less) compared to control (Figure 1). This finding mimics our recently published results using tendon from the diabetic mouse, TallyHo, which exhibited up to 60% less type I collagen extractability compared to control mice [2]. Site specific glycation was unambiguously confirmed using isotopic D- $(^{13}\text{C}_6)$ glucose (Figure 2). Rat tail tendon was incubated with and without 50 mM D- $(^{13}\text{C}_6)$ glucose in PBS at 37°C for 15 days. Mass spectral analysis of trypsin-digested collagen peptides revealed the presence of site-specific glycation (+168Da) on the $\alpha 1(\text{I})\text{K87}$ helical domain cross-linking lysine residue (20%). *In-gel* trypsin digestion also confirmed a +168Da glycation addition on the $\alpha 2(\text{I})\text{K87}$ cross-linking residue after D- $(^{13}\text{C}_6)$ glucose incubation (data not shown). Glycations could not be detected in control tissues incubated in PBS.

Discussion

Although protein glycation is predicted to be stochastic in nature, we speculate that the cross-linking lysine residues are 'selectively glycosylated'

as a consequence of a preferred local consensus sequence. In fact, we have shown that the helical domain cross-linking sites of type I collagen are specifically targeted across multiple species (mouse, rat and human). These findings will facilitate the immediate application of targeted anti-glycating therapeutics against these newly identified sites of glycation. We have previously shown that site-specific glycation of lysines have the potential to significantly impair normal lysyl oxidase controlled cross-linking in diabetic tendons. The structural and mechanical properties of tendons depend heavily on lysyl oxidase-dependent collagen cross-linking. The prevalence of AGE cross-links in aging and diabetic tissue has been proposed to significantly alter the material properties of tendon. We propose that such N-linked glycation can hinder the normal cross-linking process, so altering the content and/or placement of mature cross-links with the potential to modify tissue material properties. We predict that in diabetic and aging tendon, site-specific collagen glycation 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 all the lysyl

oxidase-driven collagen cross-links associated with diabetes and aging.

Significance

Non-enzymatic glycation of collagen has long been associated with aging and the progressive secondary complications of diabetes. Identification of the primary sites of collagen glycation and their subsequent AGE products could help in the development of targeted therapeutics used to prevent the effects of aging and hyperglycemia in musculoskeletal tissue by preventing abnormal AGE cross-links from forming in collagen.

References

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Neuromuscular Dysfunction Modulates Trabecular Bone Homeostasis in Mice

Steven D. Bain, PhD, Phillipe Huber, BS, Brandon J. Ausk, PhD, Ronald Y. Kwon, PhD, Edith M. Gardiner, PhD, Sundar Srinivasan, PhD, and Ted S. Gross, PhD

Abstract

To clarify the effects of neuromuscular dysfunction on hindlimb loading, muscle atrophy, and bone homeostasis, we quantified changes to hindlimb loading, muscle atrophy, and bone morphology following either Botulinum toxin A (BTxA) induced muscle paralysis or peripheral nerve injury (PNI) in mice. Experimentally, BTxA-induced calf paralysis caused severe muscle atrophy, altered gait kinetics and kinematics, and reduced gait-induced normal strains. PNI increased mechanical allodynia but did not alter gait, nor did it cause muscle atrophy. Further, we observed that muscle paralysis and PNI both led to severe trabecular bone loss but only BTxA-induced paralysis increased cortical bone resorption. Thus, while mechanical stimuli clearly have essential functions in bone development and adaptation, these data emphasize that neuromuscular signaling, independent of load-induced mechanical strains, may modulate trabecular bone homeostasis in normal and disease states.

Introduction

The dependence of bone homeostasis upon normal muscle function is exemplified by the rapid escalation of bone resorption and resulting degradation of bone mass induced by a wide variety of muscle dysfunction pathologies [1-3]. As muscles enable locomotion and functional activity by application of force directly to the skeleton and conditions of muscle dysfunction are associated with diminished skeletal loading, gait-induced bone deformation has been presumed to be the primary means by which normal muscle function maintains bone health [4-8]. In practice, however, it has proven extremely challenging to clarify this relation, as models that alter muscle function (e.g., tenotomy, hindlimb suspension, and sciatic nerve injury) invariably alter gait-induced bone deformation and thus the

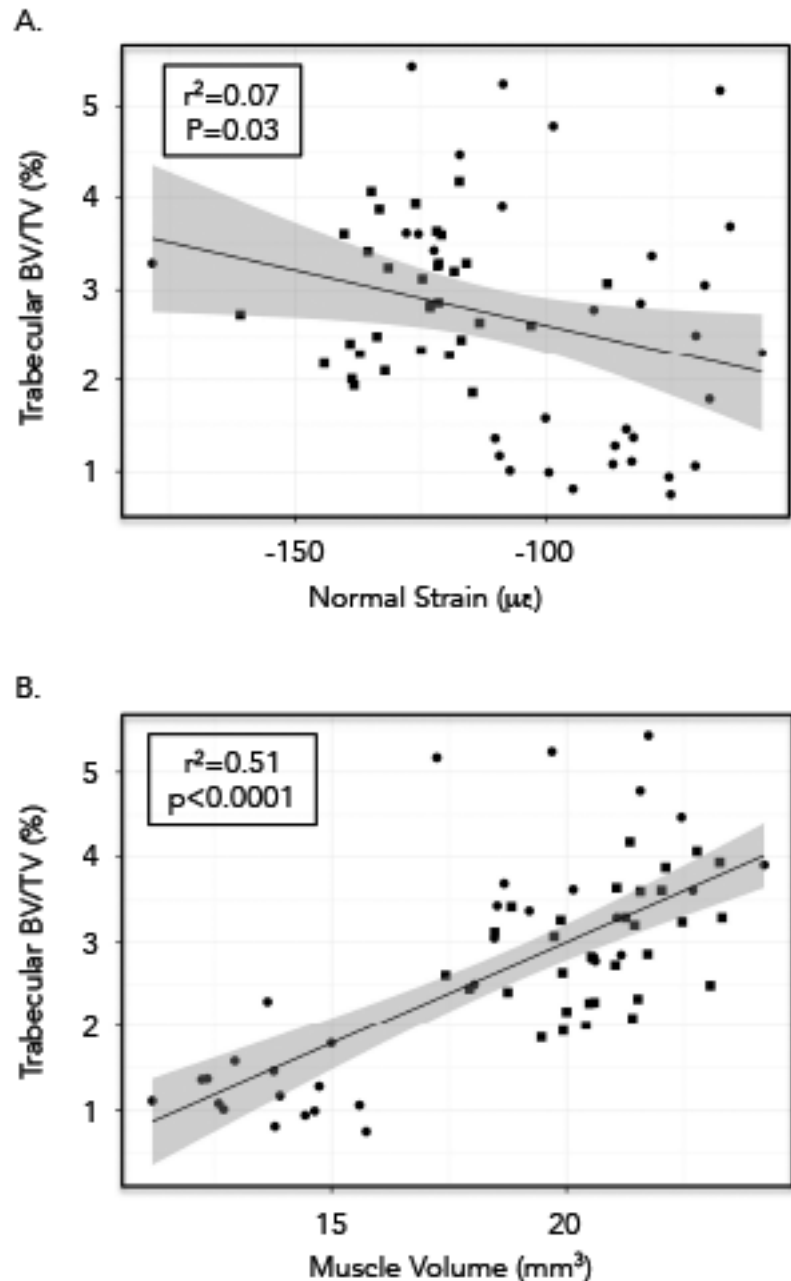


Figure 1: Regression of gait induced normal strain and lower limb muscle volume vs trabecular BV/TV across time points. While normal strain was significantly correlated proximal tibia BV/TV, it only predicted a small portion of the variance of the data (7%; A). In contrast, altered muscle volume predicted 51% of the variability of the BV/TV data (B).

mechanical environment of bone [9-12]. In this study, we therefore sought to clarify how neuromuscular dysfunction modulates trabecular and cortical bone homeostasis in mice by assessing gait kinetics and kinematics, muscle volume and bone morphology following BTxA-induced muscle paralysis or peripheral nerve injury (PNI). These *in vivo* models were selected due to the distinct yet overlapping challenges they impose on both hindlimb gait (BTxA-induced paralysis only) and neuromuscular function (BTxA-induced paralysis and PNI) [13, 14]. In contrast to the predominant literature in the field, we hypothesized that neuromuscular dysfunction, independent of gait-induced strains, would precipitate trabecular and cortical bone loss. To assess this hypothesis, we quantified peak vertical ground reaction forces (GRF) and ankle and knee kinematics during normal locomotion and used these data to estimate peak mid-diaphysis normal strains.

Materials and Methods

- Sixteen-week-old C57Bl/6 female mice were randomly assigned to undergo BTxA injection or PNI (n=8 per group). Prior to the intervention, all mice underwent activity monitoring to record locomotor activity, kinetic and kinematic assessment of gait, and microCT imaging. Data collection was repeated for each mouse on d 5, d 12 and d 28 post-intervention.
- All mice underwent activity monitoring in an open field testing apparatus and the total distance traveled (cm) and average speed (cm/sec) during a 2 hr period was determined for each mouse on d 0, d 5, d 12, and d 28.
- Gait kinetics and kinematics were assessed during free ambulation as each mouse repeatedly walked along an enclosed plexiglas walkway equipped with a miniature force plate centered in the walkway transit. Kinematic data was collected using an automated video capture system and joint angles were used in conjunction with peak GRF to derive peak normal stresses acting at the tibia midshaft. Stresses were

converted to strains based on representative tibia mid-shaft geometry and Young's Modulus ($E=20$ GPa; 15).

- High-resolution microCT was used to quantify cross-sectional muscle volumes and bone morphology. We assessed standard trabecular morphology parameters at the proximal tibia [16] and cortical bone morphology was quantified at the midshaft.
- Repeated measures ANOVAs were performed to assess the main effects of BTxA or PNI and their interactions compared to baseline control values. Bonferroni corrections were performed to identify parameter differences at each time point and parameter differences vs baseline measures ($p \leq 0.05$). Single factor linear regression was performed with BV/TV as the dependent variable for either peak strain or muscle volume.

Results

- Peak GRF and ankle and knee kinematics of the ipsilateral limb in the BTxA group were significantly altered at d 5 and d 12. By d 28 these deficits demonstrated modest recovery. In contrast, PNI did not alter gait kinetics or kinematics of the ipsilateral limb. Neither BTxA nor PNI altered contralateral peak ground reaction forces (GRF) at any time point, nor were any differences observed between contralateral limbs in the two interventions.
- BTxA-induced calf paralysis significantly reduced peak normal strain at d 5 and d 12. At d 28, the decline in peak normal strains was no longer significantly different vs d 0. Peak normal strains in the BTxA mice were also significantly reduced compared to PNI mice at each of the post-intervention time points.
- Muscle atrophy was severe following BTxA injection, reaching significance by d 5 with continued atrophy through d 12 and d 28. PNI did not alter muscle volume at any

time point.

- Trabecular bone loss following BTxA injection was significantly reduced vs d 0 at each time point. In contrast, PNI induced bone loss reached significance at d 12 but this loss was not as severe as BTxA induced alterations.
- Linear regression analysis revealed that peak normal strain was significantly correlated with metaphyseal BV/TV but only explained 7% of the variation within the data set ($r^2=0.07$; Figure 1A). In contrast, muscle volume was significantly correlated with metaphyseal BV/TV and accounted for 51% of the variation of the BV/TV data ($r^2=0.51$, $p<0.0001$, Figure 1B).

Discussion

In summary, we observed that a single BTxA injection in the calf muscle group reduced gait kinetics, altered gait kinematics, caused severe muscle atrophy, and precipitated rapid and profound loss of trabecular bone and significant endocortical resorption. PNI, while not altering gait kinetics or kinematics, or causing muscle atrophy, precipitated significant trabecular bone resorption, but did not affect cortical bone. In explaining these results, we found that peak normal strain only accounted for 7% of the observed variation while muscle volume was a much more significant predictor of the observed response. Therefore, while mechanical stimuli clearly have essential functions in bone development and adaptation, our data emphasize that trabecular bone homeostasis is highly dependent upon muscle health and, in particular, neuromuscular health.

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Acknowledgments

This work was funded, in part, by NIAMS (AR60304), The Sigvard T. Hansen, Jr. Endowed Chair, and the Zimmer Fracture Biology Professorship.

