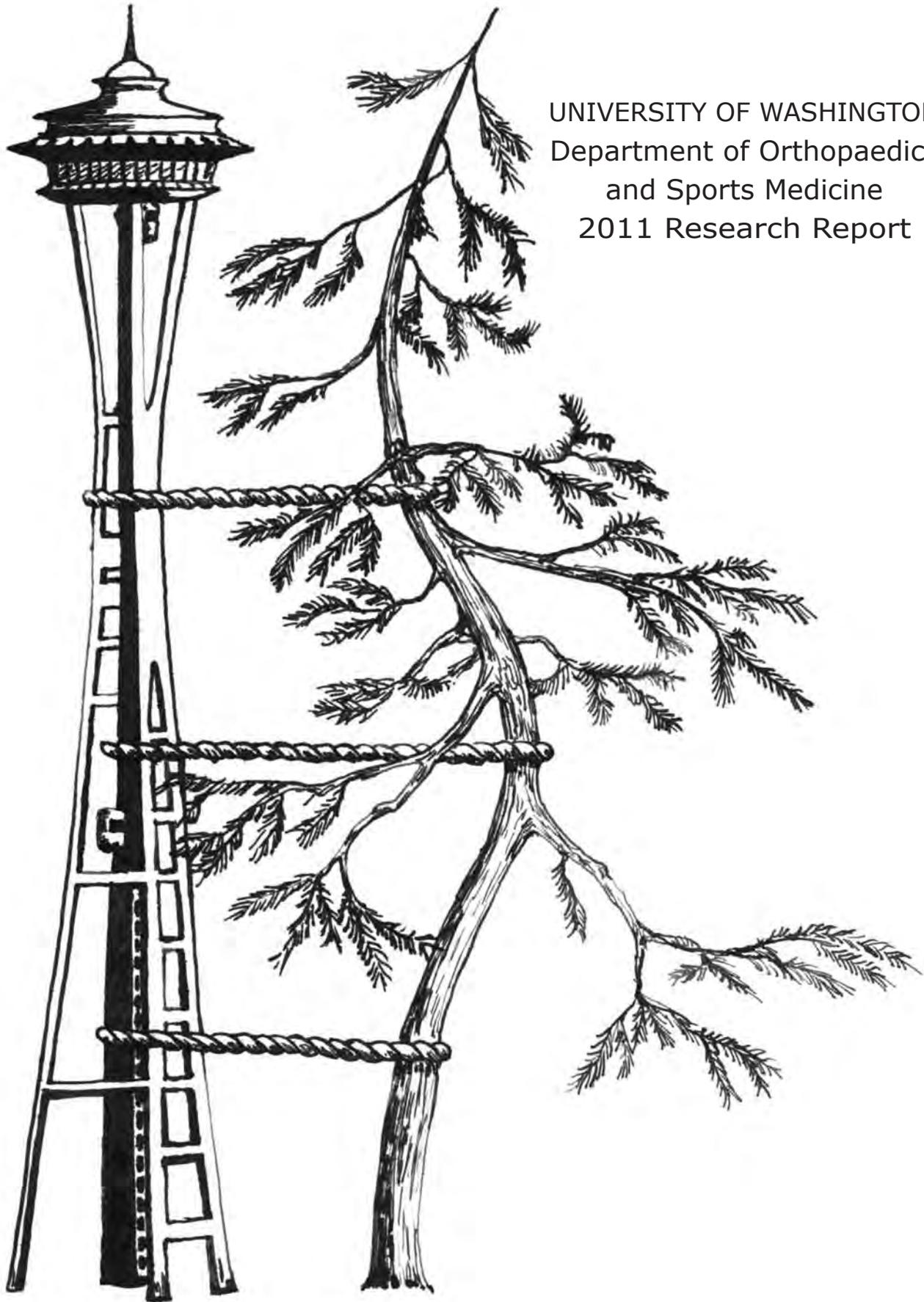




Orthopaedic Discoveries 2011

University of Washington Orthopaedics & Sports Medicine

UNIVERSITY OF WASHINGTON
Department of Orthopaedics
and Sports Medicine
2011 Research Report



UW Medicine
SCHOOL OF MEDICINE

Department of Orthopaedics and Sports Medicine
University of Washington
Seattle, WA 98195

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Front Cover Illustration: Short-eared Owl (*Asio flammeus*), Camano Island, WA, Photographer: Peter R. Cavanagh

The owl is historically associated in Western culture with wisdom although other cultures and mythologies have identified the owl with sorcery, bad luck, and ill health.

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De ar Friends
o f
University of
Washington
Orthopaedics and
Sports Medicine,
Thank you for
your interest and

support of our Department over the past year. This past academic year has brought a great deal of developments, which I would like to share with you in some opening thoughts and throughout the pages of this report. I apologize for the wordiness of this message, the volume of news does, however, require some space. Before I present to you highlights of our Department's ongoing evolution I wanted to reflect on two significant transitions affecting our faculty.

Bill

Undoubtedly you have heard by now that our former partner and Alumnus '94 Dr. William "Bill" Mills Jr. has sadly passed away after sustaining critical injuries while skiing with his son Isiah near his home in Alaska. We recognize Bill's tremendous élan as well as his multiple contributions to many different areas in clinical research, education and patient care. As Dr. M.L. 'Chip' Routt so aptly stated "Bill was simply relevant". If you haven't done so yet, please take a look at our Special Memorial Grand Rounds featuring several guest speakers who provided a review of this wonderful colleague's contributions. We will also recognize Bill's life and work in this summer's Second Annual Summit in Seattle July 28-30th at Harborview with a session on Polytrauma dedicated to him. Together with Bill's family we will provide a permanent home for the spirit and memory of Dr. William Mills Jr. in our Department rooms at Harborview for inspiration of future Orthopaedic colleagues. For further information on Bill please see the memorial starting on page 4 and refer to the following URL: <http://www.orthop.washington.edu/PatientCare/tabid/860/mid/9499/articleId/252/ctl/ReadBlog-v1/Default.aspx>

Ted

This summer a true giant and living legend of Orthopaedic Surgery working right in our own backyard - Sigvard "Ted" Hansen, M.D. - is retiring after a career spanning from Internship and residency starting in 1965 to the present day, all in the same institution. Despite the remarkable duration of his career the mystery of what to call him - 'Sig', 'Ted' or 'Dr. Hansen' - has never been conclusively resolved, least by the master himself, who seems to have taken some delight in keeping everyone guessing. As is well known to most of you, Ted's influence on

modern day Orthopaedic Surgery cannot be overstated. He changed the 'wait and see' fracture care approach into modern day trauma surgery with early and decisive minimally invasive but maximally effective interventions. In the second phase of his career he turned Foot and Ankle surgery from a 'pins and plaster' oriented improvisational craft into a specialty which could confidently reconstruct even the most desperate Foot and Ankle disorders into workable extremities using methodologically sound and reproducible modern internal fixation strategies. Sig / Ted



Sigvard Hansen, M.D. teaching residents (above) and receiving the Harborview Lifetime Achievement Award from Dean Paul Ramsey, M.D. (below).

embodies the spirit that elevates our Department to its internationally renowned status: relentless pursuit of excellence, technical perfection and dedication to 'every patient every time', even if it were to run afoul of contemporary conventional wisdoms. Again, this year's Summit in Seattle July 28-30th (<http://www.orthop.washington.edu/Portals/21/www/Patient%20Care/Newsroom/News/Summit%20in%20Seattle%202011/Summit%20in%20Seattle%202011.pdf>) will provide a forum to wish Ted well as he is heading into the Professor Emeritus phase of his career. Of his many qualities Ted's unwavering dedication to teaching has the potential of creating an especially lasting legacy. Anyone of the over 500 residents, fellows and colleagues who have had a chance to operate with the master will likely never forget the experience. The picture enclosed is less than a month old – it shows this incredible man still enjoying the opportunity to teach our next generation at our Monday morning Resident Teaching conferences. In recognition of his ongoing dedication to education our Chief Residents themselves have funded an annual award named the '**Sigvard T. Hansen, M.D. Teaching Award**' to be given starting this year to the graduating resident who has shown most initiative and effort towards education. With his skills undiminished and his crystal-clear mind as sharp as ever, Sig / Ted will hopefully continue to provide our Department with his advice and

presence for years to come.

Investigations

Our research enterprise has been able to climb to new heights in terms of major grants won over the past year – a reflection of several areas of remarkable advancements in disparate fields such as mechanobiology of bone, cartilage repair, oncologic sarcoma care, and biomechanical modeling in a number of subspecialty areas (to name a few). Our effort in coalescing musculoskeletal research into a major cohesive research effort with critical mass potential has matured from a task force status to formulation of a concept for formation of an **Institute for Translational Musculoskeletal Health (ITMSH)**. Under leadership of our Vice Chair of Research, Dr. Peter Cavanagh, and with support of our School of Medicine we have made considerable progress in making a real difference in meeting the musculoskeletal needs of our growing segment of aging but active citizens. In addition to our outstanding present-day in house research faculty we are initiating a number of key recruitments and are seeking to reshape our musculoskeletal research into a single but well-connected institute in the near future to turn this vision into reality. We are looking for supporters who are interested in joining us at in our startup phase of our game-changing ITMSH venture – please visit our website or contact me directly if you would like to learn more about our plans and

opportunities.

Teaching

Our nationally and internationally acclaimed faculty has had an outstanding year in providing education in a wide array of settings and country. We counted 37 UW presentations at our annual AAOS meeting in San Diego 2011, in addition to our faculty providing visiting professorships, chairmanships, moderator roles, and scientific presentations at over one hundred courses and society meetings in North America and around the world with organizations such as AO, AOA, ASSH, AOF, IFAB, ORS, CSRS, POSNA, NASS, AB&J, Global Spine Congress and many more. We also have a number of new initiatives to provide education in our own region: our new 'Outreach program' under direction of Dr. Sean Nork partners with local communities in the WWAMI region for high quality educational events on all things Orthopaedic and Trauma related. Based on the success of our inaugural 2010 Summit in Seattle we will provide a number of regular educational programs right here in Seattle. We have also received praise for our unique monthly CME certified **Orthopaedic Grand Rounds Minisymposia** and interdisciplinary **Spine Grand Rounds** as well as a large number of other educational meetings (see page 91 with listing of educational events) and hope that many of you will make use of these high-quality offerings whenever possible.

Most gratifying of all of our educational ventures perhaps is our resident teaching program in which faculty, fellows, and senior residents partner in providing a truly multidimensional educational experience with a steady home in the Harborview ISIS Lab facilities, which has helped our residents be nationally ranked and recognized in all measurable ways (see Residency report page 87). Our residency curriculum under leadership of our Program director Dr. Doug Hanel has implemented a number of major reallocations of our residency rotations. Some key features of our new curriculum are a full 6 month block of contiguous Pediatric Orthopaedic experience at SCH, a Foot & Ankle experience before the fellowship application deadline



An example of our outreach is Airlift Northwest. Pictured here (left to right): Sean Nork, M.D., Associate Professor UW Orthopaedics; Anthony Avellino, M.D., Professor and Vice Chair Neurosurgery; Maribeth Capeloto, R.N., UW Outreach; Christine Martin, R.N., Executive Director Airlift Northwest.



A sketch of the new location for our Sports Medicine Clinic, the soon to be remodeled Husky Stadium.

and a Sports Medicine exposure in all four senior years. Research is now a regular and planned component of the maturation process of our residents. Our Research Faculty headed by Dr. Peter Cavanagh and our clinicians with fiscal support and direct engagement will now provide a formal pathway towards successful research and publications of our residents. I view it as an early success of the inaugural year of this program that our residents presented not one case series during this year's Resident Research Day! It is largely due to the initiative of our wonderfully engaged residents that UW Medical students have now 'discovered' musculoskeletal medicine as important component to general patient well-being and have created **OSSMIG (Orthopaedic Surgery and Sports Medicine Interest Group)** to enhance educational opportunities for all four years of student learning beyond the regular curriculum. In recognition of this strong interest we have dedicated a section of our Departmental website to UW Medical students interested in Orthopaedics and our residents offer a great multitude of 'touchpoints' for future colleagues.

Healing

Over the past year our Department has withstood potentially adverse developments, such as the profound economic downturn, our ongoing Chair transition, and major systems reorganizations in solid form. Together with a number of key partners within UWMedicine we are poised to offer a number of significant developments to the health benefit of the public at large.

UWMedicine now has expanded its clinical facilities with the affiliation with Northwest Hospital in North Seattle and the recently formed strategic alliance with Valley Medical Center in Renton. Improved access to care is but one of the many key clinical initiatives. The UW Medicine '**Patients First**' Initiative has provided a valuable banner for efforts to provide unremitting quality of care to all of our patients and document our expertise, efforts and success accordingly. I am very proud of the present day accomplishments of our Department and anticipate our ongoing process evolution to be reflected in a further enhancement of our national standings in the very near future.

UWMedicine has provided tangible investments into our ability to provide access and expertise to the public in the future in unprecedented ways. Most recently, UWMedicine signed a contract with the University of Washington Athletic Department for location of a multidisciplinary **Sports Medicine Clinic** within the walls of the soon to be remodeled Husky Stadium. While UW Medicine is trendsetting in Primary Care and its expertise in managing the terrible T's (Trauma, Transplants, Tumors) is renowned, we will be able to offer a unique integrated Sports Medicine care facility to our activity- and health minded patients staffed with nationally renowned providers starting 2013. Our colleagues at **Seattle Childrens Hospital** under leadership of Dr. Ernest 'Chappie' Conrad have experienced substantial programmatic expansions in regards to faculty recruitments and resource allocations. Look for our

SCH Pediatric Orthopaedic program to make a serious impact on the national scene as a major destination facility for expert pediatric care. (see page...) In virtually all of our clinical subspecialties and facilities we will roll out novel value driven approaches to integrated musculoskeletal patient care within the next 2 years. All of these clinical projects will share the virtues of accessibility, accountability and outstanding expertise combined with demonstrable treatment quality to benefit our patients by receiving truly superior health care through us. Our leadership group including Drs. Howard Chansky, Chappie Conrad, Doug Hanel, Brad Henley, Bruce Sangeorzan, and our Director Ken Karbowski deserve great praise for their vision and continued efforts. In this context we are proud to introduce to our community two new faculty members – Michael Brage, M.D. in Foot & Ankle surgery (HMC and UWMC) and Darin Davidson, M.D., MPH in Orthopaedic Oncology (UWMC and SCCA). Both are nationally recognized and offer significant care enhancements for patients in the Northwest.

Final Thoughts

As Chair-elect of this eminent Department it is an honor to present to you this year's edition of the Orthopaedic Research Report. It reflects a tremendous amount of hard work and dedication of a good many great people. After reading this report I hope that you will feel inspired to stay connected with us in the future in ways direct (by participating in our meetings or supporting our research endeavors) or indirect (for instance through our new and interactive website or by watching our regular UWTV programming). It is a truly wonderful group of people that in past or present have contributed to our Department. *Staying in touch continues to enrich all of us through the power of our shared memories as we move onward with our lives. (Anonymous)*

Jens R. Chapman, M.D.
 Professor and Chair-Elect
 HansJörg Wyss Endowed Chair
 Department of Orthopaedics and
 Sports Medicine
 Adjunct Professor of Neurological
 Surgery

In Memoriam: William J. Mills III, M.D.

July 21, 1957 – March 15, 2011

Our UW Orthopaedic Surgery community has been hit hard with the news of the loss of our dear friend, Residency Alumnus '95 and our former faculty partner William J. Mills III, M.D. on March 15th, 2011 following a tragic skiing accident near his home in Alaska. A brief review of his life reflects a unique life so rich in experiences and accomplishments, a life, which was cruelly cut short way too soon.