Differential Muscle miRNA Expression Following Botulinum Toxin A-Induced Muscle Paralysis

Leah E. Worton, PhD, Edith M. Gardiner, PhD, Ronald Y. Kwon, PhD,

Leah M. Downey, BS, Brandon J. Ausk, PhD, Steven D. Bain, PhD, and Ted S. Gross, PhD

Abstract

Recent studies, in part from our group, have revealed that muscle paralysis induced by Botulinum Toxin A (BTxA) precipitates muscle atrophy and rapid and localized bone resorption, but that this bone loss is minimally related to changes in skeletal loading due to altered gait (1-5). Contextually, these studies provide tissue level support for a growing literature emphasizing multiple levels of communication between muscle and bone (6). Here, we summarize a recent manuscript (7), where we explored potential unidentified signaling pathways that might couple muscle atrophy and bone cell function.

Introduction

In conceiving this project, we were drawn to recent reports of micro-RNA mediation of neuronal dysfunction in muscle (8,9). Micro-RNA (miRNA) are small non-coding RNA molecules that regulate diverse cellular processes by sequence-specific targeting of messenger RNA transcripts for degradation or for suppression of translation. Given its widespread clinical use, the early molecular events and messenger RNA induction following intramuscular BTxA injection have been explored (10). However, to our knowledge, altered expression of miRNA following transient BTxA-induced muscle paralysis had not been reported. As an initial exploration, we therefore assessed expression of miRNA and potential downstream targets in muscle following a single injection of BTxA.

Methods

- Quadriceps of adult female C57 mice (16 wk) were analyzed for changes in expression of micro- and messenger RNA (qRT-PCR) and protein levels (Western blot) 7, 14, or 28 days following a single injection of

0.4, 2 or 4U Botulinum toxin A (/100g body weight).

- Our analysis focused on canonical muscle miRNAs: miR-1, miR-133a/b, and miR-206.

Results

- Muscle miR-1 and miR-133a/b were decreased at 7, 14 and 28 days following BTxA injection, whereas a dose-responsive increase in miR-206 expression at day 14 was observed.
- Expression of the miR-133a/b target genes *RhoA*, *Tgfb1* and *Ctfg*, and the miR-1/206 target genes *Igf-1* and *Hdac4*, were upregulated at 28 days following BTxA injection.
- Increased levels of *Hdac4* protein at all timepoints, consistent with anticipated expression changes in direct and indirect *Hdac4* target genes.

Discussion

We investigated early molecular responses in muscle following a single intramuscular injection of BTxA. At a dose previously associated with severe muscle atrophy (2.0U/100g), we observed significantly altered expression of muscle specific miRNAs. In particular, we noted differential regulation of muscle miRNAs from the miR-1/206 and miR-133 families and increased levels of *Hdac4* and downstream mRNA targets following transient muscle paralysis of skeletal muscle. Interestingly, upregulation of *Hdac4* mRNA and protein also occur following surgical denervation (11,12). Taken together, our data suggest that transient muscle paralysis induces altered gene expression that is similar to expression profiles associated with other types of neuromuscular dysfunction.

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Acknowledgements

These studies were supported, in part, NIH (AR64375, AR60304), the Zimmer Fracture Biology Professorship (SDB), and the Sigvard T. Hansen, Jr. Endowed Chair (TSG).

Signaling Interactions Between Beta 2 Adrenergic Receptor and Mechanotransduction

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We are investigating interactions between the signaling pathways that regulate bone formation, in the context of aging effects on bone mechanotransduction. Mechanical stimulation is anabolic in young bone but the osteoblastic response to loading is muted in aged humans and rodents [1]. Autonomic dysregulation with elevated sympathetic tone is common in the elderly [2, 3]. The sympathetic nervous system reduces bone formation through osteoblastic beta 2 adrenergic receptor (β 2AR) [4, 5]. The general hypothesis of this project is therefore that the reduced response of aged bone to mechanical stimulation may relate to an age-associated rise in sympathetic tone.

Using pharmacologic (Butaxamine, a selective β 2AR antagonist) and genetic (germline deletion of the *Adrb2* gene) approaches we have tested the effect of reduced β 2AR activity on the periosteal response to exogenous tibial loading in aged mice (22 Mo). The 21-day loading protocol entailed nine bouts of cantilever bending at moderate load (1700 μ e normal strain, 3/wk). Periosteal bone formation was evaluated by dynamic histomorphometry (calcein injections on d10 and d19). In both studies, relative periosteal bone formation rate on the loaded vs contralateral tibia was significantly higher in mice with reduced β 2AR activity vs control animals. Results with both approaches therefore are consistent with tonic sympathetic suppression of bone mechanotransduction via β 2AR and provide *in vivo* evidence of signaling crosstalk between sympathetic and mechanical response pathways in bone cells. Investigations to evaluate the degree of sympathetic modulation of mechanotransduction in young adult mice are ongoing.

In parallel studies we are investigating signaling interactions in osteoblastic cell lines and primary cultures *in vitro*, using pharmacologic and genetic approaches to alter β 2AR activity, and fluid flow to induce the cellular mechanotransduction response. These studies have identified β 2AR-mediated changes in early mechanotransduction signaling events and in downstream target gene expression. The ultimate goal of this investigation is to define signaling interactions between β 2AR, mechanotransduction and the Wnt developmental pathway, which is a potent developmental pathway important in osteoblast differentiation and in the adult bone response to mechanical stimulation. Together, our animal and cell culture studies aim to build a case that modest exercise preceded by selective β 2AR antagonist treatment may produce a robust anabolic response in the senescent skeleton via a known anabolic pathway.

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Midshaft Clavicular Fractures: Sometimes Benign Neglect Can Cause Harm

Benjamin M. Woodhead, MD and Winston J. Warme, MD

Introduction

The debate continues regarding when to pull the operative “trigger” with mid-shaft clavicle fractures in adults. Historically, most patients have done well with non-operative management and many patients with mild to moderate clavicular deformity adequately compensate following this treatment (1). While patients generally do well without many complications with conservative treatment, malunions frequently occur as some degree of shortening, displacement and angulation is often unavoidable. However, studies have shown that not all patients are satisfied with these results following non-operative management (2). Both malunion and nonunion can occur. Complications from clavicular malunions include chronic shoulder pain, brachial plexus irritation thoracic outlet syndrome and cosmetic issues (3,4). Unfortunately, it is difficult to predict which patients will develop a symptomatic malunion (5). Potential risk factors for nonunion include comminution, older age, shortening more than 2 cm, displacement and history of smoking (6,7). In one recent randomized controlled trial of ORIF versus nonoperative treatment for displaced midshaft fractures, the risk of nonunion was 2.4% versus 23%, respectively; $p < 0.0001$, yet no differences in functional outcomes were detected (8). Other comparative trials have shown decreased nonunion rates in operatively managed patients as well some advantages in the functional outcomes (9-12). For these reasons, there has been an increasing trend towards operative managements of clavicle fractures. There is a risk of the pendulum swinging in the other direction with surgery being recommended for fractures that would have likely healed uneventfully without an operation. More research is needed to help define the appropriate criteria for intervention to maximize outcomes and minimize morbidity in the form of complications as well as unnecessary

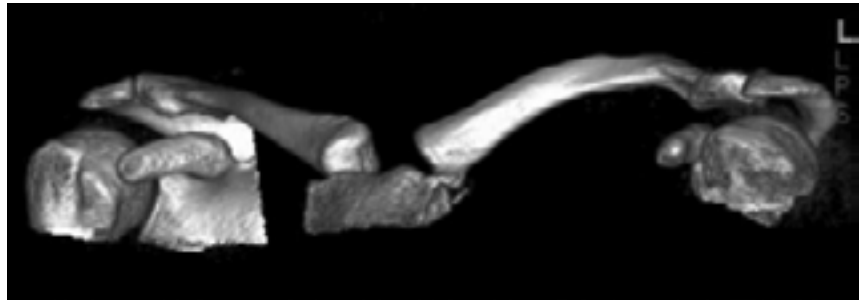


Figure 1: 3D CT reconstruction demonstrates the deformity in the coronal plane.

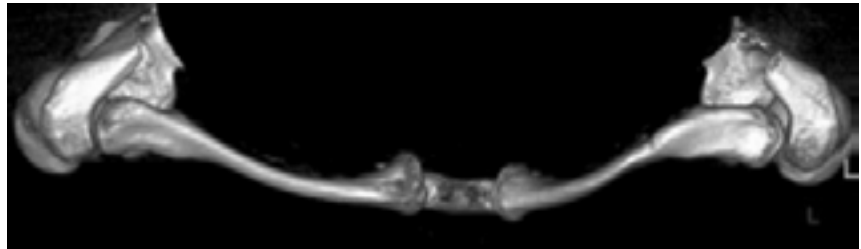


Figure 2: 3D CT reconstruction demonstrates the shortening and the axial deformity.

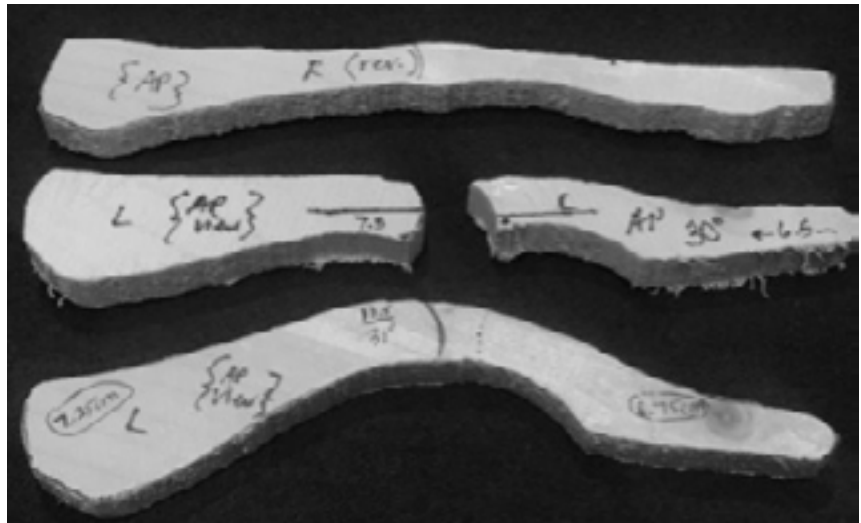


Figure 3: Wood models for the right and left clavicle were created based on the 3D CT reconstruction. The top wood model is the right clavicle in the coronal plane. This was flipped to serve as a reference for the malunited left clavicle. The bottom two images are the left clavicle deformity in the coronal plane, with and without correction.

surgeries.

The vignette that follows is a fascinating case of a young lady who was treated non-operatively

for a comminuted mid-shaft clavicle fracture. She went on to develop ulnar paresthesias, vascular claudication with arm elevation and painful scapular

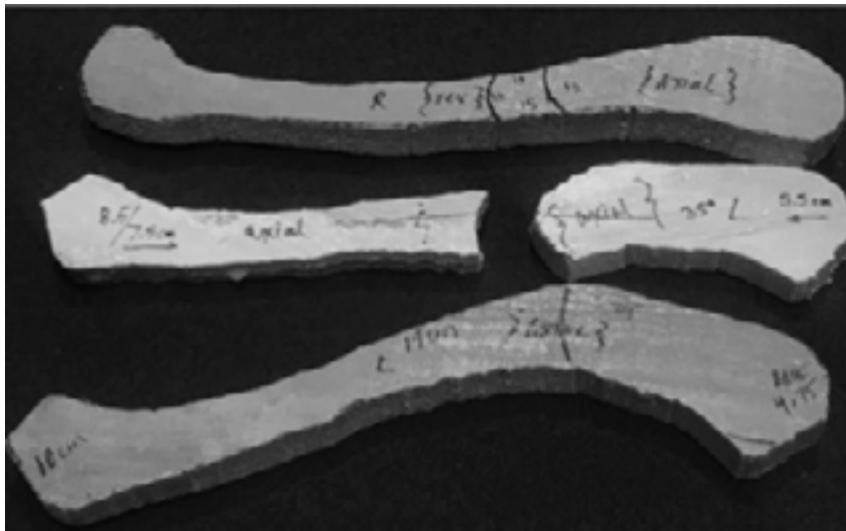


Figure 4: Wood models for the right and left clavicle were created based on the 3D CT reconstruction. The top wood model is the inverted right clavicle in the axial plane. The bottom two images are the left clavicle deformity in the axial plane, before and after angular correction.

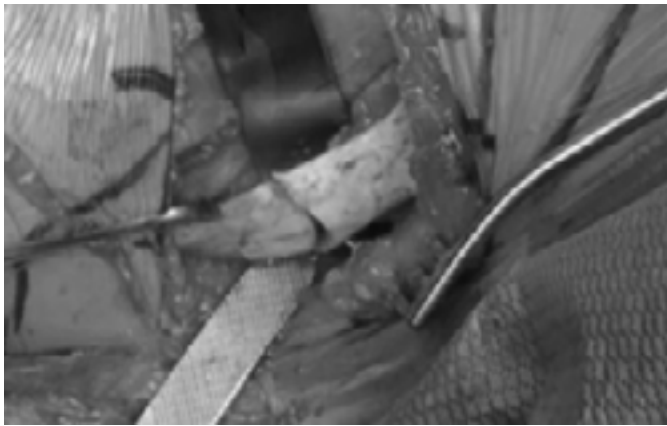


Figure 5: Coronal plane osteotomy after 30-degree correction in the coronal plane.

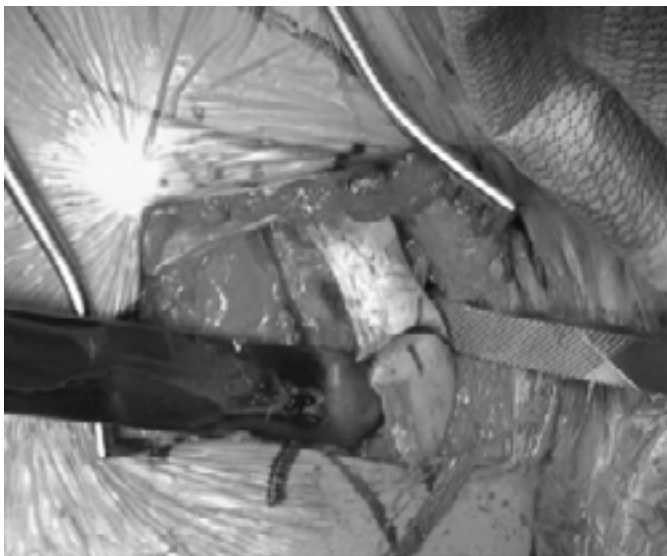


Figure 6: Axial plane osteotomy after 30-degree correction in the axial plane.

bursitis. Her symptoms resulted in avoidance of using her affected arm to minimize the symptoms. Her case is discussed below along with the surgical procedure performed to address her malunion, scapular bursitis and thoracic outlet syndrome.

History

JM is a 28-year-old female with complaints of chronic left shoulder, clavicular, neck and scapular pain. Additionally, she complains of numbness to the ulnar 2 digits and has noted her grip strength diminishing. Raising her arm above her shoulders in addition to external rotation worsens the numbness in the fingers and arm. Her symptoms began after a clavicle fracture she sustained 13 years ago while wrestling in high school. The fracture was treated non-operatively and initially did well after conservative treatment. Over the last 10 years her symptoms progressed, and she developed both neurologic and vascular dysfunction. She had difficulty with wearing clothing over her shoulder and keeping a bra strap in place is problematic. More recently, she has developed a “snapping” pain under the scapula as well as winging which has become uncomfortable both sitting and when supine. She was referred to our clinic for a surgical consultation.

Physical Exam

On exam the shortening of the left shoulder girdle was grossly apparent. Her left clavicle length was 14.5 cm and the right clavicle length was 16 cm, when measured with a tape measure. Left-sided medial scapular winging was noted which was not exacerbated with resisted forward elevation while tested

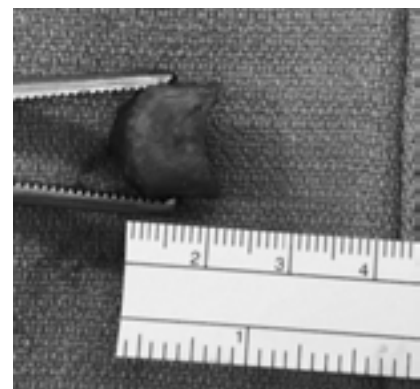


Figure 7: Tricortical iliac crest autograft harvested with crescentic saw blade in order to add 1 cm of length to left clavicle.

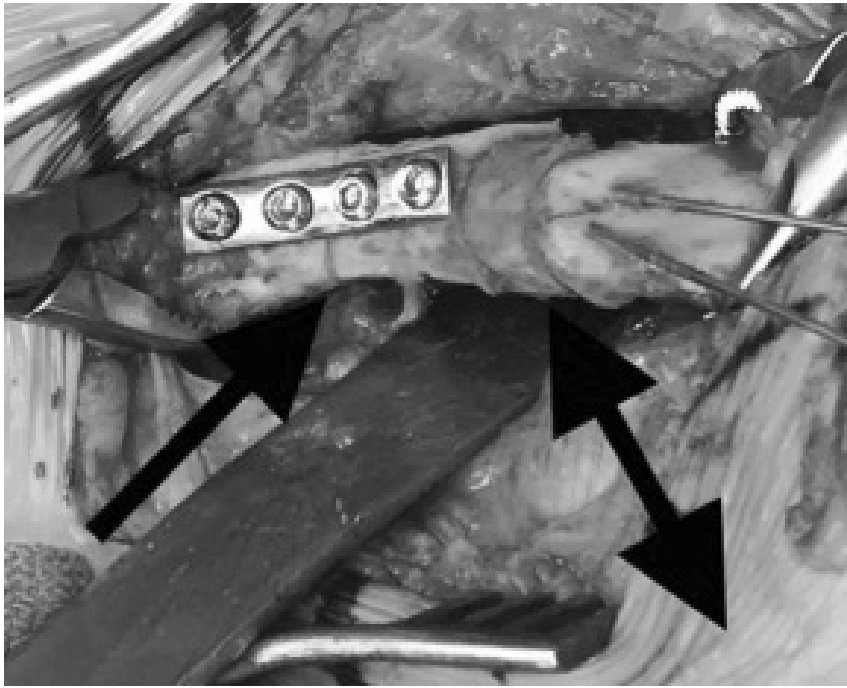


Figure 8: Reduced coronal osteotomy (single black arrow) with superior plate for provisional reduction. The axial osteotomy (double black arrow) with intercalary bone graft is held in place with K-wires.



Figure 9: Final construct with anterior and superior plates. Iliac crest autograft was incorporated into the lateral osteotomy site, compressed by the plates and secured with a locking screw.

at 30 degrees, excluding a long thoracic nerve injury. Her ulnar nerve motor and sensory exam were found to be intact and symmetric bilaterally. There was a positive Tinel's sign over the left cubital tunnel, but no ulnar nerve subluxation was seen. Her radial pulse decreased with abduction and elevation and her

hand developed a purple hue in that position.

Imaging and Preoperative Planning

Radiographs demonstrated a left clavicular malunion in two separate planes. There was evidence of 1 cm shortening of the left clavicle in

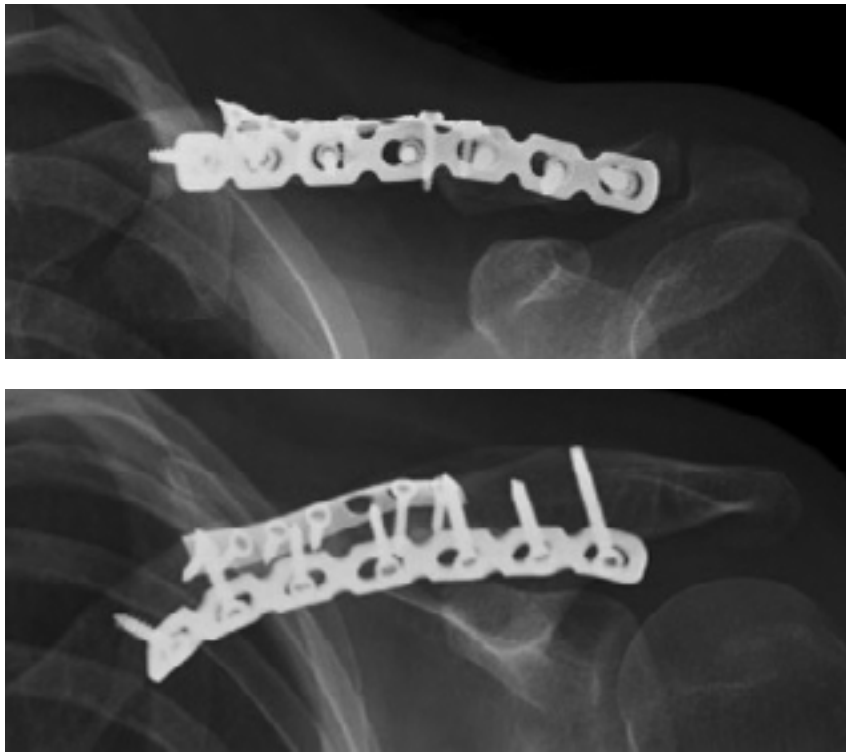
comparison to the right. This was measured on 3D CT scan (Figure 1,2). Preoperative planning was done first with tracing paper and later with the aid of wood models that showed biplanar crescentic osteotomies would be needed for correction of the angular deformities in both the axial and coronal planes (Figure 3,4). Due to the ~1 cm shortening, noted on both the 3D reformatted images and the wood models after angular correction, additional length was deemed necessary and an iliac crest bone graft was planned.

Operative Technique

The patient was set up in a relaxed beach chair position. Bilateral shoulders, clavicles, left arm, and left hip were prepped and draped in the usual fashion. A curvilinear necklace incision was made in Langer's lines and dissection was carried down to the clavicle with care to preserve supraclavicular nerves. Crescentic saw blades of 18.5 mm and 9 mm diameters were used to cut the clavicle at the points of maximal deformity in both the axial and coronal planes, respectively (Figure 5,6). The lateral (axial) osteotomy was performed first with a 30-degree angular correction made and held in place with K-wires. The larger crescentic blade was used to harvest a tricortical iliac crest graft, (Figure 7). The medial osteotomy was first plated with a 4-hole 2.7 mm semi-tubular plate to allow for insertion of the graft laterally at the axial osteotomy site (Figure 8). A 3.5 mm heat-annealed pelvic reconstruction plate was then placed anteriorly, and the 4-hole plate was exchanged to a 7-hole 2.7 semi-tubular plate to span the medial clavicle, intercalary graft and lateral clavicle (Figure 9). Excellent anterior and superior compression was achieved at the osteotomies and graft site yielding a very stable construct (Figure 10a and 10b).

Postoperative Management

The patient used a sling for the next 6 weeks with gentle modified Codman's exercises, elbow, wrist and hand range of motion allowed as well as light desk work. Healing was uneventful with the gradual resolution of vascular and neurologic symptoms by 6 weeks postoperatively. Active motion was allowed at the 6-week mark



Figures 10a and 10b: AP and Zanca radiographs of the left clavicle after reconstruction.

but strengthening and weight bearing exercise delayed until the 3-month mark.

Conclusion

This case does not settle the discussion regarding when to pull the “trigger” with midshaft clavicle fractures in adults, but emphasizes that “conservative management” may be harmful to patients who are followed over time. A balanced approach to surgical intervention should be developed individually with each patient, using shared decision making, with consideration given to the risks of non-union, malunion and the need for secondary procedures - in light of the known risks of a primary operative intervention

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Detection of a Low Bone Mass Phenotype in Somatic and Germline *wnt16* Zebrafish Mutants

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and Ronald Y. Kwon, PhD

Introduction

Osteoporosis has a strong genetic component, yet the complex, multigenic nature of this disease has hampered the identification of causal gene targets contributing to osteoporosis-related traits. Human genome-wide association studies have identified over 200 loci [1] associated with BMD and fracture risk in humans, however, most of the causal genes responsible for these associations have yet to be definitively assigned. Large-scale screens of candidate genes in model organisms provide a mechanism to attribute functional skeletal contributions of these genes to osteoporosis-related traits. Previously, we reported that rapid generation of targeted genetic mutations in candidate genes in CRISPR-edited G0 “crispant” somatic mutant zebrafish, in concert with rapid-throughput microCT-based phenomics [2], can detect mutant phenotypes for genes underlying monogenic bone disorders (e.g. Osteogenesis Imperfecta) [3,4].

Yet, the fidelity of this approach to detect subtle phenotypes expected from contributors of a multigenic disease such as osteoporosis remains in question. Here, we show the potential to detect a robust, low bone mass phenotype in somatic and germline mutant zebrafish with mutations in *wnt16*, a candidate gene with strong ties to osteoporosis-related traits in humans.