Bill's lineage was the kind of material that novels are made of: He was born July 21, 1957 to William and Elaine Mills in Anchorage, AK. His father Bill Mills Sr., M.D. was the first General Surgeon to settle down to practice in the State of Alaska and is considered a pioneer in frostbite and cold thermal injury care. Bill grew up in Anchorage and was a state championship swimmer during his high school years. He graduated from the University of Michigan in 1979 with a Bachelor of Science degree after winning the Vandenberg Scholar Award in the same year. Following several years of work in his home state of Alaska in a variety of capacities, which included commercial fishing in the Behring Sea, Bill next completed a Master of Science Degree at the University of Minnesota, Duluth in 1985. From 1985-1989 he attended the University of Colorado in Denver.

There he met his future wife Carey Jackson, a fellow medical student.

We were fortunate to have Bill join us for Internship in General Surgery and then Residency at the University of Washington from 1989 through 1995. He won the Victor Frankel Award for an outstanding scientific paper upon his graduation in 1995. Bill fulfilled his commitment to the US Navy from 1995 through 1998 mainly stationed in San Diego, California. While on staff with the Navy Bill won the Resident Teaching Award and the Gerald Cady Research Award. After retiring from the Navy, with the rank of a Lieutenant Commander, he joined our faculty as Assistant Professor in 1998 through his promotion to Associate Professor in 2004. While on full-time faculty with us at Harborview Medical Center, Bill distinguished himself with his work in Traumatology and Sports Medicine, combining these two entities with a degree of accomplishment rarely – if ever – seen. He received the UW Orthopaedic Surgery Teaching Award in 2003 in reflection of his outstanding qualities as educator. Despite being a proud father of then 3 young children and clinically highly active Bill managed

topics included descriptions of novel approaches for humerus fracture care, he reported on pelvic fracture fixation using minimally invasive techniques and reset the bar for care of patients with multiligament knee injuries.

Later on, Bill decided to follow the call of the wild and returned to his home state of Alaska from 2005 onward, joining Orthopaedic Physician Anchorage (OPA) where he rapidly became a central much admired figure in regional trauma and sports care. Back home in Alaska Bill could pursue his passions for fishing, hunting and any outdoor activity together with his family more immediately than in Seattle. Clinically, Bill remained an influential and very active Clinical Associate Professor in our Department until his unfortunate end – influencing a great many students to pursue careers in Orthopaedic Surgery.

Bill left behind his wife Carey and their children Isabel (16), Jackson (14) and Isiah (11), as well as Emily (26) and Tyler (23) from his first marriage.

A Celebration of Life was held on behalf of Bill on a beautiful Sunday afternoon in Anchorage on March 20th, 2011. These proceedings were attended



Carey and Bill Mills. Bill is wearing his infamous jeans jacket.

to publish 23 peer reviewed papers with an astounding thematic range and Journals, including JBJS, JPO, J Trauma, J Orthop Trauma, Injury and CORR to name the most popular. His

by over 1,300 friends and family who had congregated from all over North America. The Harborview and UW community also commemorated Bill's life with Memorial Grand Rounds titled



"Things Dr. Bill Mills taught us ..." at Harborview Medical Center on April 6th in front of members of Bill's family. We will also feature a special tribute to Bill in our 2nd Annual Summit in Seattle from July 28-30th with several noted guest speakers. Our Department will work with Bill's family to inspire future generations of UW Orthopaedic surgeons through the example of this man's unwavering love of family and life while practicing his craft with passionate dedication and remaining a quality person through and through.

One of Bill's children wrote the following Haiku describing his father. I cannot imagine a more concise way to describe the many qualities of Bill.

Wildly popular
Intelligent
Loving
Life changing
Incredible
Amazing
Mostly Perfect

My dad
Ingenious
Loved all people
Lived life to the fullest
Superhero (to me)



The Family of Bill requests that any donations be directed to the Juvenile Diabetes Foundation.

A Very Successful Year in Orthopaedics



Prom King Sigvard Ted Hansen, M.D.



Appointments and Promotions Committee Chair Ted Gross, Ph.D.



Our UWDOMS Research Council



Sean Nork, M.D. and our outreach speakers



Jenie and David Barei



Doug and Peggy Hanel



Drs. Buz Burkhead and Rick Matsen



Dr. Michael Copass (front middle) at Paramedics Trauma Symposium with faculty



Daphne Beingessner



Laukien Prize winner John Sidles, Ph.D.



Liu Yang, Ph.D.



Vice Chair for Research Peter Cavanagh, Ph.D., D.Sc.



Michael Lee, M.D. instructing resident Jacques Hacquebord, M.D.



Michael J. Goldberg, M.D.



Drs. Clawson, Wagner, and Hansen



Chip Routh and Jason Wilcox



Sigvard Ted Hansen and Michael Brage



Residents Aaron Chamberlain, Jennifer Hagen, and Brian Daines



UW Fellows reunion in Davos, CH: Drs. Tim Webber, Darrel Brodke, J.R. Chapman and Bruce Twaddle



Grand Rounds speakers on Clubfoot: Drs. Adam Bakker, Vince Mosca and Rob Veith

Mike Metcalf, M.D. 2011 Grateful Alumnus University of Washington School of Medicine



The Metcalf Family

Mike Metcalf was born (the 6th of 10 children) as his dad Bob was finishing orthopedic residency. As a teenager Mike helped out with his Dad's arthroscopy seminars, shuttling doctors to meetings and running slide projectors during presentations. In 8th grade, Mike decided he wanted to follow in his Dad's footsteps and become an orthopedic surgeon.

Mike received a Bachelor of Science in Biology and attended medical school at the University of Utah. After completing a senior rotation at Harborview as a medical student, Mike was excited to match at the top orthopedic program in the country and move with his family to Seattle to complete his residency at the UW. He had the opportunity to do an additional year of shoulder research with Dr. Matsen. Mike has great memories of his residency, though they were tough and busy years. His wife Jane appreciated the support of other resident wives. Resident families often socialized and commiserated on their experiences.

Mike did a Sports Medicine fellowship with Dr. Savoie in Jackson, Mississippi then returned to Utah where he specializes in shoulders at the Rosenberg, Cooley, Metcalf Clinic in Park City. Two of his current partners, Vern Cooley and Tim Beals, were also UW residents. Mike lives in Salt Lake City with his wife and 5 children (ages 9-19). He wants to give back to the UW orthopedic program because he felt very blessed by the generosity of prior residents who provided opportunities he couldn't have afforded during residency.

Craig T. Arntz, M.D. 2011 Distinguished Alumnus University of Washington School of Medicine



Top photo: The Arntz family. Bottom left: Craig and Josie Arntz. Bottom right: The Valley Orthopaedics Team - listed with their residency in parentheses - Back Row, left to Right: Chris Howe (UW), Erik Novak (UCSF, foot fellowship UW), Mark Remington (UW), Martin Tullus (UW), Rob Veith (UW), William Barrett (UW). Front Row, left to Right: Susan Cero (UW), Niket Shrivastava (Columbia), Fred Huang (UW), Craig Arntz (UW), Traci Barthel (Case Western Reserve, hand fellowship UW), John Howlett (UW), John Hendrickson (UW). Unfortunately Jason Thompson (UW) was unavailable for the picture.

Dr. Craig Arntz is an integral part of our Northwest orthopedic community. After finishing his orthopedic residency at the University of Washington, he completed a hand surgery fellowship in Lund, Sweden. He returned to the university for a shoulder and elbow fellowship where he was Dr. Frederick A. Matsen's first fellow.

After his fellowships, Dr. Arntz joined Valley Orthopedic Associates and has been there for 23 years. "I basically joined an extension of the University of Washington as many of my senior partners were ex-University of Washington orthopedic faculty," says Dr. Arntz. "I am so fortunate to have partners who are talented surgeons, exceptional people and great friends."

After he started practice, Dr Arntz played an active role as part of the clinical faculty. He staffed an orthopedic shoulder clinic at the University Hospital for 4 years. Afterwards, he ran a shoulder clinic with the residents at VA hospital for 8 more years. His dedication and enthusiasm for teaching residents is well known throughout our community.

Craig and Josie Arntz have been blessed with 5 wonderful children (Betsy, Jamie, Bryan, Kristina and Amanda). For the past twenty years Craig and Josie have been Guild members of the Juvenal Diabetes Research Foundation. Tragically, they lost their oldest daughter Betsy to complications of her diabetes last fall.

Dr. Arntz and his partners at Valley Orthopedics generously hosted an unprecedented and most memorable Alumni gathering last year, celebrating Dr. Matsen's incredible tenure as our Chairman for more than 23 years.

We are proud to honor Craig as our Distinguished Alumnus Emeritus 2011.

New Faculty



Michael E. Brage, M.D.

Dr. Michael E. Brage enters our department as an Associate Professor.

Dr. Brage joins us from the University of California (Irvine) where he was a Voluntary Associate Clinical Professor in the Department of Orthopaedic Surgery. Prior to that appointment, he was Assistant Professor of Clinical Orthopaedic Surgery as well as Director of Foot and Ankle Services at the Department of Orthopaedic Surgery, University of California, San Diego.

Dr. Brage completed medical school at the University of Illinois (Chicago) and his residency training at the University of Chicago Hospitals and Clinics.

He is not unfamiliar with the Northwest as he completed a fellowship in Foot and Ankle Surgery in our department at Harborview Medical Center in 1991-1992.

Dr. Brage is well known in the field of orthopaedic surgery. He treats disorders of the foot and ankle, including arthritis, tendon ruptures, tendinopathies, foot deformities (flatfoot, cavus feet, equinus problems), acute trauma and fractures, repair of nonunions, total ankle replacements with prostheses and with fresh allografts, repair of talar cartilage lesions, and ankle deformities.



Jason J. Wilcox, M.D.

Dr. Jason Wilcox is a graduate of the University of Notre Dame, where he received his bachelor's degree in 1998. He completed medical school at the University of Tennessee Health Science Center in Memphis with highest honors in 2004.

Jason completed his postgraduate training at the University of Washington Medical School before proceeding to the University of Utah for a fellowship in Sports Medicine.

Assistant Professor Wilcox has published research in the fields of arthroscopic reconstruction, sarcomas, and pediatric orthopaedic problems.

He specializes in knee ligament injury repair, shoulder injuries, as well as arthroscopic surgery. He sees patients at the University of Washington Medical Center and the Veteran's Affairs Puget Sound Healthcare System Seattle Division.

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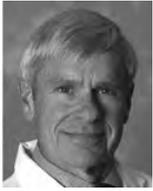


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Visiting Lecturers



Wayne Z. 'Buz' Burkhead, M.D.
2011 LeCocq Lecturer

This year at our annual LeCocq lecture on January 27th and 28th, we were honored to have Dr. Wayne Z. 'Buz' Burkhead, M.D. as our 2011 LeCocq Lecturer.

W.Z. Burkhead, M.D. a graduate of Southern Methodist University, Dr. W.Z. (Buz) Burkhead joined the W.B. Carrell Memorial Clinic in 1983.

He earned his M.D. degree from the University of Texas Medical Branch at Galveston. He then completed a residency in Orthopedic Surgery at the University of Texas Southwestern Medical School. This was followed by a fellowship in shoulder reconstructive surgery at the University of Texas Health Center at San Antonio under Charles A. Rockwood, Jr., M.D., one of the premier shoulder surgeons in the world.

The author of scientific articles, book chapters, and textbooks on the rotator cuff and dislocating shoulder, Dr. Burkhead has lectured at national, as well as international conferences. He was selected 1991 Presidential Guest Lecturer of the Japanese Shoulder Society and was a 1997 Traveling Fellow of the Royal College of Surgeons of England. He has been the guest lecturer at the National Orthopedic Association meetings of Spain and Japan.

Dr. Burkhead is widely known for the creation of modular replacement for the shoulder, and the development of advanced techniques for rotator cuff repair and shoulder stabilization. Dr. Burkhead has a special interest in athletic and industrial injuries, as well as arthritis of the shoulder. He performs arthroscopic, reconstructive and replacement surgery of the shoulder. Board certified, he is a Fellow of the American Academy of Orthopedic Surgeons and a member of the American Shoulder and Elbow Surgeons. He is also Clinical Associate Professor at the University of Texas Southwestern Medical School. Dr. Burkhead has privileges at Presbyterian Hospital of Dallas, Baylor University Medical Center and Mary Shiels Hospital.

Married and the father of three, Dr. Burkhead is the lead singer and spiritual leader of the all-doctor rock band Doctor Doctor. The band continues to play for charitable benefits and medical conferences.



Jeffrey C. Wang, M.D.
2011 OREF Hark Lecturer, Resident Research Day

This spring we were honored to have Dr. Jeffrey C. Wang as our OREF Hark Lecturer for Resident Research Day, May 20th.

Jeffrey C. Wang, M.D. is a Professor of Orthopaedic Surgery and Neurosurgery at the UCLA David Geffen

School of Medicine at UCLA. He is Director of the Orthopaedic Spine Surgery Service and Spine Fellowship Director. He obtained his B.S. degree with honors in Biological Sciences from Stanford University and proceeded to the University of Pittsburgh School of Medicine for his medical degree. After completing his residency at the UCLA Department of Orthopaedics, he completed a spine surgery fellowship with Dr. Henry Bohlman, M.D. at Case Western Reserve University Hospitals of Cleveland. He then accepted a full-time academic position at the UCLA Department of Orthopaedic Surgery and currently works at the UCLA Spine Center. He is active in clinical practice, actively runs a spine surgery fellowship program, and has a basic science research laboratory. He is involved in cutting edge research with an emphasis on novel biologics and tissue engineering for spinal fusion and disc regeneration.

Dr. Wang is on the board of directors of the Cervical Spine Research Society and on the board of directors for the North American Spine Society. He is a member of many medical organizations including the American Academy of Orthopaedic Surgeons, Cervical Spine Research Society, North American Spine Society, the Scoliosis Research Society. He was born in Mitchell, South Dakota and grew up in Fairmont, West Virginia, and now resides in Los Angeles, CA.

Digit and Limb Loss: Can We Regrow Them?

Christopher H. Allan, M.D.

Injuries to digits and limbs

Digit and limb loss and injury is a frequent and debilitating healthcare problem. One recent report found that approximately 1.2 million individuals in the United States sustained some form of amputation between 1988 and 1996. Finger amputations were the most common traumatic amputation, with 100,316 such injuries reported during the years studied. That study's authors pointed out that digit amputations managed without hospital admission (for example, injuries debrided and sutured in the emergency room) would not have been captured in the data they collected. The total number of such amputations sustained during those years was therefore potentially much greater. In addition, digit and limb amputations are survivable injuries, and so the number of persons sustaining such injuries in the years prior to 1988 or after 1996 and still living with their impairment is likely to be several times the number reported for those years.

If we include severe extremity trauma not resulting in amputation, the number of those affected grows substantially. The World Health Organization's 2003 "Report on the Burden of Musculoskeletal Conditions at the Start of the New Millennium" defines severe limb trauma as including fractures, dislocations, crushing injuries, open wounds, amputations, burns and neurovascular injuries to the extremities, and relates an incidence of 67.7 such injuries per 1000 population in the United States for the year 1996. They estimated the prevalence of such injuries at 35.8 per 1000 people,

representing 12% of all impairments from any cause, and totaling 9,475,874 persons with a loss, deformity or impairment of a limb in the United States alone. The number worldwide is certainly much larger.