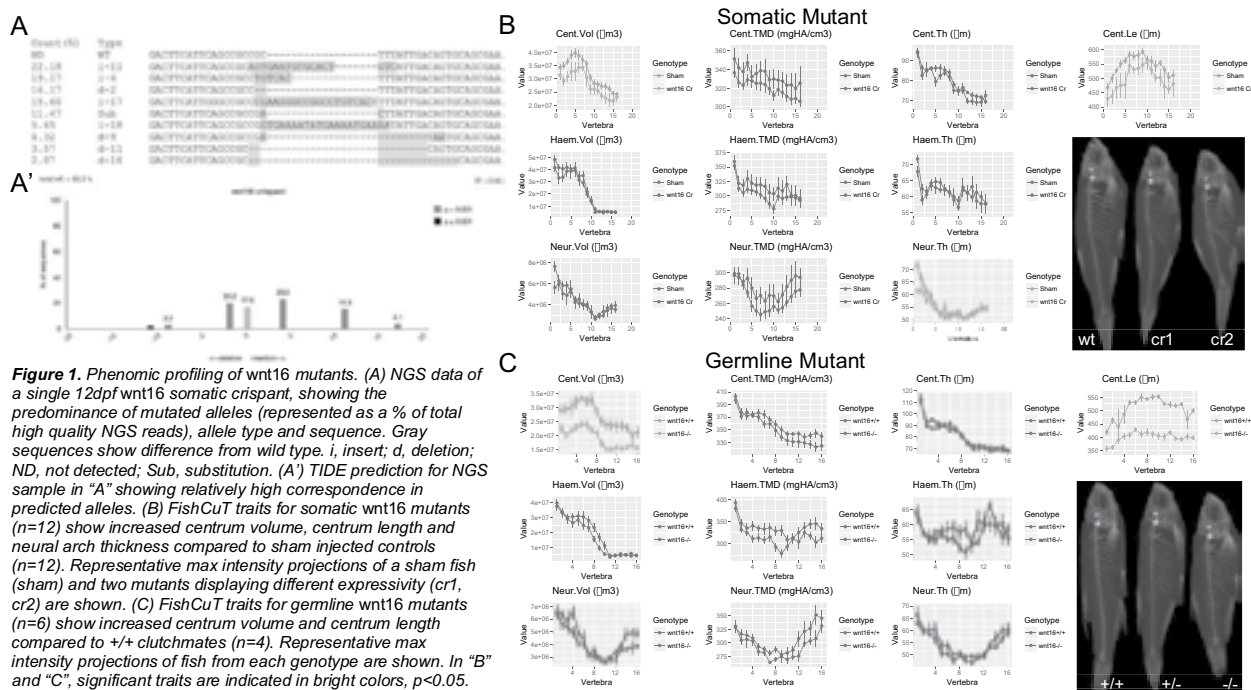
Methods

Approval for this project was granted by the University of Washington IACUC. CRISPR-based gene editing was performed by injecting zebrafish embryos with complexes containing a 3x nuclear localization signal-tagged Cas9 protein (3xNLS-Cas9, IDT) and a custom guide RNA (gRNA, Alt-R system, IDT) targeting exon 3 of *wnt16*. Somatic founders for germline transmission were bred, F1 progeny were screened for predicted loss-of-function alleles, and multiple founders

carrying an identical frameshift allele were inbred to create a stable F2 germline *wnt16* mutant. At ~3 months of age, adults were sacrificed and subjected to microCT-based phenomic profiling as described in [2].

Results

Somatic *wnt16* mutants were generated by injection of gRNA:Cas9 complexes at the 1-cell stage and a subset of larvae were individually screened for inserts and deletions (indels) at 12 days post fertilization (dpf). Quantification of indel efficiencies using Sanger sequencing and TIDE analysis revealed that efficiencies ranged from 67.4% to 93.6% with an average of 80.1%, indicating highly effective mutagenesis. Mutational efficiency was confirmed using next generation sequencing (NGS) (Figure 1A). MicroCT analysis revealed that 90dpf adult *wnt16* somatic mutants exhibited significant changes ($p < 0.05$) in centrum volume, centrum length,



and neural arch thickness compared to sham injected clutchmates (Figure 1B). Morphological defects (e.g., centrum compressions and neural arch non-unions) were observed at a significantly higher rate in *wnt16* somatic mutants compared to controls. To determine if the somatic phenotype is representative of stable loss of Wnt16, we generated *wnt16* germline mutants harboring a frameshift allele at the targeted site, and subjected these fish to phenomic profiling. Germline *wnt16* mutants exhibited a robust change in bone mass with significant decreases in centrum volume and centrum length compared to +/+ clutchmates (Figure 1C). Heterozygous *wnt16* germline mutants showed no significant changes compared to +/+ controls. These data suggest that the somatic *wnt16* phenotype is genetically penetrant and faithfully resembles that of germline *wnt16* mutants.

Discussion

The identification of new causal genes contributing to complex, multigenic disorders can open novel avenues for therapeutic treatments and drug discovery. Previously, we have showed that somatic mutants in zebrafish models of monogenic bone disorders can accurately be used to rapidly screen for skeletal defects using a phenomic approach. However, whether this approach is robust enough to detect subtle skeletal phenotypes due to changes in genes with smaller effect sizes, and which contribute to a multigenic disorder such as osteoporosis, was unclear. Here, we identify a low bone mass phenotype in zebrafish somatic and germline mutants for *wnt16*, a gene implicated in mediating inter-individual variation in BMD and fracture risk in humans [5]. Somatic *wnt16* mutants successfully recapitulated phenotypic signatures in germline *wnt16* mutants, providing evidence of the fidelity of phenotyping directly in CRISPR-edited G0 somatic mutants. Heterozygous *wnt16* germline mutants showed no significant changes compared to controls, suggesting that the somatic *wnt16* phenotypes arises from mosaic biallelic loss-of-function. In mice, loss of WNT16 affects both osteoclastogenesis and bone formation [6]. In zebrafish, the phenotype seen for *wnt16* mutants was concentrated in the centrum

(somatic and germline), a compartment normally devoid of osteoclasts, as well as the neural arch (somatic), a compartment that harbors both osteoblasts and osteoclasts. Somatic mutants for *wnt16* exhibited a significant increase in morphological defects ($p < 0.05$), mirroring consequences of loss of WNT16 in mice, in which ~30% exhibit spontaneous fractures [6]. This study broadens our understanding of zebrafish mutant phenotypes that may be predictive of human BMD and fracture risk, and provides evidence that the identification of genes that contribute to human osteoporosis-related traits in zebrafish is feasible.

Significance / Clinical Relevance

This project supports the use of zebrafish as a somatic model for the rapid screening of human candidate skeletal gene function to facilitate the discovery of causal genes mediating osteoporosis.

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Acknowledgements

This research was supported by NIH awards AR072199 and AR060661.

Rationale for Clinical Evaluation of a Negative-Pressure Wound Therapy Glove

Christopher H. Allan, MD

Hand wounds are common and can be debilitating, and present therapies often fail to permit restorative injury repair or to preserve range of motion. The ReHeal negative-pressure wound therapy glove (Figure 1) is designed to promote healing, prevent scarring and irreversible stiffness by permitting motion, preserve greater digit length, reduce infection risk, and to be easier than current NPWT dressings to apply and seal.

Negative-pressure wound therapy (NPWT; VAC dressing etc.) has been shown highly effective in the management of complex soft-tissue injuries such as those sustained in armed conflicts [1,2]. Unfortunately, the fingers, hand and wrist, while exposed and therefore frequently injured, are not well served by currently available devices. The hand's complicated anatomy makes standard NPWT foam-based dressings difficult to fit, apply and seal. Standard foam dressings become firm under suction, preventing early range of motion exercises and contributing to irreversible hand stiffness. Foam dressings are also adherent to wound beds and are non-transparent, necessitating painful dressing changes. Wound bed ingrowth into open-cell foam results in unintentional removal of newly formed granulation tissue with dressing changes, a particular problem for the thin, mobile tissues of the hand. Replacing current foam-based NPWT dressings with a specialized wound care glove designed for the clinical needs of open hand injuries provides an opportunity to simplify wound care, while improving functional outcomes and returning patients to activities with optimal performance.

Our proposed study will allow us to establish or enhance safety of the device by modifying it in response to adverse events or other needs identified during the clinical trial; these data will allow design of a final pivotal trial if required by the FDA and could lead to production for clinical use. Success in this clinical

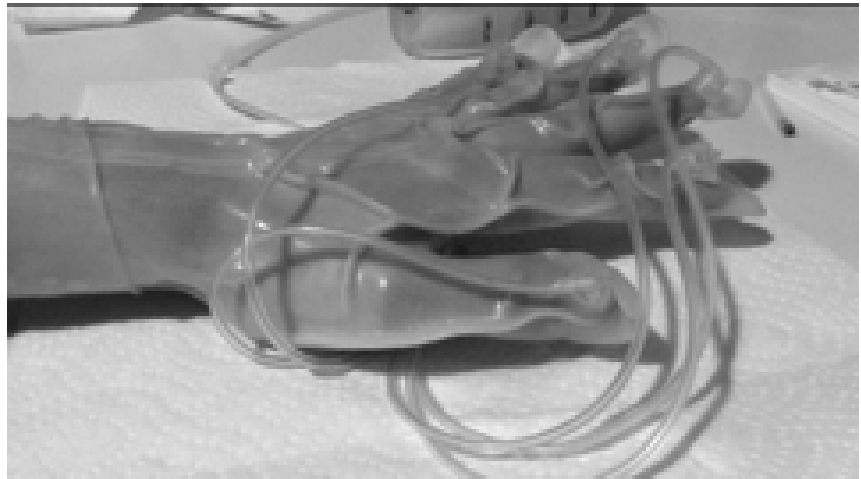


Figure 1: ReHeal negative-pressure wound therapy glove.

trial would provide an improved hand dressing resulting in better functional outcomes for an entire spectrum of soft tissue wounds of the hand. Secondary impacts include reduced hospital stays (from accelerated wound closure), decreased rehabilitation treatments (through allowing early motion therapies to prevent chronic stiffness), and more efficient wound dressing changes, with resultant cost savings.

Research Idea

The goal of the proposed clinical trial is to investigate the safety and efficacy of a flexible, non-adherent, transparent negative pressure wound therapy glove (ReHeal Glove) for finger/thumb, hand, and wrist trauma. This glove is intended to be applied immediately after surgery for open soft tissue wounds, amputations, or blast trauma to the whole hand or individual or multiple fingers. The glove is designed to promote healing, permit motion, preserve digit length, and reduce infection rate. The main functions of the glove are to apply NPWT while allowing for fluid exchange to deliver therapeutics and wound cleansing agents and remove wound exudate. This unique glove has several distinct capabilities that current commercial

wound dressing technologies are unable to provide: it is designed to 1) allow easy application of NPWT to fingers or hand, 2) permit flexion and extension of finger and wrist joints during NPWT use, 3) remain non-adherent to the wound bed for ease of removal, and 4) allow wound assessment through its transparent silicone material. Our early investigations, including a healthy volunteer pilot study, show the ReHeal Glove is easy to don and doff and maintains a vacuum seal well. Our clinical experience is that commercial NPWT dressings designed for hand use are too restrictive to allow motion, while custom-made NPWT dressings using available materials can be extremely difficult and time intensive to apply and seal to the hand due to the hand's highly contoured anatomical features. Recent studies show beginning range of motion (ROM) exercises as early as 24 hours post-injury can result in a final ROM near pre-injury levels [3,4]. Permitting motion while applying NPWT is a distinct advantage of the ReHeal Glove. Current NPWT options can require immobilization of the hand to maintain vacuum sealing, but this prevents joint motion for injuries in the early stages of recovery and risks irreversible stiffness. Another drawback of current foam-

based NPWT dressings is the ingrowth of new tissue into the foam; removal of the dressing causes pain and disruption of the wound bed—critical when the tissue mass is small, as with hands. The non-adherent and transparent ReHeal glove is designed to be easy to remove without wound disruption and to allow wound inspection through the glove without changing the dressing and interrupting therapy.

Regarding NPWT's use in hand injuries, we have shown in a DoD-sponsored pilot trial that a modified VAC dressing could be made to fit and treat amputated digit tips; all patients available at follow up healed with sufficient soft tissue regrowth to cover previously exposed bone without shortening, thereby preserving flexor tendon insertions and maximizing eventual pinch and grip strength (IPR: AMSRD-ARL-RO-SI Proposal Number: 60699-LS). Other case reports [5] also show the efficacy of NPWT for hand injuries; however, application of NPWT requires modification of currently available dressings.

Following this pilot trial and a literature review, we identified and addressed key aspects needed in a NPWT dressing for hand wound applications. We were funded by the Coulter Foundation to develop the ReHeal Glove to provide the aforementioned capabilities and advantages. We have obtained preliminary data indicating device safety from multiple team member and volunteer subject tests at varying levels of pressure for periods of up to 24 hours. This work most recently included an IRB-approved pilot trial of the glove to assess safety and function of the glove/pump system. In this trial, healthy subjects have tolerated the glove well across a four-hour period including driving, dog walking, etc. Negative pressure (vacuum) seal was maintained throughout. No skin compromise or other complications were observed during this short time period across a variety of pressure ranges from -30mmHg to -140mmHg. One modification to the device (redirection of suction tube ports to improve wearability) was suggested by a subject and has been made.

The early feasibility clinical trial proposed in this study will allow us to continue and finalize glove improvements. We will assess safety and efficacy of the glove/pump system

in ten human subjects with trauma involving single-digit, multi-digit, or more proximal hand injuries. We will assess the ReHeal glove's performance in the areas of safety, patient tolerability, ease of application and removal, ease of wound assessment, function and allowable ROM during use, time to wound healing, incidence of infection, need for additional procedures, and final active ROM after discontinuing use.

It is our goal to provide a novel, function-preserving and tissue-restoring alternative to the current standard of care involving revision amputation, gauze dressings or VAC use. This trial represents a significant step towards achieving that goal.

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Orthopaedics @ ISCRM

Ronald Y. Kwon, PhD

In an effort to expand the Department's research in musculoskeletal stem cell biology, it has recently created a new initiative with the Institute for Stem Cell and Regenerative Medicine (ISCRM) at University of Washington. This initiative involves new joint faculty appointments, dedication of space, and shared resources. This initiative will fortify the strength of Orthopaedics and ISCRM by co-localizing Orthopaedics researchers with scientists from other disciplines interested in stem cell and regenerative medicine, and providing them access to state-of-the-art technologies and core resources for research in this area.

As part of this initiative, in July 2018, the Musculoskeletal Systems Biology Lab (MSBL) moved from Harborview Medical Center to ISCRM, which is located at the UW Medicine South Lake Union campus. The MSBL is a multidisciplinary research team

(members include Drs. Claire Watson, Christopher Allan, and Ronald Kwon) whose mission is to reverse aging-induced bone fragility, and to maximize human regenerative potential. As part of the move, the team was provided dedicated wet lab space, office space, and student desks. They were also granted access to state-of-the-art core equipment and facilities at ISCRM, including the Quellos High-Throughput Screening Core, Ellison Stem Cell Core, Garvey Imaging Core, and ISCRM's Aquatics Core.

The new initiative between Orthopaedics and ISCRM has created new scientific opportunities. Soon after their move to SLU, the MSBL was awarded a collaborative grant from the Brotman Bay Institute for Precision Medicine with other ISCRM members (including Drs. Olivia Bermingham-McDonogh, Andrea Wills, Thomas Reh, and Hannele Ruohola-Baker).

For this project, the team is developing a cellular atlas of regeneration, which will be used to identify key stem cell populations and compare them across different regenerative systems. MSBL members were also awarded several ISCRM Research Awards, supported by the State of Washington. This includes Eric Katzung, an undergraduate student who was named an ISCRM Student Fellow, as well as Dr. Kwon, who was awarded a John H. Tietze Stem Cell Scientist Award. MSBL members have also participated in several ISCRM-sponsored STEM outreach events involving students from W.F. West High School in Chehalis. Taken together, the new initiative with ISCRM is expected to propel musculoskeletal stem cell research in the Department of Orthopaedics forward, while also helping to train the next generation of orthopaedic clinicians and scientists.



MSBL members at their new research space at the Institute for Stem Cell and Regenerative Medicine (ISCRM) in South Lake Union. From left to right: Samara Williams, Christopher Allan, Adrian Monstad-Rios, Eric Katzung, Rehaan Bhimani, Ronald Kwon, and Claire Watson.

University of Washington Medical Center and Northwest Hospital Orthopaedics

Chief, Albert O. Gee, MD

The University of Washington Medical Center (UWMC) and Northwest Hospital (NWH) continue to be places of growth and positive change for our Orthopaedic Surgery service.

As announced in last year's update, the UWMC and NWH are going to merge into one institution, divided onto two separate campuses. The January 1, 2020 target date for this merger is fast approaching. I'm happy to report that from our Department's perspective, we feel well prepared for this union and are eagerly looking forward. I can say this because we already have a significant orthopaedic faculty presence at NWH. Our total joint arthroplasty division has been based there for a number of years now which is anchored by Drs. Howard Chansky, Navin Fernando, Seth Leopold and Paul Manner. We are also excited to be welcoming an additional arthroplasty surgeon this upcoming year, Dr. David Fitz, who is currently completing his fellowship at Harvard/Massachusetts General Hospital and completed his residency at Northwestern University.

In other exciting NWH developments, I'm pleased to inform you of several new faculty members to our department who will be focusing their practices at NWH. We have added a new Orthopaedic Trauma/Fracture service this past year at NWH with the hiring of Drs. William Lack and Florence Unno who have been excellent additions to our faculty and are getting busy with a combination of community and complex fracture cases.

The Hand Surgery service remains busy and active at NWH with Drs. Sarah Beshlian and Stephen Kennedy. At UWMC, our Hand surgeons, Drs. Jerry Huang and Nick Iannuzzi are doing excellent as well. They continue to do a high-volume of complex cases and are both involved heavily in the training of Hand fellows.

The Shoulder and Elbow service at UWMC continues to do excellent work. Drs. Jason Hsu, Rick Matsen and Winston Warme continue to take great

care of a high-volume of both straight-forward and complex shoulder and elbow patients. Simultaneously, they continue to be one of the most productive academic divisions in our department as they advance our understanding of shoulder disorders and strive to improve surgical treatments through both clinical and basic science research. Meanwhile, they train 2 shoulder/elbow fellows a year and have now done so for almost 32 years thanks largely to Dr. Matsen's dedication to the fellowship.

Our Sports service remains active and thriving. We have Drs. Mia Hagen and Christopher Kweon as well as me. We continue to enjoy taking care of athletic injuries in patients of all ages. Dr. Hagen's practice continues to build in her sub-specialty area of hip arthroscopy but she still enjoys general sports medicine as do Drs. Kweon and Gee who do shoulder, elbow and knee surgery. Additionally, Dr. Ken Chin has also come on board this year as a

new Foot & Ankle and Sports surgeon. He joins us after completing much of his training in Baltimore. His practice will straddle both UWMC and NWH and we are excited to have him on our team! One fun fact for our Sports division, due to the continued success of Husky Athletics, our team physicians continue to enjoy traveling with our teams to places like the Rose Bowl in Pasadena, CA (see picture) and the Pac-12 Basketball Tournament in Las Vegas, NV (both the Husky football and basketball teams were Pac-12 Champs this past season! Congratulations to both!).

Our Orthopaedic Spine service continues to grow in volumes. We recently added Dr. Viral Patel and he is ramping up his surgical practice nicely. Additionally, Dr. Carlo Bellabarba, who is one of our department faculty and long-time Chief of Spine at Harborview Medical Center has made time in his busy schedule to spend at UWMC



Dr. Albert Gee and Dr. Chris Kweon at the Rose Bowl



University of Washington Medical Center

to help support Dr. Patel and work to advance our clinical and academic mission in spine surgery.

The Tumor service is doing well and is very busy serving patients with orthopaedic oncologic diseases from the WWAMI region and beyond. Dr. Matthew Thompson heads up the division and he has a full practice less than 2 years into his time at UWMC. The patient volumes are such that his new partner, Dr. Jared Harwood, who started only last fall has had to hit the ground running to keep up with demand. Both of them run interdisciplinary clinics at UWMC and the Seattle Cancer Care Alliance and Dr. Thompson spends time at Seattle Children's Hospital taking care of pediatric tumor patients while Dr. Harwood is involved with the care of Veterans at the Puget Sound VA Hospital.

We are proud to have a great many advance practice providers (APP) that support our surgeons at both UWMC and NWH and they are an integral part of the great care we provide our patients and we really could not do what we do without them.

Our UWMC APPs include: Janice Olivo, PA-C, Alex Bertelsen, PA-C, EChing Bertelsen, PA-C, Kirsten Harvey, PA-C, Carlos Caso, PA-C, Kaitlen Laine, PA-C, Jennifer Stambaugh, PA-C, Connie Ly, PA-C, Amanda Pedersen, PA-C, Jason Maris, PA-C, Lauren Colpo, PA-C, Mahra Colvin, PA-C, Priya Shah, PA-C, Jennifer Hamilton, PA-C and Julianne Krause, PA-C.

At NWH our APPs include: Peter

Hall, PA-C, Michael Taylor, PA-C, Katie Moore, ARNP and Winnie Hu, ARNP.

In addition, we have several new APPs coming onboard this year including Jason Erickson, PA-C and Wyatt Visca, PA-C who will both be working at NWH, and we have Stasia Turner, ARNP who will be supporting our surgeons at UWMC.

Thank you for all you do to support our practices and care for our patients!

In a bit of sad news, we bid farewell to Dr. Ted Wagner who was a stalwart of spine surgery in Seattle and worked for many years at UWMC and Seattle Children's Hospital. Although he has retired from his clinical practice now, I'm sure we will still see him often hanging around the department, coming to faculty meetings and our teaching conferences to impart the wisdom of his lifetime of experience and retelling his stories of the good old days of orthopaedics.

So that brings you up to date on the current state of our Department at the UWMC and NWH campuses. As you can see there is a great deal of growth going on at both sites. I believe the future is bright as we look forward to merging UWMC and NWH into one entity. We anticipate that this union will further our ability to deliver high quality care as we combine the efficiencies of NWH with the reputation of clinical excellence of UWMC and thus continue to advance our Departmental mission of improving the musculoskeletal health of the public.

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 42,000 visits with over 2,500 surgeries. Additional faculty in pediatric sports medicine and orthopedic surgery has expanded both our expertise and clinical availability.

The Everett outpatient clinic has opened, increasing our northern presence beyond King County. Our south clinic at Federal Way remains a busy outpatient site. We have also launched an outreach clinic in Missoula, Montana, and continue with Yakima, Tri Cities, Wenatchee and Olympia outreach sites. The Bellevue surgical center is opening an additional operating room to increase day surgical capacity, and 8 new state of the art operating rooms are planned in the current construction ongoing at Seattle Children's Laurelhurst campus.

Spine

The Spine program at Seattle Children's encompasses a wide spectrum of disorders spanning infantile congenital deformities, through adult type conditions such as degenerative disc disease, spinal column tumors, and disc herniation with radiculopathy. Dr. Krengel is the Director of our Pediatric Spine Program. Dr. White maintains his leadership and focus on treating patients with early onset scoliosis and skeletal dysplasias. He works intimately with Dr. Greg Redding of the pulmonary department focusing on the effects of severe spinal deformities in these children on pulmonary function, growth and quality of life indicators. Along with Dr. Redding and Viviana Bompadre, PhD he is one of the largest contributors to the Growing Spine Study Group, collaborating with other centers around the country and world to better define the best methods to treat spinal deformity in children with early onset scoliosis.

Dr. Bauer continues to focus on Adolescent Idiopathic Scoliosis, and complex congenital and neuromuscular spine deformities. She has also become



Seattle Children's Hospital Everett Clinic

our expert in the surgical treatment of high grade spondylolisthesis, disc herniations in children and adolescents, cervical spinal deformities, stenosis and instability, and spinal tumors. She organized and implemented the hospital Clinical Standardized Work projects for prevention of surgical site infections and Spine Surgery. She was recently chosen by the SRS for the prestigious Edgar Dawson Traveling Fellowship.

Dr. Blumberg has significant interests in scoliosis surgery, mainly adolescent idiopathic and neuromuscular scoliosis. He also has interests in hip preservation surgery and pediatric trauma as well. He has been active with research projects and is part of the CORTICES study group, a collaboration of pediatric orthopedic surgeons dedicated to improve the quality, safety and value in the management of orthopedic conditions. He has also been refining a spine surgery safety checklist to improve and better standardize the pre-operative time-out before spinal fusion surgery.