Present treatments and their limitations

The consequences of even the smallest of these injuries can be significant, particularly for those individuals losing a thumb or multiple digits. Present treatments can restore only some of the function lost. As surgeons, we can attempt replantation (Figure 1) of amputated parts (if the part arrives in replantable condition and the patient's medical status allows), revise amputations to help accommodate later prosthesis fitting, borrow tissue from other locations (as with a toe-to-thumb transfer), and even transplant hands. It is extremely rare, however, for any of these treatment options to restore normal function, and all have potentially severe side effects. Replantation can fail, and complications related to the use of anticoagulation after surgery can lead to heart attack, stroke, or death. Successfully reattached parts rarely recover full sensory and motor function, and can be prone to painful cold intolerance. Prosthesis use cannot restore sensibility (although proprioceptive feedback is present), and may result in breakdown of skin on the residual limb stump. Tissue transfer can result in donor site deficits, such as gait disturbance after a toe-to-thumb procedure. Transplantation of hands requires (for now, at least) long-term

immunosuppressive drug therapy, which carries with it risks of infection and malignancy.

For all of these reasons, there is growing interest in what the fields of regenerative healing and tissue engineering might offer for our patients with severe extremity trauma.

Regeneration

The ability to regenerate lost body parts is present to a remarkable degree in urodeles (newts and salamanders), which can replace entire limbs, but is much less successful in higher vertebrates. Nevertheless, the observation has been made that distal fingertip amputations in children (Figure 2), and possibly adults as well, can heal with regrowth of normal tissue rather than scar. There is a great deal of interest in identifying the cellular and molecular mechanisms involved and in applying this information to amputations at more proximal levels. While the volume of tissue lost may prove too great a barrier to regeneration of a complete human limb, it seems plausible that amputated human digits might one day be induced to regrow. It is also possible that cellular and molecular events in the digit tip regrowth or regeneration process could be combined with the principles of tissue engineering to allow us to develop better solutions for digit and limb injury.

This phenomenon of digit tip regrowth has not been well studied in humans due to the lack of nondestructive methods for evaluating the healing wound. We have recently reported an in vitro human fetal digit



Figure 1a: Loss of four fingers in log-splitting accident. 1b: Amputated fingers. 1c: Final result after microsurgical reattachment: viable but stiff and poorly sensate digits.

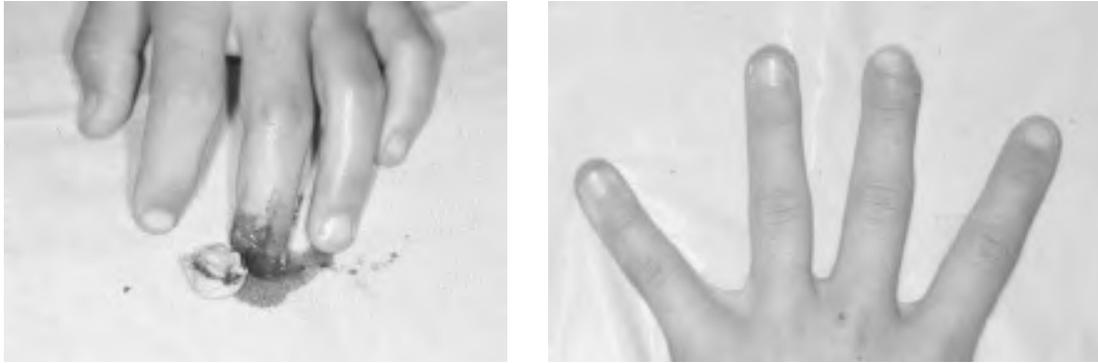


Figure 2: Seven-year-old child: tip amputation of middle finger; healed with regrowth of multiple tissue types.

model that offers opportunities for investigation not previously available.

Human studies

Building on observations in human children and on laboratory work in the mouse, our group has recently described the first in vitro human fetal digit model of healing response after tip amputation. Fetal digits from donated specimens of estimated gestational ages (EGAs) of between 45 and 95 days were removed from hands and cultured for one day to four weeks with or without tip amputation. Immunostaining for Msx1 in control human fetal digits revealed a pattern of expression beneath the nail field and distal to the nail fold similar to that reported in the mouse, where Msx1 is associated with regeneration (in theory, by keeping a population of stemlike cells in reserve). In tip-amputated human fetal digits of 57 days EGA, a population of cells distinct from epithelium was found to express Msx1 in increased amounts at the regrowing tip by 4 days after amputation (Figure 3). This region was almost completely covered with epithelium by 7 days post-amputation. Immunostaining of digits for cytokeratin-19 (a marker for skin) showed an epithelium advancing over the cut distal phalangeal surface so that near-complete closure was seen by 7 to 14 days, depending on the specimen. Other data (not shown) also suggest that the zone of Msx1 expression decreases as differentiation in the fetus progresses with maturity.

We have recently begun experiments to determine the possible sources of the cells (distinct from epithelium) which grow to cover the cut distal digit tip. Possibilities include dedifferentiation of local tissue (to a blastema-like state,

a collection of stemlike cells as in the newt); proliferation of cells local to the tip site; or migration of cells to the tip from adjacent regions—for example, the Msx1-expressing region beneath the nail field, functioning as a type of stem cell reservoir. In our model, expression of Msx1 gives us a marker by which the cells participating in this regenerative response can be identified and isolated for further study.

In order to evaluate the role of proliferation as a possible source of Msx1-expressing cells at the regrowing tip after amputation, we used double fluorescent immunolabeling to attempt to colocalize Msx1 with Ki67 (a marker of cellular proliferation). Msx-1 and Ki67 showed mutually exclusive expression, making it unlikely that the increase in Msx1 expression after tip amputation is due to cell proliferation at the wound site. This leaves in situ upregulation of Msx-1 expression (with or without dedifferentiation of local cells) or migration of Msx1-expressing cells from other site(s) as viable explanations for the presence of increased numbers of Msx1-expressing cells at the site of tip amputation. These questions are being asked now in further work; results might help us harness this process to address larger volumes of tissue loss.

Tissue engineering

While pursuing a regenerative approach to digit and limb injury may one day have clinical value, it may be useful to evaluate the potential for tissue-engineering replacement parts as well. This growing discipline originated from the fields of transplant surgery (driven by the shortage of available organs for transplantation) and reconstructive surgery. The

fabrication of tissue-engineered constructs requires a scaffold, a population of competent cells, and signaling molecules to direct those cells to synthesize the desired matrix, replacing the original scaffold as it degrades over time. When host-derived cells are used, the end result is tissue native to the recipient with no foreign material against which the host immune system might react. In this way, the three components of tissue engineering—cells, cytokines, and scaffold—mirror those involved in regeneration.

Some limited work has been done to attempt to devise tissue-engineered replacements for digits or parts thereof, but the field is in its infancy.

A significant part of the difficulty lies in the fact that replacing even so small a part as a digit tip requires many different tissue types. While there exists a large body of literature addressing the isolation and culture of mesenchymal stem cells and their use in seeding scaffolds, it may be that lessons from the study of digit tip regeneration will suggest improvements in our choices of cells, scaffolds and signaling molecules. In this way, better understanding of the regenerative phenomenon may allow us either to stimulate improved regeneration in situ for larger volumes of tissue loss, or to tissue-engineer replacements for lost parts more successfully.

One near-term goal combining regenerative and tissue-engineering approaches might be to devise a “next-generation” digit prosthesis, replacing present metal and silicone components with a tissue-engineered central post which could truly heal into host bone, and an outer surface which

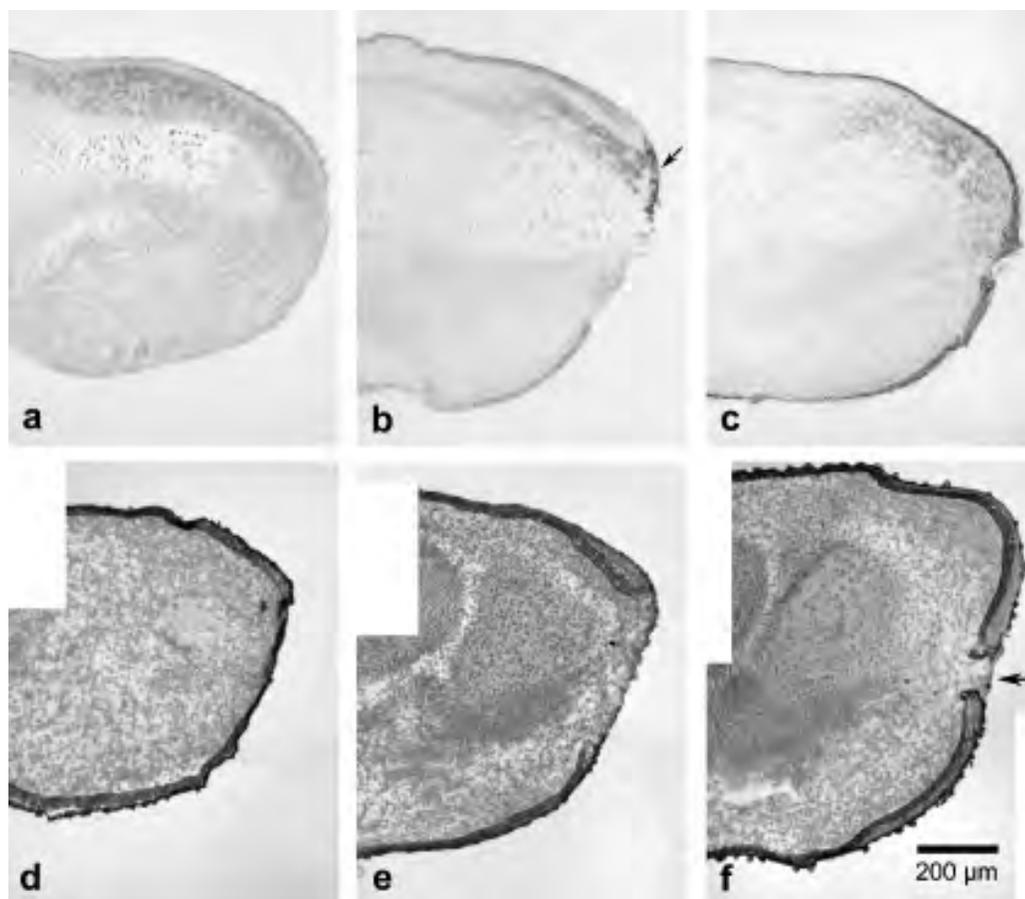


Figure 3: 57 day EGA digits, immunostained for Msx1 (top row) and cytokeratin-19 (bottom row). Each column shows one digit stained for two separate antigens. Left column: control digit without tip amputation. Center column: digit post-tip amputation, four days in culture (arrow in panel B: Msx1 expression at amputation site, distinct from epithelium—compare with panel E—and not seen in control specimen). Right column: digit post-tip amputation, seven days in culture (arrow in panel F: advancement of wound epithelium over amputation site with increased time in culture; note thickness of reforming epithelium at wound edges as compared with uninjured epithelium).

could fully integrate with the recipient's skin at the amputation site. Such a construct might reduce the present rate of inflammation and infection, and could potentially be designed to allow for ingrowth of cutaneous nerves to provide true sensibility—though this would likely require sensory end-organs in the engineered digit's skin. The most important challenge may be reliable vascular inflow and outflow. Some options include incorporating tissue-engineered vessels implanted into the replacement digit, or constructing channels lined with growth factors to induce angiogenesis. Present constructs have all required implantation in immune-compromised mice to allow vascular ingrowth and so a different strategy will be required for clinical use. Intermediate steps could integrate such present-day surgical treatments as crane or groin flaps to vascularize the part.

Summary

Digit and limb loss or severe injury occur frequently and affect many millions of persons worldwide, resulting in decreased quality of life and years of lost productivity. Present treatment options for these injuries are inadequate, restoring lost function imperfectly and placing the patient at significant additional risk. The concurrent development in recent years of molecular techniques for studying regeneration and biological approaches to engineering replacement tissues offer us opportunities not previously available. No one specific present-day technology shows certainty of success, but collectively it is highly likely that some of what is being studied now will become common practice in our lifetimes.

Further reading

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Transient Muscle Paralysis Inhibits Formation of Heterotopic Bone

Steven D. Bain, Ph.D.

Introduction

Heterotopic ossification (HO) is the formation of lamellar bone outside the skeletal periosteum. While the pathophysiology of HO is not clearly understood, traumatic events impacting the neuromuscular system have been implicated. Indeed, recent findings demonstrating that the dysregulation of bone morphogenetic protein 4 (BMP4) at the neuromuscular junction (1,2) is a precursor of HO pathology provides a link between neuromuscular dysfunction and the development of HO. In this context, we recently observed that botulinum toxin A (BTxA)-induced paralysis of the calf muscle in a mouse bone-injury model inhibited over 90% of the callus response to surgically

induced trauma of the tibia. This response appeared to be due to blockade of neuromuscular signaling by BTxA as control experiments in which BTxA was injected directly into the bone injury did not inhibit callus formation nor was there any effect on muscle action. Given the known mechanism of action of BTxA (i.e. inhibition of neurotransmitter release), we hypothesized that blockade of neuromuscular signaling by BTxA would inhibit ectopic mineralization. Therefore, we implemented a mouse model to assess the *in vivo* effects of BTxA on the development of heterotopic bone.

Material and Methods

Heterotopic Ossification Model

- An intramuscular injection of

50 μ L of Matrigel (Becton Dickinson) basement membrane matrix impregnated with 2.5 μ g of bone morphogenetic protein 4 is injected intramuscularly to form a mineralized nodule approximately 50 mm³ in volume.

- Matrigel is a liquid at 4°C that solidifies after injection into the body (at 37°C), forming a compact, encapsulated nodule in which heterotopic bone will form.

MicroCT Imaging

- *In vivo* microCT imaging (Scanco vivaCT 40) was used to quantify the onset, extent and time course of HO.

- Serial high resolution imaging (10.5 μ m voxel) was performed with the mice under general anesthesia (isoflurane; 25 min total anesthesia

Transient Muscle Paralysis with BTxA Inhibits Heterotopic Ossification

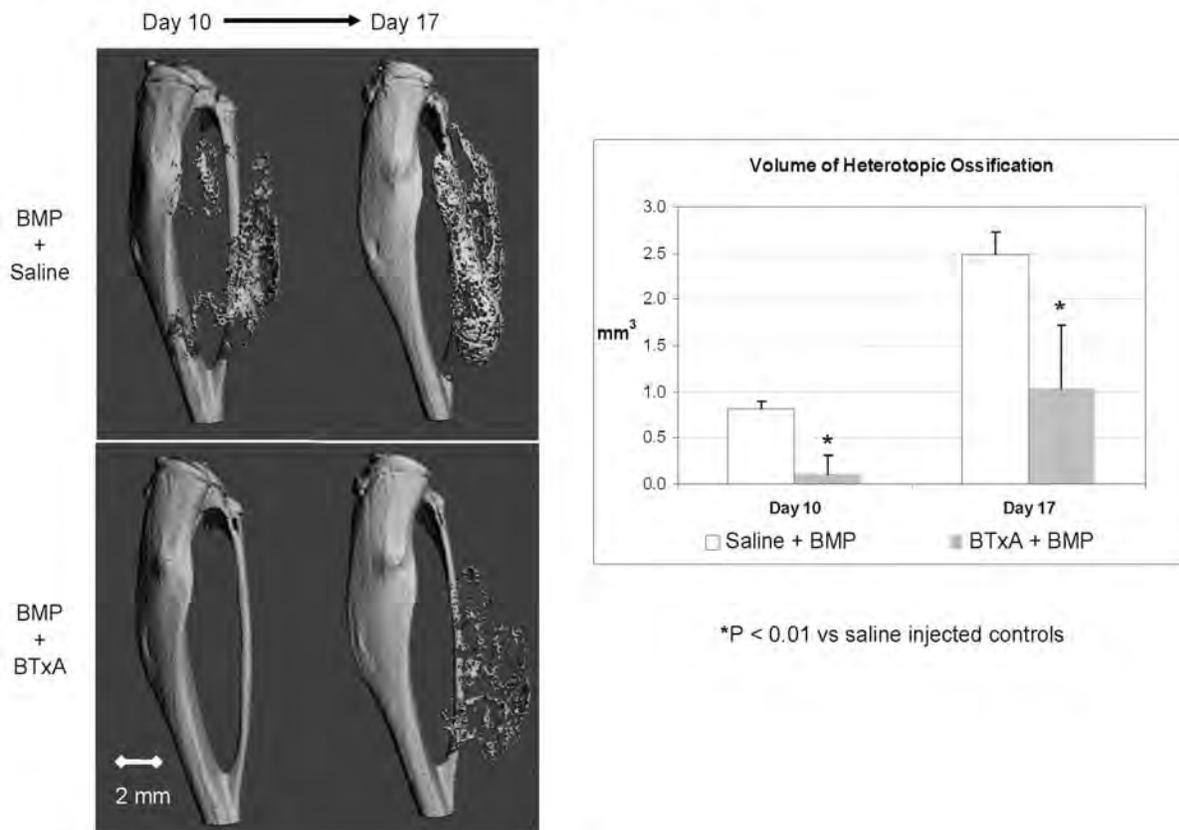


Figure 1: Transient Muscle Paralysis with BTxA Inhibits HO Formation.

per scan).