Sports

The Seattle Children's Sports Medicine Program is composed of pediatric sports orthopedic surgeons, sports medicine trained pediatricians and a physiatrist, an adolescent

medicine physician, physician assistants, certified athletic trainers, and sports physical therapists. We provide care at multiple sites including Seattle, Bellevue, North, and South campuses. Our athletic trainers are located at 41 greater Seattle area high schools, providing excellent care for our student-athletes as well as involved in numerous outreach activities and events including Girls on the Run, Special Olympics, and UW sports camps. We are engaged in collaborative pediatric sports medicine research. We are excited to begin a pediatric sports medicine fellowship in the summer of 2020 in partnership with the University of Washington Primary Care Sport Medicine Family Medicine Fellowship Program.

Our two full-time sports surgeons, Drs. Michael Saper and Gregory Schmale, remain busy treating patients with ACL tears, patellar instability, and shoulder instability, as well as osteochondritis dissecans of the elbow, knee, and ankle, having performed nearly 500 sports-related surgeries in the past year. Each of our surgeons are members of the Pediatric Research in Sports Medicine society Research Interest Groups and are currently participating in multicenter studies of meniscal tears and discoid menisci, tibial spine fractures, rehabilitation after ACL injury, and the treatment of medial

epicondyle fractures.

Now in its eleventh year, the Athletic Training Program has emerged as the regional leader in providing on-site healthcare for young student-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 22 different school districts covering 40 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 53,000 assessments including over 500 concussions and close to 100,000 treatments to young athletes.

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. Dr. Vince Mosca

has been at the cornerstone of this expertise. He has been selected as a visiting professor nationally and internationally. His textbook of surgical treatment of pediatric foot and ankle deformities is considered a “must read” for pediatric orthopedic surgeons. Dr. Tom Jinguji, a pediatrician and 20-year adjunct member of our Department, continues to expertly help manage the care of children with clubfoot deformities.

Neuromuscular

The management of the orthopaedic aspects of patients with neuromuscular disease is currently led by Dr. Ted Sousa. Care of these children crosses subspecialty and specialty boundaries and we continue to partner with rehabilitation medicine, physical therapy, orthotics and occupational therapy to deliver comprehensive state of the art care to these patients. 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 the goal is perform all procedures to address these deformities at a single operation. Our gait laboratory that is in development will allow for complex modeling of children’s gait to optimize the surgical plan for these patients.

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 a nationally and internationally recognized program, and has now procured over \$1,000,000 in industry sponsored research. Our program at Seattle Children’s Hospital is the only center in the country for any of these studies being conducted by an orthopedic surgery department. In the community, our group actively supports and collaborates with both the national and regional leadership of Little People of America (LPA). Dr. Klane



Seattle Children’s Hospital

White serves on the Medical Advisory Board for LPA. This year, we will also participate in the Marfan Regional Symposium in Seattle.

Bone Tumor

At Seattle Children's Hospital, the pediatric bone and soft tissue tumor service, a multidisciplinary service that includes our two oncologic surgeons, Antoinette Lindberg and Matthew Thompson, cares for patients with benign and malignant bone and soft tissue tumors as well as cancer-related Orthopaedic 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. Dr. Lindberg was recently honored by receiving the prestigious family choice award.

Hand and Upper Extremity

Our hand and upper extremity program, led at SCH by Dr. Suzanne Steinman, continues to grow with over 4000 clinic visits and more than 400 surgeries this past year for children with congenital, neuromuscular and trauma related issues. We had a record turn-out for our Limb Difference Social this past spring, bringing together families for fun and social support. We look forward to our next social, June 23rd, at the Mountaineers Club with Outdoors For All, where our families will get to go rock climbing. We continue to be involved in the national CoULD (Congenital Upper Limb Difference) registry as one of the leading sites for enrollment. This has led to several national projects that have been presented nationally and internationally, with some resulting in change of practice for rare conditions.

Trauma

Fracture care and musculoskeletal infection continue to represent one of the largest volumes of patient care for the Orthopedic Department. This year has seen in collaboration with the Infectious Disease department and musculoskeletal radiology a continued evolution of the management of bone and joint infections. The adoption of rapid sequence MRI has allowed for the assessment of suspected infection

cases to differentiate between surgical and non-surgical management without the need for sedation. This has proved to be a significant benefit for both patient as well as the logistics of coordinating care, as with sedation an open OR as well surgeon needed to be available during the sedation interval. Dr. Todd Blumberg, trained in our residency and then at the famed pediatric orthopaedic program "CHOP" at the University of Pennsylvania, has taken an interest in pediatric fracture care.

Research

We have successfully implemented the electronic collection of patient-reported outcome measures (PROMs) in the Ankle and Foot, Sports and Spine clinics. With this tool, clinicians have been able to obtain real-time functional data on their patients. The data is also being used for research purposes. It is our goal to strengthen our involvement in outcomes research and continue to increase the national recognition of our clinical and research program.

With more than 80 open studies, including 2 randomized-controlled trials, 10 multi-site prospective studies, and 6 clinical registries our faculty at Seattle Children's are actively involved in research for different pediatric conditions. Dr Todd Blumberg was the recipient of a Seattle Children's Academic Enrichment Fund for his study on pediatric infections. His study will evaluate whether the use of sedated MRI is reduced following implementation of an MRI abbreviated protocol. Dr. Bauer was the recipient of a POSNA Microgrant this year.

Dr. Klane White is participating as the site PI of several multicenter, multinational clinical trials for pediatric patients with Achondroplasia. These studies have helped placed our skeletal dysplasia program as one of the top programs at the national level.

Harborview Medical Center Orthopaedics

Chief, Carlo Bellabarba, MDCM

Departmental Promotions

2018-19 saw the well-deserved promotions of Daphne Beingessner, MD to Professor, and Conor Kleweno, MD to Associate Professor in the Department of Orthopaedics and Sports Medicine.

Medical Center

Harborview continues to run at greater than full capacity year-round, providing state-of-the-art Level-1 trauma care and elective orthopaedic care to a wide cross-section of Seattle's growing population.

ability to provide high quality, cost-effective care to the region's most complex and vulnerable patients.

Research and Education

Under the direction of research coordinator Julie Agel, MA, and the Director of Clinical Research, Reza Firoozabadi, MD, the Harborview orthopaedic faculty continue to conduct a variety of prospective and multi-center research studies, as well as retrospective clinical studies and basic science projects, and have maintained a leadership role worldwide in helping determine how orthopaedic

well as for visiting surgeons who travel from throughout the globe year-round to immerse themselves in the Harborview orthopaedic experience first-hand.



(Left to right) Daphne M. Beingessner, MD, Professor and Conor P. Kleweno, MD, Associate Professor

Clinical Care

The 2018-19 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, has continued its yearly climb, emphasizing the importance of Harborview as a source of experienced, uniquely specialized care in the treatment of musculoskeletal conditions within our region, while adding additional challenges to our

conditions are best evaluated and treated. Harborview also continues to be a key contributor to the multicenter Major Extremity Trauma Research Consortium (METRC), with the goal of enhancing the quality of trauma care globally.

Harborview remains a key component of the University of Washington Department of Orthopaedics' teaching program, which provides ample learning opportunities for a large number of our fellows, residents, medical students and advanced practice providers, as

VA Puget Sound Orthopaedics

Chief, Nicholas P. Iannuzzi, MD

The Puget Sound Veteran's Administration (VA) Medical Center remains a tertiary referral center within the VA Northwest Health Network, helping to serve patients from Washington, Alaska, Montana, Idaho, Wyoming, and parts of Oregon. We continue to provide the highest level of care for our veterans while training future surgeons and advancing the field of orthopaedics through research.

In the past year, we have seen two faculty additions to our service, which have expanded the breadth and volume of care that the orthopaedic surgery service is able to provide. Dr. William Lack, a fellowship trained orthopaedic trauma surgeon, has joined us from Loyola University in Chicago, and Dr. Jared Harwood, a fellowship trained orthopaedic tumor surgeon, has joined us after completing his fellowship at the University of Chicago. Both have been excellent additions to the service and have demonstrated their commitment to patient care, resident education, and research.

Drs. Lack and Harwood join Drs. Chansky, Sangeorzan, Gee, and myself to cover nearly all orthopaedic subspecialties including Hip and Knee arthroplasty, Foot and Ankle surgery, Shoulder and Sports Medicine, and Hand and Upper Extremity surgery. With the addition of our new faculty, Dr. Fred Huang has recently "retired" from his role providing per-diem coverage. We would like to take this opportunity to acknowledge his years of assistance and exemplary service.

As attendings, we have the great privilege to work with a number of residents and medical students, including 2 Chief Residents, a PGY-4, PGY-3, and PGY-2 level residents. The addition of new faculty has been a boon for their experience, and as faculty, we are extremely fortunate for their assistance as they work to cover a busy and diverse service.

Our physician extender team is one of the highlights of the VA. Dustin Higbee, PA-C, Steve Casowitz, PA-C, Amy Katzenmeyer, NP, Renato Rafi, PA-C, and Martin Hendricks, PA-C



VA Puget Sound Health Care System - Seattle Division

assist in both the operating room and clinic and provide excellent care for our veterans. We would like to take a moment to recognize Annette Testa, LPN for her years of service as well. She will be missed, but we wish her the best in her retirement.

Not to be overlooked are two of the most important members of our team. Monette Foltan, RN and Katherine German, RN are our nurse coordinators, serving in this role for 15 and 7 years, respectively. Nurse Coordinator is hardly an adequate description of the role that they serve, as they manage the logistics behind complex clinic and OR schedules while serving as a primary point of contact between the veteran and the orthopaedics service. Cindy Lostoski, our administrative assistant, and Diane Diggins, our service line manager continue to handle our day-to-day administrative duties and keep us all in line.

The VA Center for Limb Loss and MoBility, *CLiMB*, has completed its 20th year and moved in to a new 7000 ft² space as of March 2019. The expanded lab houses The Gait Lab, the Biplanar Lab, the 3D printing lab and Robotic Gait Simulator in one space, allowing greater interdisciplinary collaboration.

In addition to the lab director, Bruce Sangeorzan, MD, the musculoskeletal investigators group includes Bill Ledoux PhD, Dan Norvell PhD, Patrick Aubin PhD, Joseph Iaquinto PhD, Brittney Muir PhD, and Jiang Cheng PhD. The work done in the Center is supported by grants from the Department of Veterans Affairs, the NIH, The DoD and other agencies.

Overall, the Puget Sound VA Orthopaedic Surgery Service is as strong as ever. We welcome the recent additions to our faculty, and we look forward to new opportunities for education and research while we continue to provide exceptional clinical care in the service of America's Veterans.

Our Clinical Orthopaedic Mission: A Year in Review

Ken Karbowski and Karl Engdahl

The Department experienced another strong clinically productive year, even as it was required to manage faculty vacancies in a number of key clinical areas. While overall case numbers were down versus those for FY17 (at a modest 1.5% overall), the Department did achieve the same level as the prior year at Harborview, and actually experienced growth during this span at Seattle Children's Hospital and Medical Center.

Another closely monitored measure of the Department's productivity lies in its volume of work based Relative Value Units, or wRVUs, which signify the intensity of work required to perform the various surgeries, and the absolute quantity of surgeries, other procedures, and clinic visits. By this measure, the Department did experience growth in Fiscal Year 2018 versus prior year.

The Department's overall plateau in clinical production was largely attributable to several clinical faculty departures in AY18; however, the Department has, in response, since recruited a number of key faculty, each of whom has already achieved strong practice growth:

- Jennifer Bauer, MD (Pediatric Spine)
- Todd Blumberg, MD (Pediatric Trauma and Spine)
- Mia Hagen, MD (Sports)
- Matthew Thompson, MD (Tumor)
- Will Lack, MD (Trauma and General Orthopaedics)
- Viral Patel, MD (Spine)
- Jared Harwood, MD (Tumor)

Even as clinical volumes were largely unchanged, the Department did achieve revenue gains in its various practices. This was due to increased case complexity as well as the ability of the School's leadership, in conjunction with the University of Washington Physicians practice plan (UWP), and the Children's University Medical Group (CUMG) to negotiate and maintain favorable contracts with

Work RVUs	FY14	FY15	FY16	FY17	FY18
10-UWMC	44,883	30,091	31,582	34,516	37,003
20-ISC	4,034	4,221	4,507	4,415	3,541
30-ROOSEVELT	26,070	26,817	28,248	28,416	29,668
40-SCCA	1,168	1,279	1,754	1,300	1,605
50-LWPN	34	445	393	381	411
60-HMC	141,568	146,620	148,107	149,782	145,970
80-OFFSITE	2,060	345	37	44	25
81-NWH	15,498	24,782	28,149	32,473	34,253
All	225,354	235,510	235,857	251,326	253,375

Figure 1: Work based Relative Value Units (wRVUs)

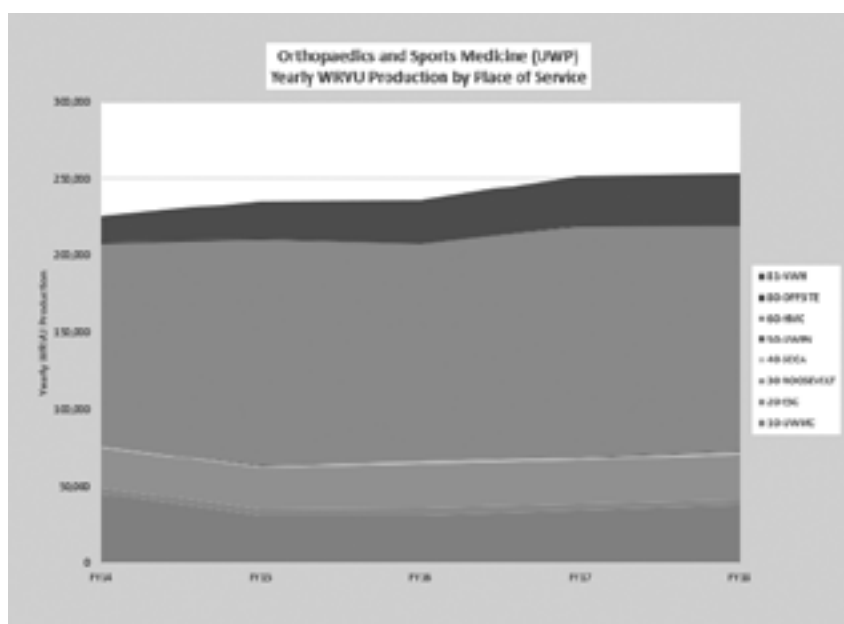


Figure 2: Yearly wRVU production by place of service

key insurers. The Department is well positioned for growth of both its adult and pediatric practices in the coming year, as the practices of our FY17 and FY18 candidates continue to mature and as a sizeable number of additional clinical faculty will be added to its ranks. We have recently been joined by Florence Unno, MD and Ken Chin, MD, both located at NWH, with more faculty hires to come.

We have not neglected the importance of high-quality cost-effective care. There are initiatives at each of our hospitals to "bend" the "Healthcare Value Equation". These initiatives include measurement of health outcomes, understanding of actual costs and expenses, and the

development of standardized pathways to minimize variability and costs while maximizing clinical improvement. This focus on cost-containment and quality led to Northwest Hospital receiving a \$183,000 "bonus" from the Centers for Medicare and Medicaid Services (CMS) as part of the Comprehensive Joint Replacement Reconciliation Program. We are also anticipating annual savings in the range of millions of dollars as a result of an implant cost-reduction program at UWMC, NWH and HMC. These savings will not impact the quality of patient care.

Orthopaedic Surgery Residency Program

Douglas P. Hanel, MD, Christopher Y. Kweon, MD, and Lisa A. Taitzman, MD, MPH

The University of Washington Department of Orthopaedics & Sports Medicine is a top training destination for medical students pursuing orthopaedic education. The tradition is rich and storied, with residency graduates spread across the United States in both academic and community settings, providing unparalleled care to patients who have sustained musculoskeletal disease and trauma. The residents who train here, who provide compassionate care, and who connect the faculty to one another are uniformly considered the strongest aspect of the University of Washington residency program.

The relationship that exists between the residents and faculty here is truly laudable. The standard of excellence to which the faculty hold the residents has been continually reinforced over years of high achievement, high performance, and high character by all graduating residents. Correspondingly, the standard to which the faculty hold themselves is to always do what is best for our patients and provide an example for the residents to be a physician-surgeon. There are few places where an orthopaedic resident will be so deeply involved in the care of patients than is experienced here. Our residents encounter the entire breadth of orthopaedic pathology and deliver

care to the entire social spectrum of the Pacific Northwest. Whether a patient is the CEO of a tech company in South Lake Union or living in poverty in Pioneer Square, they are all treated with the same compassion and exacting standards of clinical care.

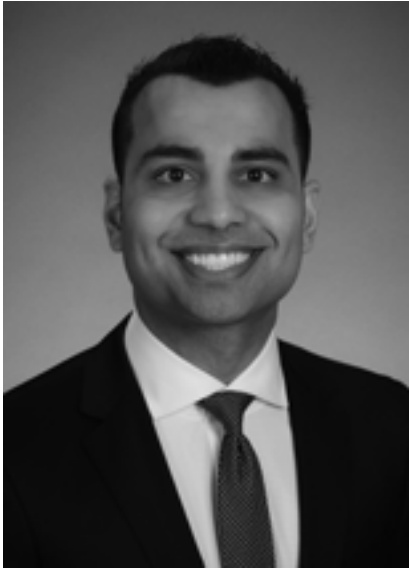
The singular mission of UW Medicine is to improve the health of the public. As a part of that mission, the University of Washington Department of Orthopaedics & Sports Medicine is committed to a culture of openness, civility and respect, employing and training a diverse group of clinicians and staff and providing quality and equitable healthcare to all persons in need of our expertise. Our residency program has always been one of the most diverse within orthopaedic surgery and we continue to make efforts to create opportunities for students from diverse backgrounds to explore a possible career in orthopaedic surgery. Dr. Chansky, Dr. Taitzman and Dr. Greg Walker (Post Graduate Year 3) recently represented the department in Philadelphia at the annual meeting for The Student National Medical Association (SNMA). The mission of the SNMA is to support current and future underrepresented minority medical students, addressing the needs of underserved communities, and increasing the number of clinically

excellent, culturally competent and socially conscious physicians. Our Chairman Dr. Chansky and his wife Kari have also started an endowment to help fund our newly created Diversity Visiting Student Program which is designed to give medical students from diverse backgrounds a chance to experience the exceptional training that our department has to offer.

Finally, after an historic run as Program Director, overseeing the rise of the residency program to elite status, Doug Hanel, MD will hand the administrative rigors of maintaining our high standards for resident education to Chris Kweon, MD and Lisa Taitzman, MD. With this transition he leaves a culture of compassion, hard work, and empathy for the patients we have the privilege of serving. His clinical practice will continue as well as his impact on resident training as a faculty member. In anticipation of his continued influence and taking advantage of the educational foundation that we, as a department have established, an endowment for research in resident education is being established in his name. It is fully recognized that we have the foundation and commitment to take our residency program to even greater heights as we develop the next generation of orthopaedic physician-surgeons.



Graduating Residents



Zahab Ahsan, MD

Zahab will be moving to New York City to begin fellowship in Sports Medicine at the Hospital for Special Surgery. He will be joined by his wife, Wara, who will be completing her 4th year of medical school in NYC. After completion of fellowship and medical school, Zahab and Wara plan to coordinate practice and residency on the West Coast or the Midwest.



Kate Bellevue, MD

Kate will be moving to North Carolina to complete a fellowship in Hand and Upper Extremity Surgery at Duke University. After her fellowship, she plans to return to and practice in the Puget Sound Area, where her husband, Oliver, works as a general surgeon.



Matthew Baron, MD

Matt plans to pursue a fellowship in orthopaedic trauma surgery with the Sonoran Orthopaedic Trauma Surgeons of Scottsdale and Phoenix, AZ. He will be moving down to Arizona with his future wife Winnie Hu, after they tie the knot on Orcas Island this July. They plan to practice somewhere in the Mountain West region.



Jonathan Kark, MD

Following graduation, Jon, his wife Sherri, and their 2 children, Lyla and Maddox, will be staying in the Seattle area where he will complete a Spine fellowship at Harborview Medical Center. Following fellowship, Jon hopes to secure an academic position at a teaching institution.

Graduating Residents



Erik Magnusson, MD

Erik and his wife, Carly, will stay in Seattle while he completes a fellowship in Orthopaedic Trauma at Harborview Medical Center. Carly will continue to work at Virginia Mason Medical Center as a hospitalist. They hope to remain in the Pacific Northwest after Erik completes fellowship.



Mary Kate Thayer, MD

After graduation, Mary Kate and her husband Lew will be moving to Baltimore where she will complete a fellowship in Hand Surgery at the Curtis National Hand Center. Afterwards, they will be coming back home to the Seattle area where Mary Kate will be starting practice.



Adam O'Brien, MD

Adam, his wife Mallory, their daughter Quinn, and dog Baylee will be moving to Houston where he will complete a fellowship in Sports Medicine at UT Houston. After fellowship, he hopes to stay and practice in the great state of Texas.



Claudia Thomas, MD

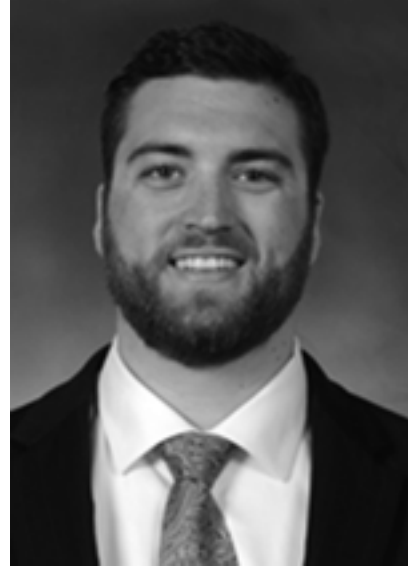
Claudia and her husband, Chris, will be moving to Pittsburgh for her sports medicine fellowship at Allegheny General Hospital, after which Claudia will practice with the US Air Force. With family and friends across the country, they are excited to keep their post-military plans open.

Incoming Residents



Michael Alley, MD

Michael was raised in Wyoming and attended the University of Wyoming, receiving a BS in Molecular Biology and Physiology. He then received a medical degree from the University of Washington. When not engaged with clinical duties, Michael enjoys hunting, fly fishing, trips into the mountains and golf.



Max Coale, MD

Max grew up on a horse farm outside of Baltimore, Maryland. He earned his undergraduate degree from Princeton University, before graduating from the University of Maryland School of Medicine. Outside of work, you'll find him cooking in the kitchen, watching sports, or hiking with his wife and dog, Moose. Max's areas of interest are trauma and sports medicine.



Kurtis Carlock, MD

Kurtis grew up in Fairfax Station, Virginia, and attended the University of Virginia for his undergraduate studies. He earned his medical degree at New York University in Manhattan. His areas of interest include trauma, arthroplasty, and sports medicine. Outside of work, Kurtis enjoys skiing, hiking, running, baseball, and board games.



Derek Nhan, MD

A native of Seattle, Derek graduated with a BS from the University of Washington. He then earned his medical degree from the University of Colorado. Between his 3rd and 4th years there, he completed the Poggi Orthopaedics Fellowship at Johns Hopkins and received a certificate from the Bloomberg School of Public Health.

Incoming Residents



Ena Nielsen, MD

Ena grew up in Mesa, AZ. She attended the University of Southern California for both her undergraduate and medical studies. Her area of interests are pediatrics, oncology, and trauma. Outside of work she loves running, hiking, soccer, and cooking.



Pooja Prabhakar, MD

Pooja was born in Chennai, India and grew up in Houston, Texas. She graduated from UT Austin with a BA in Economics before completing her medical education at UT Southwestern in Dallas, Texas. Her interests include global health and health disparities. She enjoys tennis, Indian classical dance, and cooking.



Avrey Novak, MD

Avrey grew up in Spokane, Washington and attended the University of Washington for her undergraduate studies, she then went on to complete her medical degree at UW. Her areas of interest include trauma and arthroplasty. In her spare time she enjoys hiking, skiing, soccer and crabbing with friends and family.



Matthew Vincent, MD

Matt was born and raised in the Seattle, WA area and attended Harvard University for his undergraduate studies. He went on to earn his medical degree at University of Washington School of Medicine. His areas of interest include spine, hand, and trauma. Outside of work, Matt enjoys hiking, travel, rowing, and film.