- Imaging was performed on the muscle region in which the Matrigel implant had been placed with the scan centered on the HO nodule.

- Accumulated radiation dose from the microCT scans is well below the radiation exposures that are used to treat HO in human patients (3,4).

- Standard image analysis algorithms were used to determine nodule volumes and BMD, as we and others have done previously (5).

Experimental Design

The calf muscles of 3 mice were injected with 2 U/100 g body weight of BTxA (20 µl injection volume) and 3 mice were injected with 20 µl of sterile saline. Following the BTxA or saline injections, the calf muscles were then injected with BMP4-impregnated Matrigel (2.5 µg/50 µl). To assess the formation of heterotopic bone, serial microCT scans were performed 10 and 17 days post-implantation.

Results and Discussion

Compared to saline injected controls, BTxA clearly inhibited HO mineralization at both time points (Figure 1). These pilot data provide preliminary evidence that blockade of neuromuscular signaling can inhibit the induction and mineralization of HO. If confirmed in follow up studies, this approach holds significant potential to be more efficacious and less likely to induce side effects compared to current therapeutic regimens such as radiation and non-steroidal anti-inflammatory drugs. Furthermore, demonstrating that transient muscle paralysis induced by BTxA can be used as a prophylactic treatment to prevent the onset of HO would be a novel use of an existing therapeutic with potential to greatly improve patient outcome and lower health care costs.

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Iatrogenic Syndesmosis Malreduction Via Clamp

Daphne M. Beingessner, M.D., Anna N. Miller, M.D., David P. Barei, M.D., Joseph Iaquinto, M.D., and William R. Ledoux, Ph.D.

Introduction

Multiple recent papers have examined ankle fractures, and specifically fixation of syndesmotic injuries. It has been shown that closed syndesmotic screw fixation can lead to malreduction of the syndesmosis,[1] and that malreduction is also possible with open syndesmosis reduction, even with direct visualization.[2] The purpose of this study was to evaluate how variations in angulation of clamp placement to hold syndesmotic reduction and subsequent syndesmotic screw placement can lead to malreduction of the syndesmosis.

We hypothesized that inaccurate placement of intraoperative clamps and trans-syndesmotic screws can cause malreduction of the ankle syndesmosis.

Materials and Methods

- Fourteen (seven matched pair) intact cadaveric lower extremities up to the knee joint.
- CT ankle to assess normal

anatomic syndesmotic alignment

- All syndesmotic ligaments and interosseous membrane sectioned
- CT scans with clamp at 0°, 15°, and 30° (Figure 1)
- Lateral fibular screw at either 0° or 30° across syndesmosis
- Repeat CT scan
- Posterolateral fibular screw at either 15° or 30°
- Final CT scan
- CT scan data valuated for syndesmosis reduction and compared with "intact" original CT

Results

See Tables 1-3. 0° clamp placement gave significant posterior translation and overcompression of the syndesmosis. 15° clamp placement caused internal rotation and significant overcompression. 30° clamp placement caused internal rotation and significant overcompression. See Figure 2.

For lateral screws, 0° gave significant posterior translation and

overcompression of the syndesmosis; 30° did not cause significant translation, but did cause significant overcompression.

For posterolateral screws, neither 15° nor 30° caused significant translation, however, there was still significant overcompression of the syndesmosis.

Discussion

To our knowledge, our study is the first to analyze potential causes of syndesmotic malreductions, including the contribution of clamp or syndesmotic screw placement. We showed that, depending on the angle of application, clamp placement can significantly affect the reduction of the syndesmosis. In addition, both our clamp and screw reductions showed significant overcompression of the syndesmosis in all cases. This overcompression is again often not evident on intraoperative radiographic examination, and may be a cause of

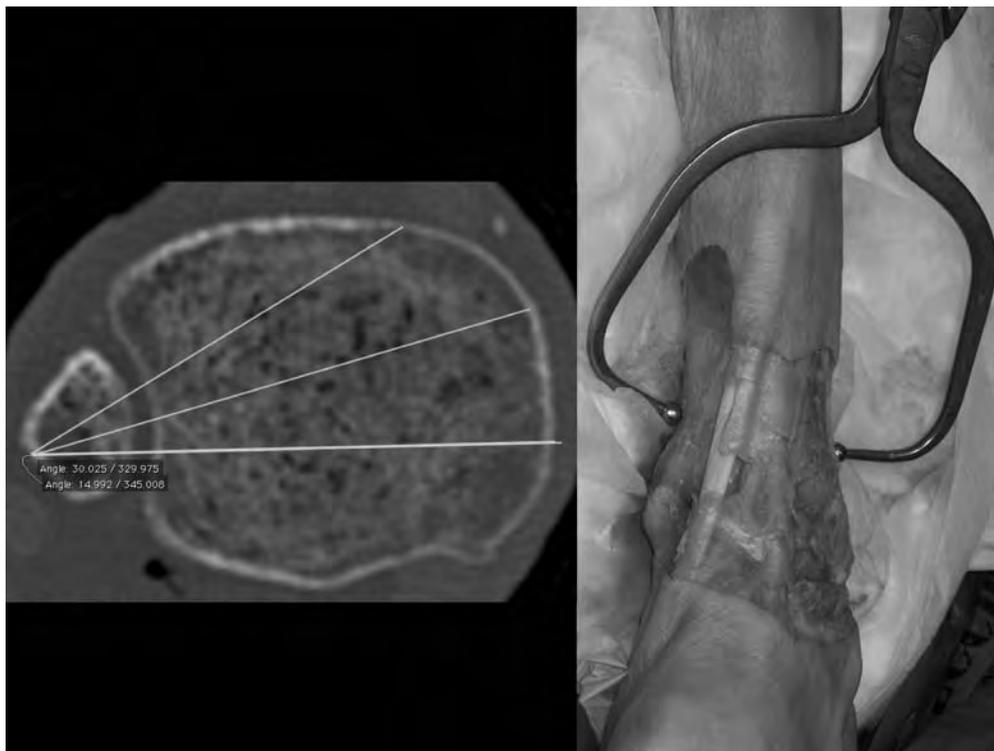


Figure 1: CT scans with clamp.

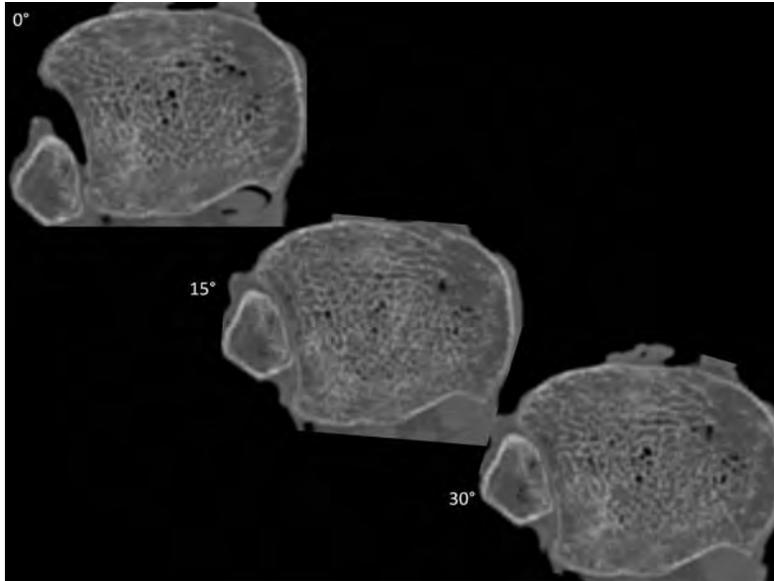


Figure 2: CT scans with clamp at 0, 15, and 30 degrees.

Clamp Angle	Anterior Facet (mm)	Posterior Facet (mm)	Mid-Incisura (mm)		
Pre-Clamp	1.7	1.8	2.1	2.0	2.0
0°	-2.8*	-1.5*	0.8*		
15°	1.2*	1.5		0.6*	
30°	1.5	2.7*			0.6*

Table 1: Average measurements for clamps placed at 0°, 15°, and 30°. Mid-incisura distance is variable pre-clamping due to exclusion of completely dislocated specimens from this measurement. *=statistically significant (p<0.05)

Screw Angle	Anterior Facet (mm)	Posterior Facet (mm)		Mid-Incisura (mm)	
Pre-Screw	1.7	1.9	1.8	2.0	1.8
0°	-0.5*	0.3*		0.9*	
30°	1.2		2.1		0.8*

Table 2: Average measurements for lateral screws placed at 0° and 30°. Posterior facet measurement is variable pre-screw due to different cadaver limbs in the 0° and 30° angulation groups. Mid-incisura distance is variable pre-screw due to exclusion of completely dislocated specimens from this measurement. *=statistically significant (p<0.05)

Screw Angle	Anterior Facet (mm)	Posterior Facet (mm)		Mid-Incisura (mm)	
Pre-Screw	1.7	1.8	1.9	1.8	2.0
15°	0.3	1.5		0.4*	
30°	0.6		1.3		0.4*

Table 3: Average measurements for posterolateral screws placed at 15° and 30°. Posterior facet measurement is variable pre-screw due to different cadaver limbs in the 15° and 30° angulation groups. Mid-incisura distance is variable pre-screw due to exclusion of completely dislocated specimens from this measurement. *=statistically significant (p<0.05)

patient complaints of ankle stiffness with syndesmosis screws in place or, conversely, increased motion and relief of symptomatology after screw removal.

We believe that future studies in this area could include the use of intraoperative CT, as radiographic evaluation is not always accurate; the small malreductions seen in this study would likely not be evident with standard intraoperative fluoroscopy.

Our study showed that clamp and screw placement can significantly affect not only the direction of the fibula during syndesmosis reduction, but can also cause overcompression of the syndesmosis. We recommend that surgeons performing syndesmosis fixation carefully assess their reduction and take care to avoid these iatrogenic malreductions. Specifically, with the information from this study, we believe that surgeons should try to angle any trans-syndesmosis clamp towards 15°, rather than 0° or 30°. In addition, it is crucial to avoid overcompression of the syndesmosis with the clamp, which was a constant finding in all groups.

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Variability in Foot Morphology

Stephen K. Benirschke, M.D. and Patricia Ann Kramer, Ph.D.

Study Rationale

Conventional wisdom dictates that the human foot should have both a medial longitudinal arch and an adducted first metatarsal in order to be fully effective¹⁻³. A century of clinical observation has established, however, that foot morphology is variable among normally functioning people, but how much variation exists has yet to be determined.

Research Question

How much variability exists in angular and linear measurements of the foot, is the variability among measurements associated, and does foot size contribute to this variability?

Methods

Study design: digital measurements of lateral and anteroposterior radiographs of uninjured feet taken to rule-out fracture or as comparison views for a contralateral fracture

Measurements

- Sample size of 50 feet (from 25 men and 25 women)
- Angular measurements: intermetatarsal angle; medial and lateral arch; calcaneal pitch; subtalar inclination; Böhler's angle and angle of Gissane

- Linear measurement: foot length
- Measured twice, minimum of two months apart, then averaged

Statistical analysis

- Intra-class correlation coefficients = 0.61-0.99 between first and second measurements
- Kruskal-Wallis test to detect gender differences
- Ordinary least squares analysis to detect relationships between measurements
- Alpha = 95%
- Bonferroni correction

Results

- See Table 1 for descriptive

statistics of women and men and specific values for the foot shown in Figure 1.

- Men have longer feet than women, but the angular measurements did not differ between genders.
- See Table 2 for pairwise correlations between angular measurements.
- Angular measurements are not affected by foot length.
- None of the angular measurements explained more than ~20% of the variation in any other angular measurement.
- Flatter medial arches were correlated with more abducted first metatarsals and more vertically inclined posterior facets.

Discussion

- Our data are similar to previously published values.
- Considerable variability exists in foot and especially calcaneal shape.

Measurement	Units	Women			Men			Figure 1
		Mean	Min	Max	Mean	Min	Max	
Intermetatarsal	°	9.80	4.10	15.15	8.61	4.10	15.40	10
Medial Arch	°	125.77	106.80	139.35	124.23	111.15	139.60	127
Lateral Arch	°	145.88	122.55	157.50	143.67	123.45	160.75	148
Calcaneal Pitch	°	19.40	12.55	35.00	19.78	9.95	33.80	19
Subtalar inclination	°	38.93	31.24	44.88	37.05	30.73	44.53	47
Böhlers Angle	°	32.82	18.65	42.75	34.07	19.45	44.9	152
Angle of Gissane	°	124.74	115.54	138.81	126.28	119.13	131.09	113
Foot Length	mm	177.69	161.40	201.50	200.90	174.05	219.75	202

Table 1: Descriptive statistics of the measurements.

	Inter-metatarsal	Medial Arch	Lateral Arch	Calcaneal Pitch	Subtalar inclination	Böhlers Angle	Angle of Gissane	Foot Length
Intermetatarsal	1.00							
Medial Arch	0.31	1.00						
Lateral Arch	0.25	0.79	1.00					
Calcaneal Pitch	-0.23	-0.81	-0.94	1.00				
Subtalar inclination	0.32	0.49	0.36	-0.37	1.00			
Böhlers Angle	-0.24	-0.21	-0.22	0.27	-0.06	1.00		
Angle of Gissane	0.04	0.06	0.19	-0.24	-0.42	0.15	1.00	
Foot Length	-0.37	0.03	0.00	-0.06	-0.14	0.04	0.12	1.00

Table 2: Correlations of angular measurements in the combined sample. Shaded boxes represent statistically significant pairwise correlations.