ACEs and Fellows



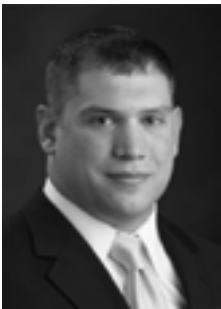
Jerad Allen, MD
Trauma



Kristin Cola, MD
Pediatrics



Robert Jacobs, MD
Trauma



Gonzalo Barinaga, MD
Hand



Ashraf El Naga, MD
Spine



Kimberly Jacobsen, MD
Trauma



Arash Calafi, MD
Foot & Ankle



Joseph Fox, MD
Pediatrics



Edward Jung, MD
Spine



Albert Chan, MD
Oncology



Don Hoang, MD
Hand

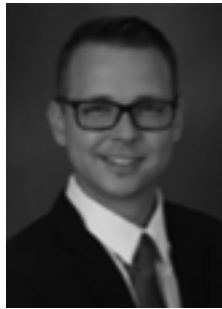


Jorge Manrique-Succar, MD
Oncology

ACEs and Fellows



Erin Miller, MD
Hand



Ryan Schmucker, MD
Hand



Robert Wojahn, MD
Trauma



Matthew Napierala, MD
Shoulder & Elbow



Jennifer Tangtiphaibontana, MD
Trauma



Benjamin Woodhead, DO
Shoulder & Elbow



Eric Rebich, DO
Spine



Megan Walters, MD
Foot & Ankle



Alexander Sawatzke, MD
Foot & Ankle



Nathan A. Wigner, MD, PhD
Spine

Research Grants

National Institutes Of Health

Blood Flow Restriction for Anterior Cruciate Ligament Reconstruction
Scott Telfer, EngD

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
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

Static Preload Confounds Bone Anabolism
Sundar Srinivasan, PhD
Steven D. Bain, PhD
Ted S. Gross, 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 for Limb Loss and MoBility (CLIMB)
Bruce J. Sangeorzan, MD

Do Rocker Bottom Shoes and Ankle-Foot Orthoses Reduce Pain and Improve Mobility for Ankle Osteoarthritis Patients?
Bruce J. Sangeorzan, MD
Patrick M. Aubin, PhD

American Board of Medical Specialties

ABMS/ABOS Visiting Scholar Program
Amy Cizik, PhD, MPH

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 2018 Fellowship Program Grant
Winston J. Warme, MD

Acumed

Acumed Education Grant
Jerry I. Huang, MD

Antegrade Intramedullary Compression Screw Fixation of Metacarpal Fractures: a CT and Cadaver Study
Jerry I. Huang, MD
Don Hoang, MD

Research Grants

Arthrex, Inc.

Arthrex Fellowship Educational Grant
Winston J. Warne, 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

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

Brotman Baty Institute

Single Cell Atlas for Regeneration
Ronald Y. Kwon, PhD

Conventus Orthopaedics, Inc.

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

DePuy, Inc.

DePuy Synthes AO Basic Course R2s
Douglas P. Hanel, 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

Institute for Stem Cell and Regenerative Medicine

A Novel Wnt Interaction Underlying Appendage Regeneration
Ronald Y. Kwon, PhD

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, MA
Bruce J. Sangeorzan, MD
Conor P. Kleweno, MD
Daphne M. Beingessner, MD
David P. Barei, MD
Lisa A. Taitzman, MD, MPH
M. Bradford Henley, MD
Michael E. 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

Research Grants

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, MPH

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

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 OA

Conor P. Kleweno, MD

COTA Trauma Fellowship

David P. Barei, MD

Synthes USA

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

UW Royalty Research Fund

A Novel Wnt Interaction Underlying Genetic

Risk for Osteoporosis

Ronald Y. Kwon, PhD

Department Publications 2018-2019

A list of publications authored by our faculty from January 2018 to May 2019. 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.
2. Adams MR, Koury KL, Mistry JB, Braaksma W, Hwang JS, **Firoozabadi R**. Plantar Medial Avulsion Fragment Associated With Tongue-Type Calcaneus Fractures. *Foot Ankle Int*. 2019 Mar 6;1071100719830948.
3. Aklilu S, **Barei DP**, Chew FS. Disengagement and intrapelvic migration of a dynamic helical hip screw. *Radiology case reports*. 2019 Feb;14(2):291-7.
4. Andring N, **Kennedy SA**, **Iannuzzi NP**. Anomalous Forearm Muscles and Their Clinical Relevance. *J Hand Surg Am*. 2018 May;43(5):455-63.
5. **Bain SD**, Huber P, Ausk BJ, **Kwon RY**, **Gardiner EM**, **Srinivasan S**, **Gross TS**. Neuromuscular dysfunction, independent of gait dysfunction, modulates trabecular bone homeostasis in mice. *J Musculoskelet Neuronal Interact*. 2019 Mar 1;19(1):79-93.
6. **Bauer JM**, Butler MP, Schoenecker PL, Schoenecker JG. Trochanteric-sparing Proximal Femoral Resection for Arthritic Spastic Hips. *Techniques in Orthopaedics*. 2018;Publish Ahead of Print.
7. **Bauer JM**, Ditro CP, Mackenzie WG. The Management of Kyphosis in Metatropic Dysplasia. *Spine Deform*. 2019 May;7(3):494-500.
8. **Bauer JM**, Moore JA, Rangarajan R, Gibbs BS, Yorgova PK, Neiss GI, Rogers K, Gabos PG, Shah SA. Intraoperative CT Scan Verification of Pedicle Screw Placement in AIS to Prevent Malpositioned Screws: Safety Benefit and Cost. *Spine Deform*. 2018 Nov - Dec;6(6):662-8.
9. **Bauer JM**, Yanamadala V, Shah SA, Sethi RK. Two Surgeon Approach for Complex Spine Surgery: Rationale, Outcome, Expectations, and the Case for Payment Reform. *J Am Acad Orthop Surg*. 2019 May 1;27(9):e408-e13.
10. **Bauer JM**, Yorgova P, Neiss G, Rogers K, Sturm PF, Sponseller PD, Luhmann S, Pawelek JB, Shah SA, Growing Spine Study G. Early Onset Scoliosis: Is there an Improvement in Quality of Life With Conversion From Traditional Growing Rods to Magnetically Controlled Growing Rods? *J Pediatr Orthop*. 2019 Apr;39(4):e284-e8.
11. Bayomy AF, Bompadre V, **Schmale GA**. The Impact of Transphyseal Anterior Cruciate Ligament Reconstruction on Lower Extremity Growth and Alignment. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association*. 2019 Mar;35(3):940-9.
12. Bayona CEA, Somerson JS, **Matsen FA, 3rd**. The utility of international shoulder joint replacement registries and databases: a comparative analytic review of two hundred and sixty one thousand, four hundred and eighty four cases. *Int Orthop*. 2018 Feb;42(2):351-8.
13. Bellevue KD, Thayer MK, Pouliot M, **Huang JI**, **Hanel DP**. Complications of Semiconstrained Distal Radioulnar Joint Arthroplasty. *J Hand Surg Am*. 2018 Jun;43(6):566 e1- e9.
14. **Blumberg TJ**, Bremjit P, Bompadre V, **Steinman S**. Forearm Fixation is Not Necessary in the Treatment of Pediatric Floating Elbow. *J Pediatr Orthop*. 2018 Feb;38(2):82-7.
15. **Blumberg TJ**, DeFrancesco CJ, Miller DJ, Pandya NK, Flynn JM, Baldwin KD. Firearm-associated Fractures in Children and Adolescents: Trends in the United States 2003-2012. *J Pediatr Orthop*. 2018 May 2.
16. **Blumberg TJ**, Woelber E, **Bellarbarba C**, **Bransford R**, Spina N. Predictors of increased cost and length of stay in the treatment of postoperative spine surgical site infection. *Spine J*. 2018 Feb;18(2):300-6.
17. Bouchard M, Mattioli-Lewis T, Czerniecki S, Shenoi S, **Goldberg MJ**. Czech Dysplasia Masquerading as Juvenile Idiopathic Arthritis. *J Clin Rheumatol*. 2018 Oct 30.
18. Bram JT, Baldwin KD, **Blumberg TJ**. Gram Stain is Not Clinically Relevant in Treatment of Pediatric Septic Arthritis. *J Pediatr Orthop*. 2018 Oct;38(9):e536-e40.
19. Brown MC, Westermann RW, **Hagen MS**, Strnad GJ, Rosneck JT, Spindler KP, Lynch TS. Validation of a Novel Surgical Data Capturing System After Hip Arthroscopy. *J Am Acad Orthop Surg*. 2019 Feb 12.
20. Cahill PJ, Samdani AF, Brusalis CM, **Blumberg T**, Asghar J, Bastrom TP, Pasha S, Refakis CA, Pahys JM, Flynn JM, Harms Study G, Sponseller PD. Youth and Experience: The Effect of Surgeon Experience on Outcomes in Cerebral Palsy Scoliosis Surgery. *Spine Deform*. 2018 Jan;6(1):54-9.
21. Carr DA, Saigal R, Zhang F, **Bransford RJ**, **Bellarbarba C**, Dagal A. Enhanced perioperative care and decreased cost and length of stay after elective major spinal surgery. *Neurosurg Focus*. 2019 Apr 1;46(4):E5.
22. Chang IJ, Sun A, Bouchard ML, Kamps SE, Hale S, Done S, **Goldberg MJ**, Glass IA. Novel phenotype of achondroplasia due to biallelic FGFR3 pathogenic variants. *American journal of medical genetics Part A*. 2018 Jul;176(7):1675-9.
23. Cheng CW, **Cizik AM**, Dagal AHC, Lewis L, Lynch J, **Bellarbarba C**, **Bransford RJ**, **Zhou H**. Body mass index and the risk of deep surgical site infection following posterior cervical instrumented fusion. *Spine J*. 2019 Apr;19(4):602-9.
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- glue embolization and excision for the treatment of venous malformations. *CVIR Endovasc.* 2018;1(1):22.
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 28. Dagal A, **Bellarbarba C**, **Bransford R**, Zhang F, Chesnut RM, O'Keefe GE, Wright DR, Dellit TH, Painter I, Souter MJ. Enhanced Perioperative Care for Major Spine Surgery. *Spine (Phila Pa 1976).* 2018 Dec 19.
 29. Eby SF, Hilaire TS, Glotzbecker M, Smith J, **White KK**, Larson AN, Children's Spine Study G. Thoracogenic spinal deformity: a rare cause of early-onset scoliosis. *Journal of neurosurgery Spine.* 2018 Dec 1;29(6):674-9.
 30. Favinger JL, Hippe DS, Davidson DJ, Elojeimy S, Roth ES, **Lindberg AW**, Ha AS. Soft Tissue Sarcoma Response to Two Cycles of Neoadjuvant Chemotherapy: A Multireader Analysis of MRI Findings and Agreement with RECIST Criteria and Change in SUVmax. *Acad Radiol.* 2018 Apr;25(4):470-5.
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 32. French MH, McCauley JC, Pulido PA, **Brage ME**, Bugbee WD. Bipolar Fresh Osteochondral Allograft Transplantation of the Tibiotalar Joint: A Concise Mid-Term Follow-up of a Previous Report. *J Bone Joint Surg Am.* 2019 May 1;101(9):821-5.
 33. Ghotme KA, Alvarado-Gomez F, Lampe C, **White KK**, Solano-Villareal M, Giugliani R, Harmatz PR. Spinal cord issues in adult patients with MPS: transition of care survey. *Childs Nerv Syst.* 2018 Sep;34(9):1759-65.
 34. Gibly RF, Shomaker T, Bompadre V, **Steinman SE**. Understanding the spectrum of paediatric mechanical finger and hand trauma seeking acute care. *Journal of children's orthopaedics.* 2018 Dec 1;12(6):622-8.
 35. Gistelincx C, **Kwon RY**, Malfait F, Symoens S, Harris MP, Henke K, Hawkins MB, Fisher S, Sips P, Guillemy B, Bek JW, Vermassen P, De Saffel H, Witten PE, Weis M, De Paepe A, **Eyre DR**, Willaert A, Coucke PJ. Zebrafish type I collagen mutants faithfully recapitulate human type I collagenopathies. *Proc Natl Acad Sci U S A.* 2018 Aug 21;115(34):E8037-E46.
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 37. **Githens M**, Garner MR, **Firoozabadi R**. Surgical Management of Atypical Femur Fractures Associated With Bisphosphonate Therapy. *J Am Acad Orthop Surg.* 2018 Dec 15;26(24):864-71.
 38. Glassman DM, Magnusson E, Agel J, **Bellarbarba C**, **Bransford RJ**. The impact of stenosis and translation on spinal cord injuries in traumatic cervical facet dislocations. *Spine J.* 2019 Apr;19(4):687-94.
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