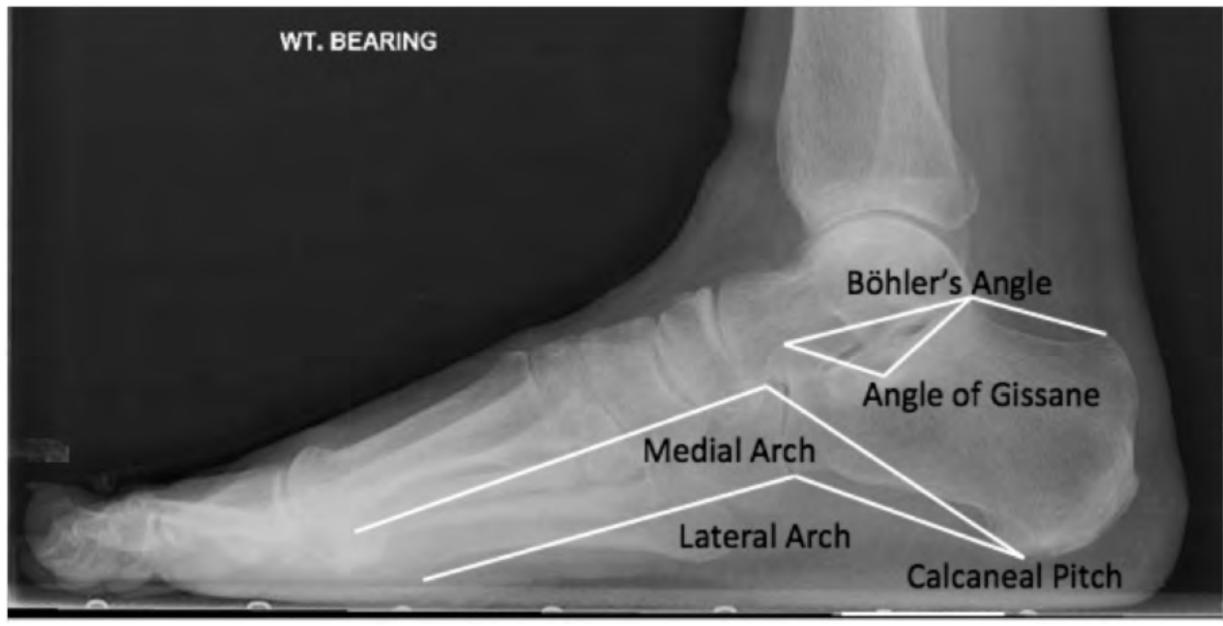


Figure 1: Lateral view.

Consequently, views of the contralateral (uninjured) foot are necessary in order to restore normal foot anatomy when reconstructing after trauma.

- The intermetatarsal angle in people with no chronic foot pain varies from 4 - 15° with a mean of 9°.
- We find some evidence for Morton's functional complexes, but the relationship between the height of the arch, the orientation of the first metatarsal, and the posterior facet is weak.

Conclusion

- The principle finding of this research is that the foot morphology varies considerably among people.
- Nonetheless, an abducted first metatarsal is associated with a flatter foot. Whether or not this association is causal remains to be determined.
- Orthopedic reconstructions to repair traumatic injury should be informed by an understanding of contralateral morphology (if available).

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Fresh Osteochondral Allografts for Talar Dome Reconstruction

Michael J. Brage, M.D.

The Problem

Osteochondral defects (OCD) of the talar dome can occur from injuries or osteochondritis dissecans in relatively young patients who are physically active. If left untreated this can lead to severe tibio-talar arthritis with pain, stiffness and progressive deformity and pain. There are no really satisfactory treatment options. Debridement with arthroscopy or complex ankle

reconstruction surgery with either fusion surgery or ankle replacement are the extremes of surgical care with little in between. Talar dome cartilage reconstruction has been attempted with microfracture surgery, OATS procedures and simple serial debridements with few satisfactory. Nonoperative care is focused on maintaining range of motion and delaying the inevitable onset of

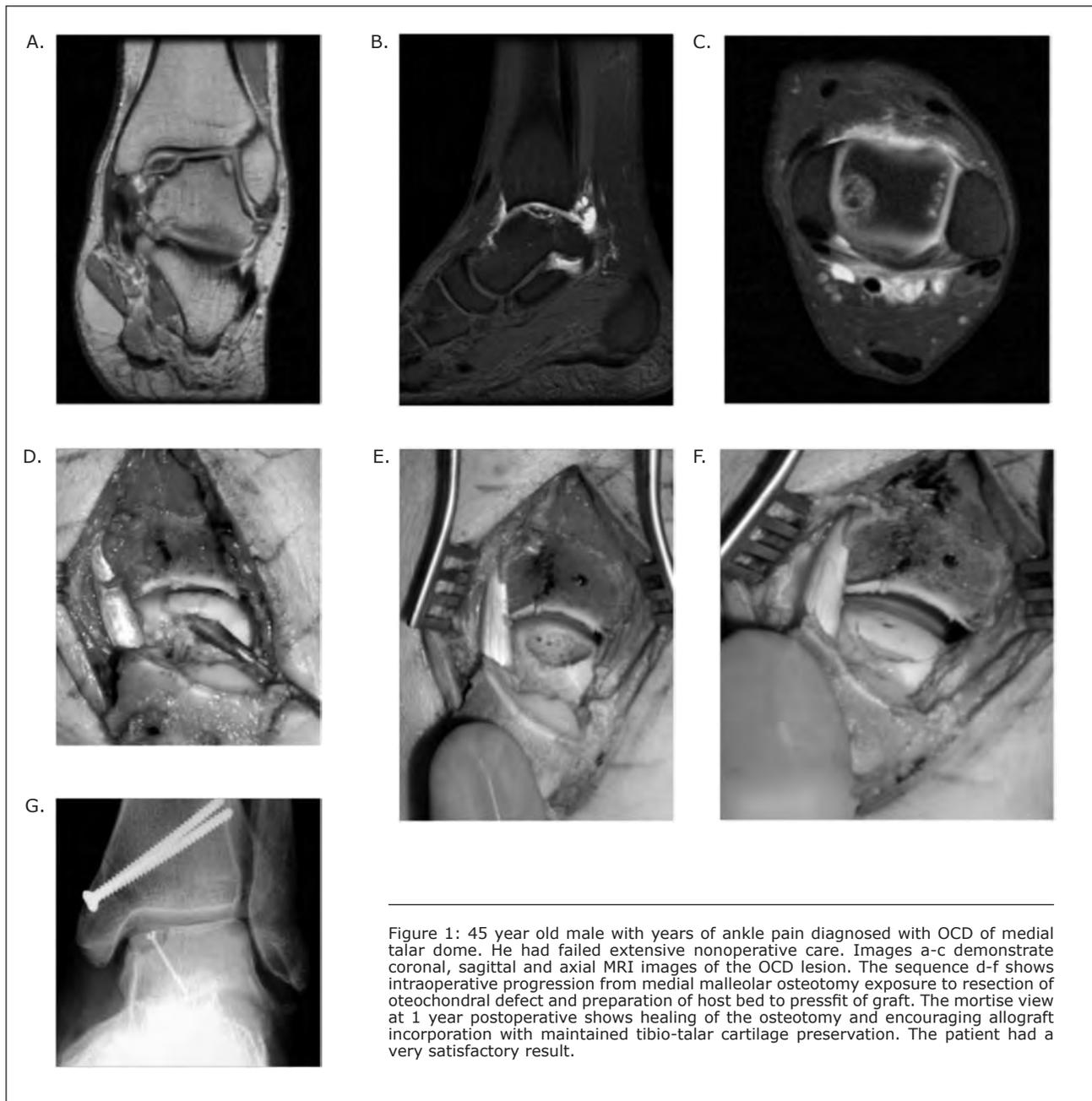
disabling ankle symptoms as long as possible.

Differential Diagnosis

Other sources of hindfoot pain must be excluded

Examine for ankle instability - be prepared to correct

Examine hindfoot alignment - correct any significant deformity before or during OCD repair



The Hope

Talar dome defects with medial or lateral defects that are 10 mm in size, and up to but not larger than half of the talar dome can be considered for reconstruction with osteochondral allograft.

Technique

- Graft considerations:
 - Size-matched donors
 - Measured width of Talus 5mm below articular surface on AP ankle x-ray
 - Correct for magnification
 - Good relationship with tissue bank Joint Restoration Foundation (Denver)
 - Allograft procurement within 24 hours of death
 - Transplantation with 21 days
 - Extensive donor screening (requires 2 weeks of time)

- Surgical approaches
 - Medial – medial malleolar osteotomy
 - Lateral – lateral malleolar osteotomy
 - Anterolateral – tillaux osteotomy
 - Posterior – posterior malleolar osteotomy
 - Anterior – ankle distraction method

- Surgical Technique
 - Create precision sized osteochondral plugs
 - Custom press fit graft
 - The hemi-talus graft for larger defects

Postoperative regimen

- Weight bear restriction depends on graft size
- Whole dome or hemi-talus no weight for 3 months
 - Smaller lesions no weight for 6 weeks
- Early motion once wound healed
Formal physical therapy at 6 weeks
Full activity allowed by 6 months

Results

Four year follow-up: No graft resorptions, no infections, satisfactory functional and pain recovery in eight patients. Reoperations were necessary one nonunion of fibula osteotomy, one nonunion of medial malleolus osteotomy.

Conclusions

Encouraging early results with superior functional results compared

to alternatives.

Based on case series this technique appears meritorious for further study.

Drawbacks are reliance on reliable high quality tissue center and reliance on surgical expertise.

Literature comparison

In the last 10 years six published patient studies!

- 3 case series without control groups (21 patients total)
- 3 case studies of a single patient
- Level IV evidence: 15 of 21 patients with good or excellent results

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Monitoring Functional Outcomes After Surgery: Inspiration from Experiments in Space

Peter R. Cavanagh, Ph.D., D.Sc., Andrea M. Hanson, Ph.D., Elliot Lee, and Paul A. Manner, M.D.

Introduction

The main goal of many orthopaedic procedures is to restore a patient's function. A large segment of orthopaedic research (so-called "outcomes research") is devoted to the assessment of whether or not this goal has been achieved. The assessment tools of outcomes research are often questionnaires or surveys where patients are asked such questions as "How much does pain interfere with your normal work?", or "Is it difficult for you to reach up high?" Only rarely does outcomes research involve measurement of functional outcomes – such as range of joint motion, amount of load bearing, or the total number of knee flexions in a given day. Our research group is exploring a number of approaches

to measuring functional outcomes in studies that have been informed by our experience in experiments conducted on astronauts on the International Space Station. These studies and similar measurement methods we are developing for future missions to the moon and Mars, have shown us that it is possible and useful to measure performance data even when the patient is in a very remote location!

The Philosophy

The analysis of walking and other human motions has historically been conducted in gait labs where a patient is studied using video cameras, motion capture systems, force, and pressure measuring devices, as they take a few steps under the close supervision of the experimenter. In most cases only

a few steps are studied. This approach is really important when a detailed analysis of the biomechanics of human movement is required, but there is now an increasing emphasis on measuring how a patient functions in his or her own daily life and on how much activity is actually being performed. This requires making measurements in the patient's own living environment while the investigator is not always present. To date, our experience in collecting such data has included making measurements of joint motion, muscle activity, and foot forces on the International Space Station orbiting approximately 200 miles above the earth. With support from NASA grants, we have monitored the activity of astronauts during entire days of living in microgravity (see

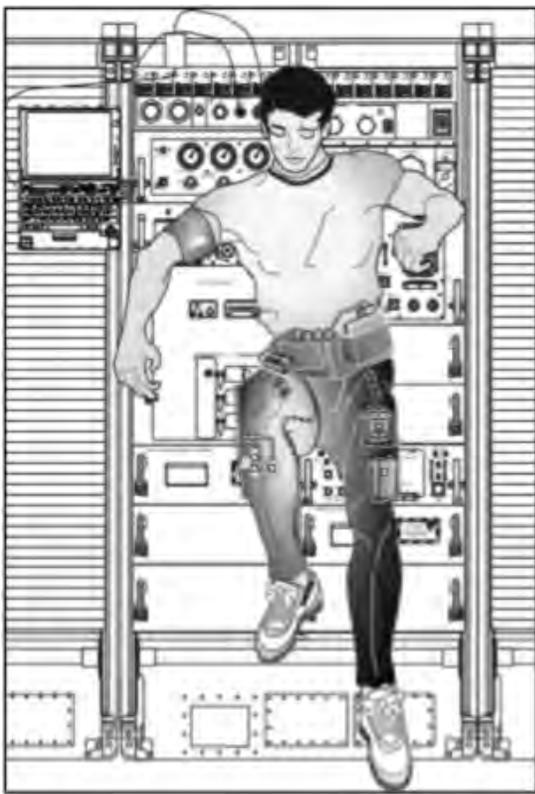


Figure 1a: Schematic diagram of a lower extremity monitoring suit used in space that contains sensors to measure foot forces, joint angles, and muscle activity.



Figure 1B: An astronaut wearing the lower extremity monitoring suit while running on the International Space Station treadmill.

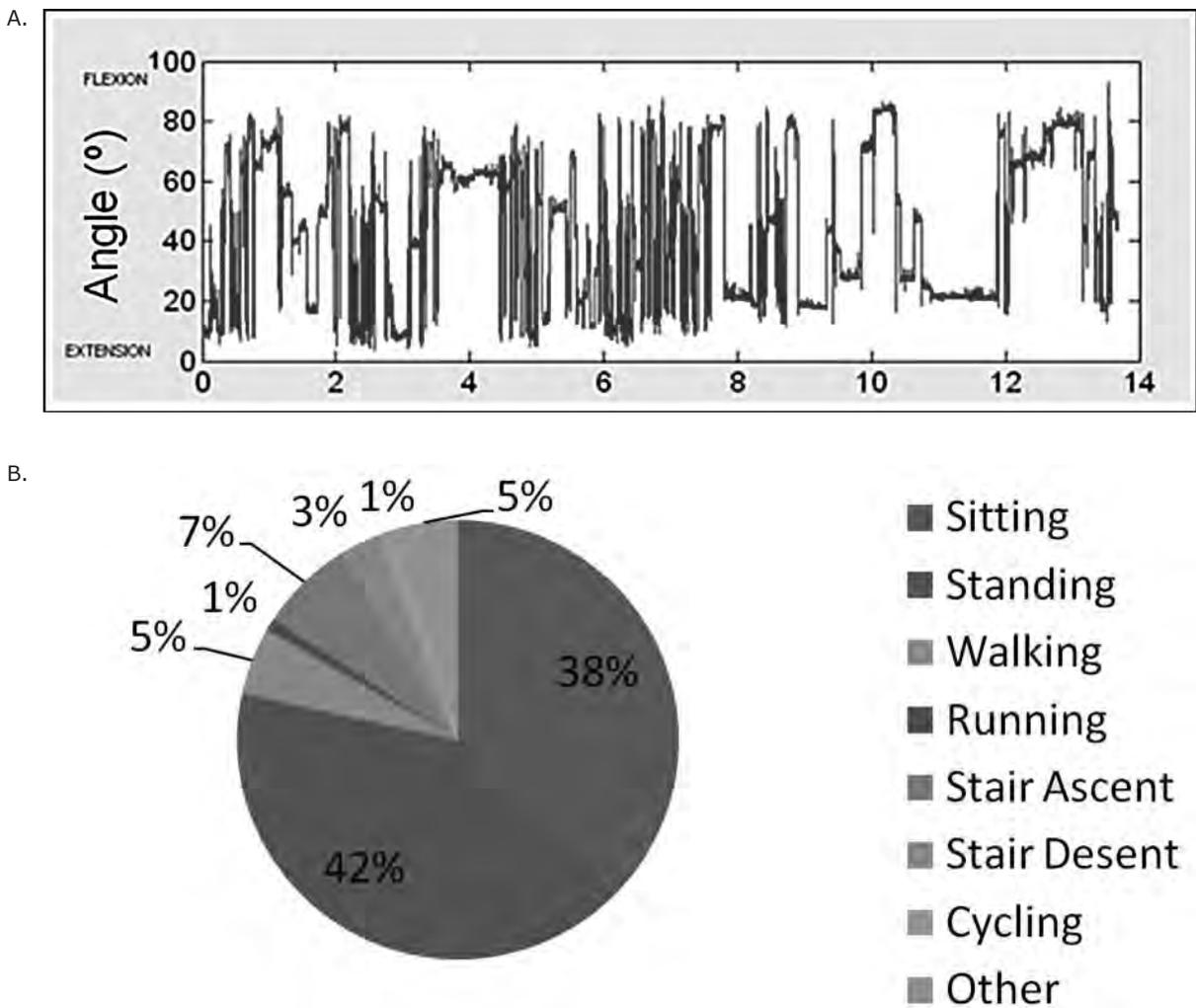


Figure 2: A. Knee angle as a function of time during free living over several hours. B. Artificial Neural Network software generated an activity profile from the angle-time data predicting that this person spent the majority his time standing or sitting.

Figure 1) in efforts to design more effective countermeasures against disuse atrophy of bone and muscle. This research in low-earth orbit has provided valuable experience which we now intend to use on earth to study orthopaedic outcomes.

The Sensors

Most people are familiar with simple activity monitors, such as ankle and waist-mounted pedometers. These devices can be used to determine total ambulatory activity over a period of time in a free living environment, which may be an important indicator of a patient's functional ability post surgery. Today, a wide range of sophisticated sensors are available commercially, many of them packaged for attachment to an ambulating

patient in a very unobtrusive way. While some sensors save data to a small on-board computer (as was the case in our Space Station experiments) others have wireless capabilities such as Bluetooth or cellular telephone transmission to send the data to a remote location. Of particular interest for orthopaedics are joint angle sensors and a class of very small sensors called IMUs (inertial measuring units) which often incorporate not only accelerometers (devices that measure "shock") but also gyroscopic rate sensors (to measure angular speed) and gravity sensors (to tell what the orientation of the unit is). The fact that these devices are now readily available can be attributed to the mass production of millions of such sensors for air bags in cars and in cell phones

(for example, the display rotates on an iPhone when it is rotated because of a gravity sensor) – which has lowered the price of these sensors for their use in other applications.

Analyzing the Data

All of the sensors described above generate a lot of data - which typically streams from the device at 100 samples per second or more. Computer processing is required and some rapid processing is needed to make sense of the data and provide useful feedback to the user. In one application in our laboratory, we are measuring knee angles during entire days in patients who have undergone total knee joint replacement. Data is collected on a smart phone in the patient's pocket and it can be transmitted via a cell phone

network back to the Medical Center where it is processed and passed through a series of computer programs to extract as much information as possible about the performance of the wearer. We can recognize what the wearer was doing by a system of Artificial Neural Networks in which a computer program is trained to look for certain recognizable features of the user's activity. A simple example involves identifying the magnitude and timing of the peaks in the knee flexion angles during different activities. For example, walking, climbing stairs, and cycling have quite different signatures when the number of peaks in each size category together with their standard deviations and distributions are evaluated. A neural network can easily distinguish what activity is in progress when adequately trained with a sufficient amount of this kind of data. The raw signal for hours of knee angle activity shown in Figure 2A can be reduced by a neural network to the pie chart shown in Figure 2B which indicates that this person spent the majority of his day standing and sitting. In other experiments, we are processing signals from shoe-mounted accelerometers using spectral analysis to characterize the frequency components of the signals which are then used to assist in activity recognition.

The Future

Our ultimate goal is to have sensors worn by the patient autonomously send a report of functional performance and activity to the patient's electronic medical record where it can be used for decision making in continued rehabilitation efforts. Consider the example of a patient who has had a knee joint replacement but is not progressing well 3 months after surgery. She may be hesitant to schedule another follow-up visit with her surgeon, but a body-mounted sensor could alert her care team that she only flexed the knee 50 times during the day compared to the normal use of several thousand knee bends. With this information, a smart system could automatically schedule the patient for an immediate office visit where her status could be evaluate and a new rehabilitation plan devised. There is little doubt that remote monitoring will increase in future post-

operative care paradigms as it is likely to be an efficient and cost-effective way of monitoring patient outcome.

Recommended Reading

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Mesenchymal Expression of Type II EWS-Fli1 Fusion Protein Affects Skeletal Development in Transgenic Mice

Howard A. Chansky, M.D. and Liu Yang, Ph.D.

Introduction

Ewing's sarcoma is thought to be of either a neural crest or mesenchymal origin. Ewing's sarcoma also harbors different fusion subtypes as a result of variations in the location of the t(11;22) translocation breakpoint. Type I fusion (between EWS exon 7 and Fli1 exon 6) and type II fusion (between EWS exon 7 and Fli1 exon 5) are the two most common subtypes observed in Ewing's sarcoma. It has been reported that type I fusion generally has a better clinical outcome than type II fusion, but whether such a correlation really exists between the fusion subtypes and clinical prognosis of various Ewing's family tumors is not conclusive. To investigate whether expression of type II EWS-Fli1 fusion protein in mesenchymal cell lineages is sufficient for tumor formation, we generated transgenic mice harboring the type II EWS-Fli1 fusion gene that is normally not expressed. Mating of these transgenic mice with Cre mice specifically activates expression of Type II EWS-Fli1 in early limb bud mesenchyme, making it possible to study mesenchymal expression of type II EWS-Fli1 in an animal model.

Methods

Generation of conditional EWS-Fli1 transgenic mice --- EWS-Fli1 cDNA with type II fusion was cloned into the NotI-EcoRI sites of the pCLE2 vector. After confirmation of the EWS-Fli1 sequence, a 5 kb targeting fragment containing the GFP cDNA and type II EWS-Fli1 cDNA was released from the pCLE2-EWS-Fli1 (type II) vector by digestion with SalI-HindIII. The purified DNA targeting fragment was then used in pronuclear injection of mouse embryos. Mice harboring the transgenes were identified by PCR and expanded in a C57BL/6 background.

Differential staining of cartilage and bone in newborn mice --- For whole mount staining of the skeletons, newborn pups were sacrificed the same day after birth, followed by removal of skin, viscera and adipose tissues. The specimens were stained for 1 week in Alcian blue 8GS and Alizarin red S at 37°C.

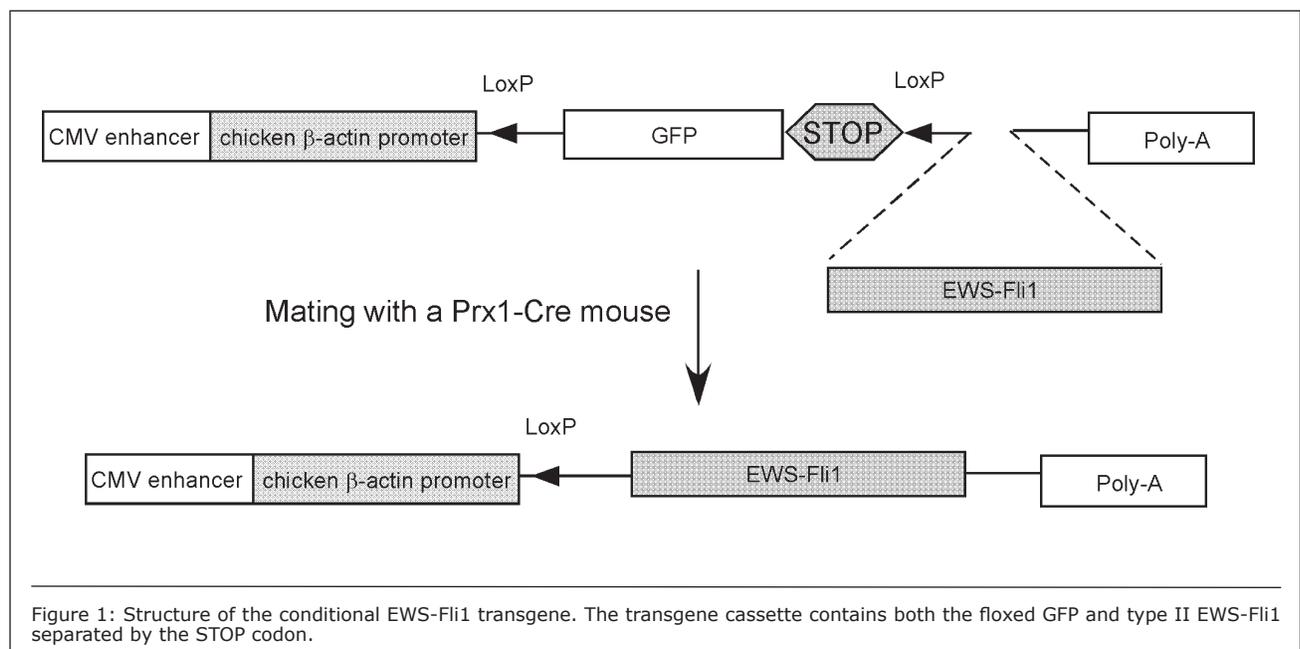
Results

Transcription from the pCLE2-EWS-Fli1 (type II) targeting fragment can give rise to a large transcript encoding both GFP and EWS-Fli1. Because translation terminates at the first stop

codon within the GFP cDNA, no EWS-Fli1 protein will be made from this transcript and the EWS-Fli1 transgene is thus silenced. Since two LoxP sites flank the GFP cDNA, the GFP sequence can be removed from the targeting fragment by Cre recombinase and the resultant transcript will only express type II EWS-Fli1 (Fig. 1).

We have chosen the Prx1-Cre mouse strain for breeding with mice harboring the conditional type II EWS-Fli1 allele. The Cre coding sequence in this strain is under the control of the paired related homeobox 1 (Prx1) promoter and Cre activity is specifically expressed in mesenchymal-derived tissues. After breeding, double-positive pups were generated at the expected Mendelian ratio at birth. While similar in size and weight to wild-type littermates at birth, double-positive mice exhibited slower growth and were significantly smaller one week after birth.

To understand how type II EWS-Fli1 expression in mesenchymal cells affects skeletal development, we prepared whole skeletons of newborn pups with different genotypes for comparison. We first examined the newborn skulls comprising bones that are formed



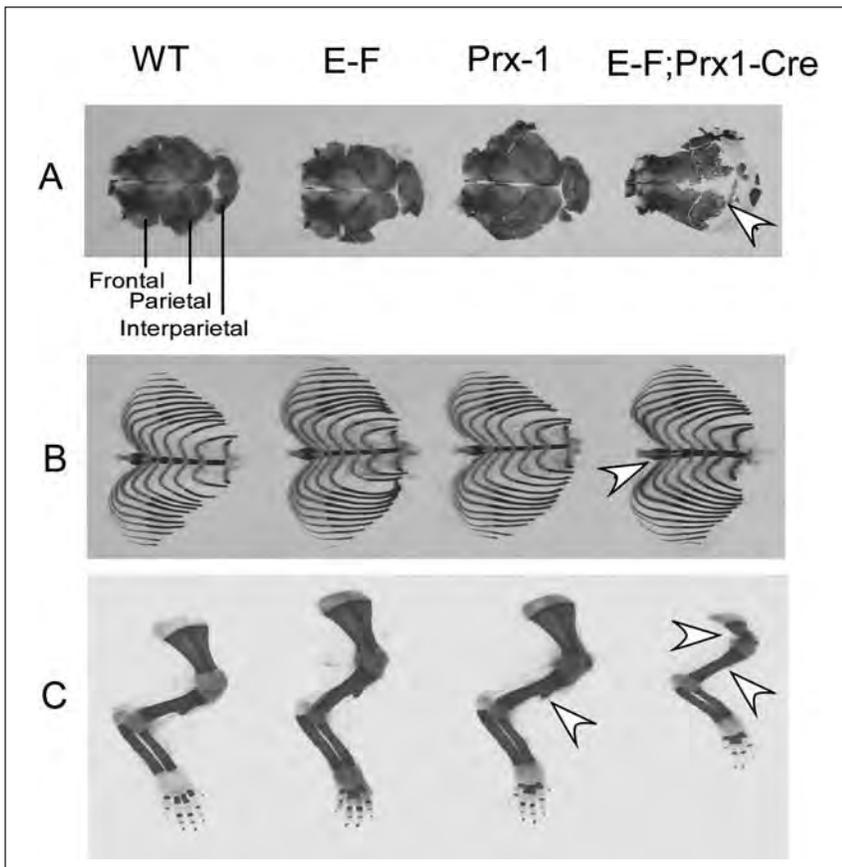


Figure 2: Skeletal defects in double-positive newborn mice. A, as shown by an open arrow, the frontal and parietal bones of the skulls were hypoplastic, the interparietal bones were delayed, and the sutures were widened. B, delayed ossification of ribcage at the sternum is indicated by an open arrow. C, malformation of the scapula and a lack of deltoid tuberosity are marked. Alizarin red stains mineralized bones, whereas Alcian blue stains cartilage.

through intramembranous ossification, a process in which mesenchymal cells differentiate directly into osteoblasts. As shown in Fig. 2A, the frontal, parietal and interparietal bones of the skull were separated by narrow sutures in wild-type newborn pups and those with either EWS-Fli1 or Prx1-Cre alone. The skulls of double-positive newborn pups, however, showed signs of delayed ossification of the frontal and parietal bones and a near complete lack of formation of the interparietal bones. The sagittal suture was thus significantly widened as a result.

In addition to delayed intramembranous ossification of flat bones of the skull, mesenchymal expression of type II EWS-Fli1 also impedes endochondral ossification, a bone-forming process that requires a cartilaginous template. As shown in Fig. 2B, rib cages prepared from wild-type newborn pups and those with either EWS-Fli1 or Prx1-Cre showed similar development of the sternum.

However, in double-positive newborn pups delayed ossification of the sternum was evident as demonstrated by a wider-than normal xiphoid process with two well-separated ossification centers. When scapulae were compared between among these animals, severe defects were observed only in the scapulae of newborn pups that were double-positive for EWS-Fli1 and Prx1-Cre (Fig. 2C). The scapulae of these double-positive pups were significantly smaller than those from normal littermates. They were also deformed. A notable defect in the forelimbs of double-positive mice was the lack of deltoid tuberosity, a bone protrusion on the shaft of the humerus to which the deltoid muscle attaches.

Conclusion

These defects in newborn pups with mesenchymal expression of type II EWS-Fli1 clearly demonstrate that the fusion protein affects skeletal development *in vivo*. Mice with

mesenchymal EWS-Fli1 expression, however, did not exhibit any sign of the tumor after observation of more than 9 months. This suggests that EWS-Fli1 fusion protein alone may not be sufficient for tumorigenesis and it may require a "second hit". The availability of these conditional transgenic mice makes it feasible to analyze the effects of conditional EWS-Fli1 expression in other tissues or cell types in the presence of additional genetic alterations.

Levels of Evidence in Clinical Orthopaedic Research: What Is the Role of the Randomized Controlled Trial?

Darin Davidson, M.D.

Abstract

Evidence based medicine provides a framework with which clinicians can apply evidence for clinical decision making. Determination of the best available evidence can be difficult, leading to the establishment of levels of evidence and, based upon these levels, grades of recommendations. Within this paradigm, the randomized controlled trial (RCT) is considered the gold standard research design, however there are many challenges in the use of this methodology in surgical practice. The purpose of this review is to consider alternatives to the RCT in clinical Orthopaedic research.

Background

One of the cornerstones of clinical practice is use of the principles of evidence based medicine, which



Darin Davidson presented his research on the subject discussed in this article at the University of Washington Department of Orthopaedics and Sports Medicine Resident Research Day on May 20, 2011 (above).

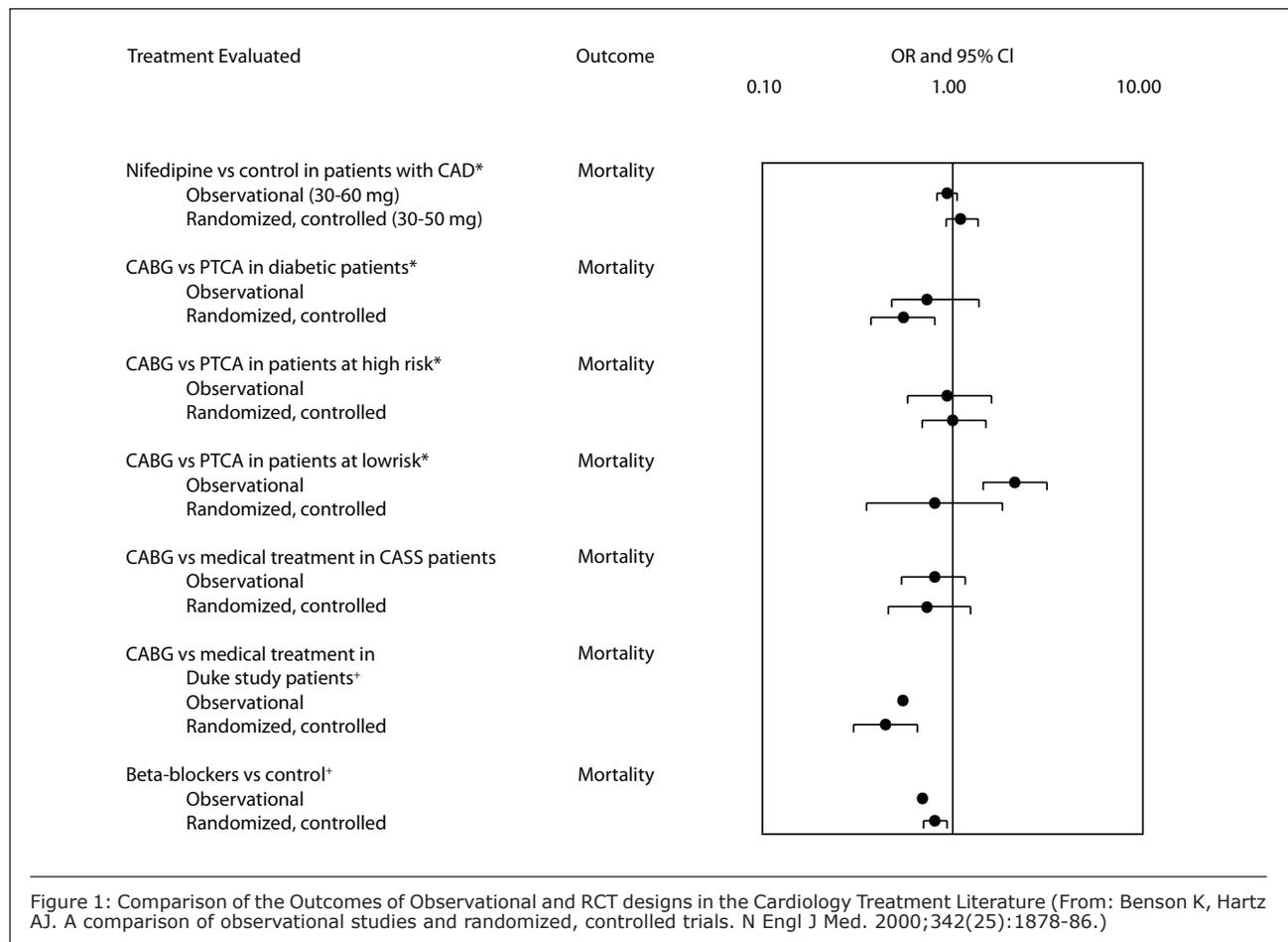


Figure 1: Comparison of the Outcomes of Observational and RCT designs in the Cardiology Treatment Literature (From: Benson K, Hartz AJ. A comparison of observational studies and randomized, controlled trials. N Engl J Med. 2000;342(25):1878-86.)

Grade of Recommendation/ Description	Benefit vs Risk and Burdens	Methodological Quality of Supporting Evidence	Implications
1A/strong recommendation, high-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1B/strong recommendation, moderate quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1C/strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	Observational studies or case series	Strong recommendation, but may change when higher quality evidence becomes available
2A/weak recommendation, high-quality evidence	Benefits closely balanced with risks and benefits	RCTs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and benefits	RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2C/weak recommendation, low-quality or very-low quality evidence	Benefits closely balanced with risks and benefits	Observational studies or case series	Very weak recommendations: other alternatives may be equally reasonable

Figure 2: Updated Grading of Recommendations of the Literature (From: Guyatt G, Gutterman D, Baumann MH, Addrizzo-Harris D, Hylek EM, Phillips B, et al. Grading Strength of Recommendations and Quality of Evidence in Clinical Guidelines: Report From an American College of Chest Physicians Task Force. *Chest*. 2006;129:174-81.)

combines the results from the best available evidence with expert opinion and patient values¹. Though randomized controlled trial (RCT) methodology can be readily applied in the study of medications, its integration into surgical practice is considerably more difficult.

The Dilemma

Use of RCTs in clinical Orthopaedic research can be very challenging, leading to difficulties in study design and execution. What is the role of RCTs in future clinical Orthopaedic research and are there alternatives?

Levels of Evidence

- In an attempt to facilitate interpretation and integration of the available evidence, systems for ranking the level of evidence provided by a study have been designed.
- These classifications, such as those incorporated by leading clinical Orthopaedic journals including *The Journal of Bone and Joint Surgery*, place the highest level of evidence on systematic reviews and meta-analyses of RCTs, followed by individual RCTs, which are considered a higher level of evidence than observational studies.
- RCT methodology was initially integrated into clinical practice in areas of medicine, particularly related to medications.

- The nature of surgical research is inherently different to clinical medicine and, as such, the application of RCT design in surgery is challenging.

- The strength of the evidence provided by a study is dependent upon the quality of the study.

Barriers to RCTs in Orthopaedic Research

- There are several potential barriers to the design and execution of RCTs in surgical populations, such as patient desires and expectations, surgeon willingness to participate in a randomized trial, difficulty in blinding treatment, and homogeneity in the procedure being studied.
- The difficulty in completing an RCT in Orthopaedic populations has been demonstrated in reviews of the quality of reported RCTs in the Orthopaedic literature.
 - Dulai et al² found that only 19% of RCTs in pediatric Orthopaedics met the threshold for satisfactory methodologic quality.
 - Bhandari et al³ reported that greater than 50% of reported RCTs had significant limitations, particularly related to lack of concealment, lack of blinding of outcome, and patient exclusions.
 - Some of these issues were encountered in the SPORT trial of the management of lumbar disk

herniation⁴. Despite a large multi-center collaborative randomized trial over a four year period, there was a large proportion of patient cross-over between non-operative and operative treatment groups. As a result, conclusions of treatment superiority were not possible.

Alternatives to RCTs

- Given these challenges in the use of RCTs in Orthopaedic populations, consideration of alternative research designs is warranted.
- Studies in clinical medicine populations have compared the results obtained in high methodologic quality observational studies with the results from high quality RCTs⁵⁻⁶. Both studies demonstrated that the treatment effect estimates reported in the observational studies were not systematically different from those reported in the RCTs (Fig 1).
 - These findings suggest that a high quality observational study can provide a high level of evidence, which potentially is similar to RCTs.
 - Updated grades of recommendation for study findings have incorporated this concept with the inclusion of a criterion related to the risk/benefit profile of the treatment⁷. In certain circumstances, an observational study can provide a higher level of evidence than an RCT

(Fig 2).

Summary

- Application of evidence based medicine principles includes consideration of the best available evidence.
- The inherent challenges in RCT design and execution in Orthopaedic populations has been demonstrated to impact the quality of reported trials.
- As observational study designs have been shown to provide similar estimates of treatment effects, compared to RCT designs, consideration should be given not only to use of observational study designs in clinical Orthopaedic research but also to the ability of these designs to provide a high level of evidence and grade of recommendation.
- As with any clinical research topic, the research question should be determined and the most appropriate and feasible study design to answer the question selected.

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Scapholunate Ligament Reconstruction Using An Acellular Dermal Matrix: A Biomechanical Study

Amirhesam Ehsan, M.D, Dong G. Lee, Ph.D, Adam J. Bakker, M.D, Peter R. Cavanagh, Ph.D, D.Sc., and Jerry I. Huang, M.D.

Introduction

Scapholunate ligament injuries are the most common cause of carpal instability (Figure 1). Repair or reconstruction of the scapholunate interosseous ligament is advocated to avoid the progression of carpal instability and development of

radiocarpal and midcarpal arthrosis. A number of surgical techniques have been described for treatment of chronic scapholunate ligament instability using bone-retinaculum-bone (BRB) autografts, tendon weave reconstructions, and dorsal capsulodesis.

We hypothesize that scapholunate ligament reconstruction using an acellular dermal matrix is a technically simple and biomechanically comparable technique to previously described surgical reconstructions.

Methods

Study Design: Controlled Laboratory Study

- The scaphoid and lunate with the entire scapholunate ligament were harvested from cadaveric specimens.

- Group I: Native Scapholunate Ligament in 4 specimens

- Group II: The scapholunate ligament was transected and reconstructed using a 1mm thick acellular dermal matrix (Arthroflex) and 4 micro suture-anchors in 4 specimens (Figure 2).

- Group III: The scapholunate ligament was transected and reconstructed using a 1.5 mm thick acellular dermal matrix (Arthroflex) and 4 micro suture-anchors in 4 specimens.

- The specimens were potted in metallic cylinders.

- Tensile testing of both the intact and reconstructed specimens was performed using a servohydraulic materials testing machine and data acquisition software.

- Both the native scapholunate ligaments and SL reconstructions were preconditioned prior to formal tensile testing.

- The tensile test apparatus applied a distractive load of 0.17 mm/sec (10 mm/min) until the specimens reached ultimate failure.

- The load-displacement data was obtained and plotted in real-time during the measurement.

- Failure force, failure displacement, stiffness, and energy to failure were analyzed via post data processing.

- Mode of failure was documented for each specimen.

Results

- See Table I.

- In group I, the mode of failure



Figure 1: Patient with a chronic scapholunate ligament injury with scapholunate diastasis and a significant DISI deformity.

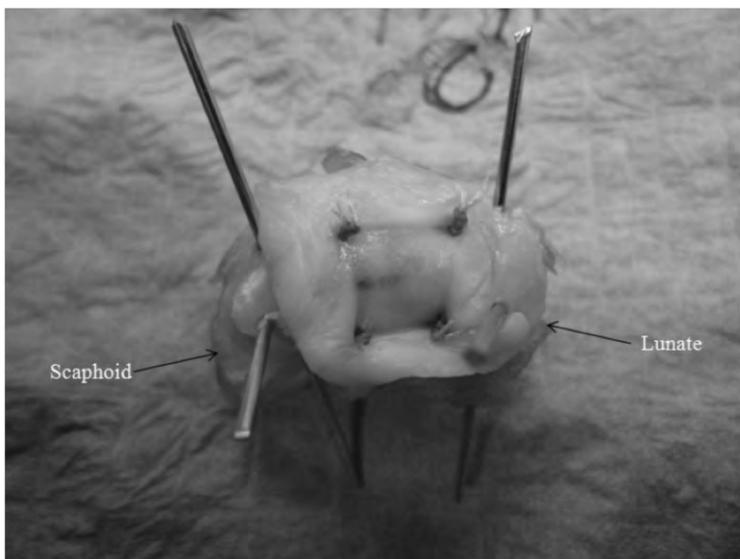


Figure 2: Scapholunate Ligament Reconstruction using Arthroflex Acellular Dermis

	Ultimate Failure Force (N)	Stiffness (N/mm)	Failure Displacement (mm)
Group I: Native SL	192.0 ± 51.1	86.8 ± 30.9	4.5 ± 1.9
Group II: 1.0mm Matrix	78.7 ± 9.5	24.2 ± 6.5	5.3 ± 1.5
Group III: 1.5mm Matrix	101.1 ± 22.1	24.0 ± 9.1	7.5 ± 2.5

Table I: Biomechanical Results.

was at the scapholunate ligament midsubstance in all specimens.

- In group II, the mode of failure was at the suture-matrix interface in all specimens.
- In group III, the mode of failure was at the bone-suture anchor interface in all specimens
- Native scapholunate ligament demonstrated highest failure force and stiffness.

Discussion

- Scapholunate ligament reconstruction using Acellular dermal matrix and suture anchors demonstrates similar biomechanical properties to previously described reconstruction techniques.
- Scapholunate ligament reconstructions using 1mm Acellular dermal matrix failed at the suture-matrix interface while reconstructions using 1.5mm dermal matrix failed at the bone-suture anchor interface, demonstrating increased strength of the thicker Arthroflex matrix.
- Our proposed scapholunate reconstruction technique is a technically simple procedure without any added potential donor site morbidity.
- SL reconstruction using Acellular dermal matrix warrants clinical investigation as a potential treatment alternative for chronic scapholunate instability.
 - Limitations:
 - Only tensile loading was applied, the reconstructions may demonstrate different biomechanical properties when tested under torsional loading.

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Use of Computed Tomography Scans in Detection of Scapholunate Injuries in Distal Radius Fractures

Eugene Farnig, M.D. and Jerry I. Huang, M.D

Background

Intra-articular distal radius fractures are significant and complex injuries, with high rates of associated soft tissue injuries. Arthroscopy has identified scapholunate injuries in as many as 54% of patients [1], with a 3-fold increase in intra-articular fractures [2]. Arthroscopic evaluation at the time of surgery can detect and even treat these injuries, but routine use of arthroscopy is not generally performed. On the other hand, CT scans, which have been shown to alter treatment plans in IA distal radius fractures, are commonly obtained prior to surgery [3, 4]. We sought to investigate the rate of static scapholunate widening on pre-operative CT scans of distal radius fractures, and to identify fracture characteristics associated with widening.

Methods

- All preoperative CT scans of the wrist performed at a single institution for distal radius fractures between 2007 and 2010 were reviewed.
- Fracture characteristics, including fracture pattern, articular step-off, and ulnar variance were measured
- Width of the scapholunate interval on coronal projection was measured and graded as follows:
 - Grade 1: Normal
 - Grade 2: < 3 mm but asymmetric
 - Grade 3: > 3 mm
- Chi-squared analysis was used to identify fracture characteristics

associated with abnormal SL widening

- Using 3 observers to grade 40 coronal CT slices at two different time points, inter- and intra-observer reliability of this grading system was calculated

Results

- 166 CT scans of the distal radius were reviewed, with 143 intra-articular and 23 extra-articular fractures.
- 46 patients (28%) with asymmetric widening of the SL interspace were noted.
- 40 patients with grade 2 and 6 patients with grade 3 scapholunate widening.
- No statistically significant difference in age between the patients with normal wrists and those with scapholunate widening (43.4 vs. 48.4, $p = 0.12$).
- Significantly higher rate of scapholunate widening in intra-articular fractures (31%) when compared to extra-articular fractures (4%) ($p = 0.007$).
- Scapholunate widening was seen in only 1 patient with an extra-articular distal radius fracture.
- Sagittal split between the scaphoid and lunate facets was associated with significantly higher rates of scapholunate widening (37% vs. 20%, $p = 0.024$).

Discussion

- Intercarpal soft tissue injuries are common in intra-articular distal

radius fractures. Routine use of arthroscopy have been advocated by some surgeons as previous studies have demonstrated the incidence of scapholunate ligament injuries to be as high as 54% in patients with intra-articular distal radius fractures [1]. We found the incidence of scapholunate injuries to be 31% in intra-articular fractures compared to 4% of extra-articular fractures. This is similar to the findings of Richards et al, who noted rates of 21.5% and 6.7%, respectively, in intra- and extra-articular distal radius fractures [2].

- Diagnosis of scapholunate injuries can be challenging in the acute trauma setting. Provocative maneuvers often used to identify SL injury are not reliable in patients with distal radius fractures, as pain from the fracture can mask the relevant findings. Carpal alignment can be difficult to assess with standard preoperative radiographs. Advancing imaging with CT scans is frequently obtained in patients with distal radius fractures, particularly those with intra-articular involvement [3, 4].

- Grade 3 scapholunate injury with greater than 3 mm of diastasis was present in only 6 of the 46 cases of asymmetric scapholunate widening.

- In patients with distal radius fractures and high grade injuries to the SL ligament, conservative management predictably leads to worse outcome. Early detection and treatment of scapholunate ligament



Figure 1: Coronal CT images demonstrating SL widening. Grade 1 (left) is considered normal. Grade 2 (middle) asymmetric gap less than 3 mm. Grade 3 (right) greater than 3 mm.

injuries are paramount to prevent future development of carpal instability and post-traumatic arthrosis in the wrist.

- In summary, fractures of the distal radius have a high rate of associated SL injury, and identification of high grade injuries requiring treatment is challenging. In order to identify patients who would benefit from arthroscopy and treatment, CT scans, which are routinely obtained, can be used as a screening examination. In the future, a prospective comparison of CT findings to arthroscopic findings and the collection of validated outcome measures will be necessary to validate this screening methodology.

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Biological Response of Osteoblasts to 3D Periodic Porous Titanium Scaffolds Fabricated by A Novel Electron Beam Melting Method

Russell J. Fernandes, Ph.D., Raj Bordia, Ph.D., and Nik Hrabe, Ph.D.

Introduction

Stress shielding is a phenomenon observed in bone following replacement with load-bearing metal implants, for example, hip stems. A mismatch between the higher stiffness solid metallic implants and the more compliant bone leads to remodeling at the bone-implant interface and often implant loosening. Newer lower-modulus hip stem implants have reported clinical success for as far as ten years post-implantation. For example, the Epoch hip stem from Zimmer achieves a lower elastic modulus by an implant design that has a thin cobalt-chrome-molybdenum core and a thick polymeric outer layer (1). With longer implant lifetimes becoming the norm, motivation to address stress shielding has been revived. The drive to design biocompatible implant materials with improved mechanical compatibility seems justified.

Porous metals show promise in reducing the effects of stress shielding in orthopaedic applications. The potential to optimize elastic modulus and yield strength through the control of structural properties such as relative density, pore size, and strut size makes porous materials attractive to address stress shielding. Additionally, porous metals would potentially allow bone in-growth into

the pores likely strengthening the bone-implant interface. Porous titanium is an obvious choice considering the established biocompatibility of titanium alloys in orthopaedic applications.

The aim was to fabricate porous titanium structures over a range of relative densities using electron beam melting (EBM) and to characterize their structural properties and in-vitro biological response.

Methods

Electron Beam Melting Processing Technique (EBM): Titanium powder (75 μ m, spherical, gas atomized) is spread on a start plate and select areas are sintered/melted using an electron beam. Layer-by-layer construction of 3D parts using computer aided design (CAD) files to control shape and structure (2). Structure is also controlled via build parameters such as beam current, beam speed, acceleration voltage and layer thickness. This method has the required control over structure to accomplish complex gradients of elastic modulus. Relative density was measured by the Archimedes method. Pore and strut size were determined via quantitative micro-computed x-ray tomography. Yield strength and elastic modulus were calculated from monotonic compression tests.

Cell Culture: Ti-6Al-4V structures were passivated according to ASTM F86 and sterilized via soaking in ethanol and exposure to UV light. Human osteosarcoma cells (SAOS-2) were seeded on the scaffolds (105 cells/scaffold). McCoy's 5A media with 10% fetal bovine serum (FBS) and 10 μ g/mL ascorbate was changed every 2-3 days and culture plates were maintained at 37°C and 5% CO₂.

Biochemical Characterization: Proliferation assays (Promega MTS assay), biochemical analysis of collagen protein (collagen content, SDS-PAGE and Scanning electron Microscopy, SEM), were performed at one week intervals up to four weeks.

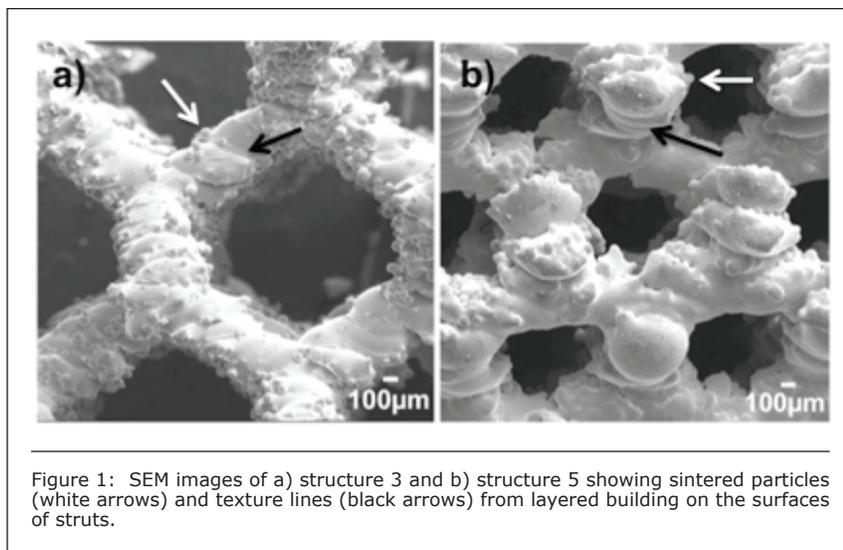
Results

a) Scaffold Processing: The CAD model emulated a unit cell structure of a diamond. Four structures were built over a range of relative densities, strut sizes, pore sizes (Figure 1), having elastic modulus as seen in Table 1. Elastic modulus of normal cancellous bone is 0.2-2.0 GPa and control cortical bone ~15.2 GPa. Yield strengths range from 41.7 MPa-112.7 MPa over the range of pore sizes.

(b) Cell Proliferation: Increase in the number of cells, for all structures, from week 1-2 suggested cells attached and proliferated on the Ti-6Al-4V scaffolds. A plateau of proliferation from week 2-4 for all structures was observed and could represent a period of extracellular matrix production.

(c) Collagen Analysis: The average amount of collagen per sample (0.01mg/cm²) was twice as much as previously reported for SAOS-2 cells grown in monolayer [3]. An increase in collagen content with time for all structures was seen and an increasing content of Type I and V collagen with time in culture was observed by SDS-PAGE.

(d) SEM analysis: Osteoblast attachment on surface and within pores of the construct was confirmed. As seen in Figure 2, a layer of cells was observed within a week (a) and an



Structure	Scaling of CAD Model	Beam Speed (mm/s)	Archimedes Relative Density	Avg Pore Size (μm)	SD (μm)	Avg Strut Size (μm)	SD (μm)	Yield Strength (MPa)	Elastic Modulus (Gpa)
1	0.6013	240	0.39	525	142	398	111	101.4	6.40
3	1.0915	240	0.17	1428	327	444	117	41.7	0.89
4	0.7239	240	0.30	724	190	412	108	62.9	3.59
5	0.75	125	0.40	633	174	530	148	112.7	6.79

Table 1: Structural parameters for EBM Ti-6Al-4V scaffolds.

increase in fibrillar content with time in culture for all structures was observed. By week 3, higher ordered structures (e.g. collagen fibrils, bundles, fibrous meshworks) are seen.

Conclusions

The porous Ti-6Al-4V structures fabricated by electron beam melting show elastic modulus within the range of normal cancellous bone. The in-vitro biological response is favorable and osteoblast-like cells attach and proliferate on and within the pores of the Ti-6Al-4V scaffolds. More importantly, collagen content increases with time for all structures, bone-typic type I and V collagen is synthesized and fibrils are visible in

the extracellular matrix with time in culture. Designing porous Ti-6Al-4V implants for in-vivo studies in large animals models can now be considered.

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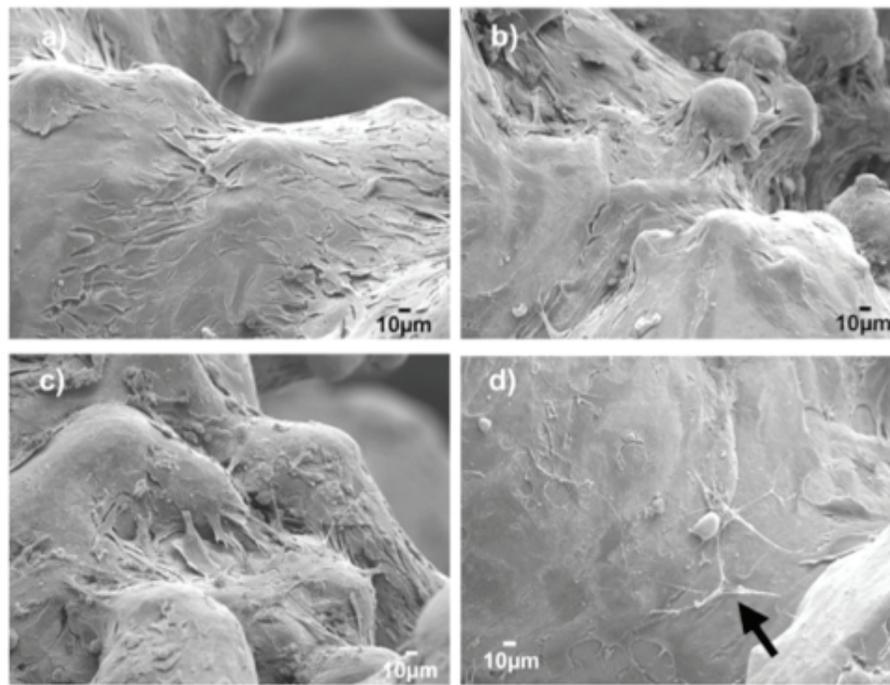


Figure 2: SEM images of structure 3 scaffolds after a) 1 week, b) 2 weeks, c) 3 weeks and d) 4 weeks in culture. Note flattened cells on the scaffold surface (a) and cells spanning sintered particles (b) and surface undulations (c). The black arrow in d) points to fibrillar elements.

A Simplified Method for Chondrogenic Differentiation of Mouse Embryonic Stem Cells

Andrew Ghatan, M.D., Howard A. Chansky, M.D., and Liu Yang, Ph.D.

Introduction

We have been successful in directing the differentiation of mouse embryonic stem (ES) cells towards chondrogenic differentiation *in vitro*. ES cells are grown on monolayer mouse embryonic fibroblast (MEF) cells. Embryoid bodies (EB) are formed through a novel technique, developed in our laboratory, that is less tedious and less costly than prior approaches. These EBs are then induced to become chondrocytes by culture in chondrogenic medium. This process takes advantage of the virtually limitless proliferative capacity and pluripotentiality of mouse ES cells as a substrate for the procurement of chondrocytes (Figure 1). This technique has varied potential applications in the study of chondrocytes and chondrogenesis *in vitro*.

Experimental Methods

Mouse embryonic fibroblast (MEF) cells were allowed to grow in culture media to 95% confluence over 24 hours, and were then growth-arrested by addition of mitomycin-. After 2.5 hours, the culture medium was replaced with fresh medium without mitomycin and replenished daily thereafter. These growth-arrested MEF feeder cells can then be used to support the growth of ES cells in culture.

Cells from the G4 mouse ES cell line were spun down at 3,000 rpm for 5 minutes, resuspended in 2 ml MEF medium containing 1×10^3 units/ml LIF (leukemia inhibitory factor), and then plated on top of MEF feeder cells. This culture needs to be maintained by daily medium change until the ES cells are ready to be expanded again.

For our experiment, MEF feeder

cells must be separated from ES cells prior to formation of embryoid bodies (EBs) by ES cells. For this, ES + MEF feeder cells were first broken into individual cells by trypsin digestion, then plated onto gelatin-coated plates. Since MEF cells rapidly adhered to gelatin-coated plates while the ES cells did not do so, ES cells remained in suspension and were collected after one hour in the gelatin-coated plates.

To form embryoid bodies, freshly isolated ES cells were suspended in MEF-medium without LIF. Two days later, formation of EBs was clearly visible. These EBs were then collected and plated onto gelatin-coated 24-well plates, and cultured in chondrogenic medium. As a negative control, some EBs were cultured only in MEF medium.

Results

During four weeks of culture in

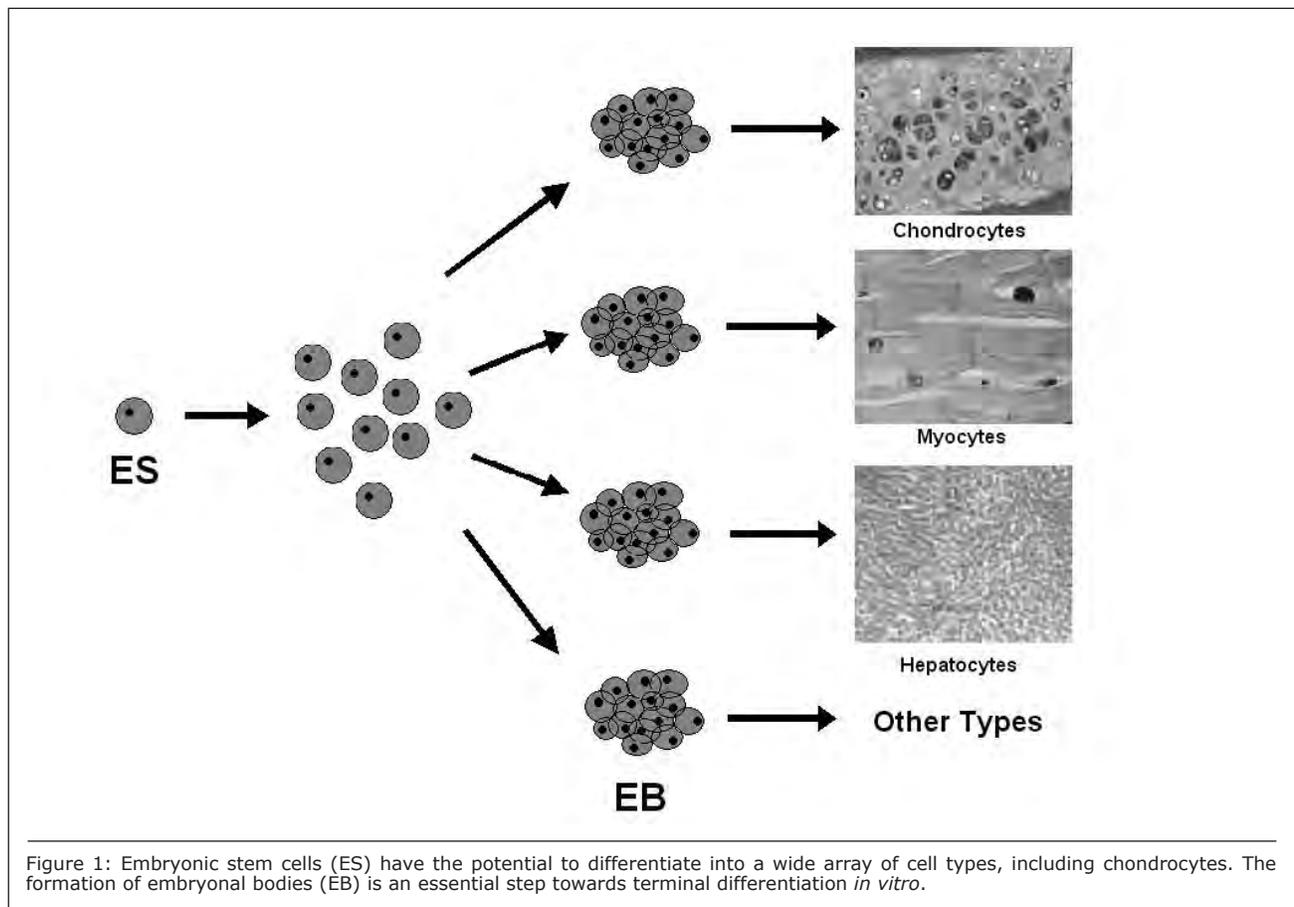
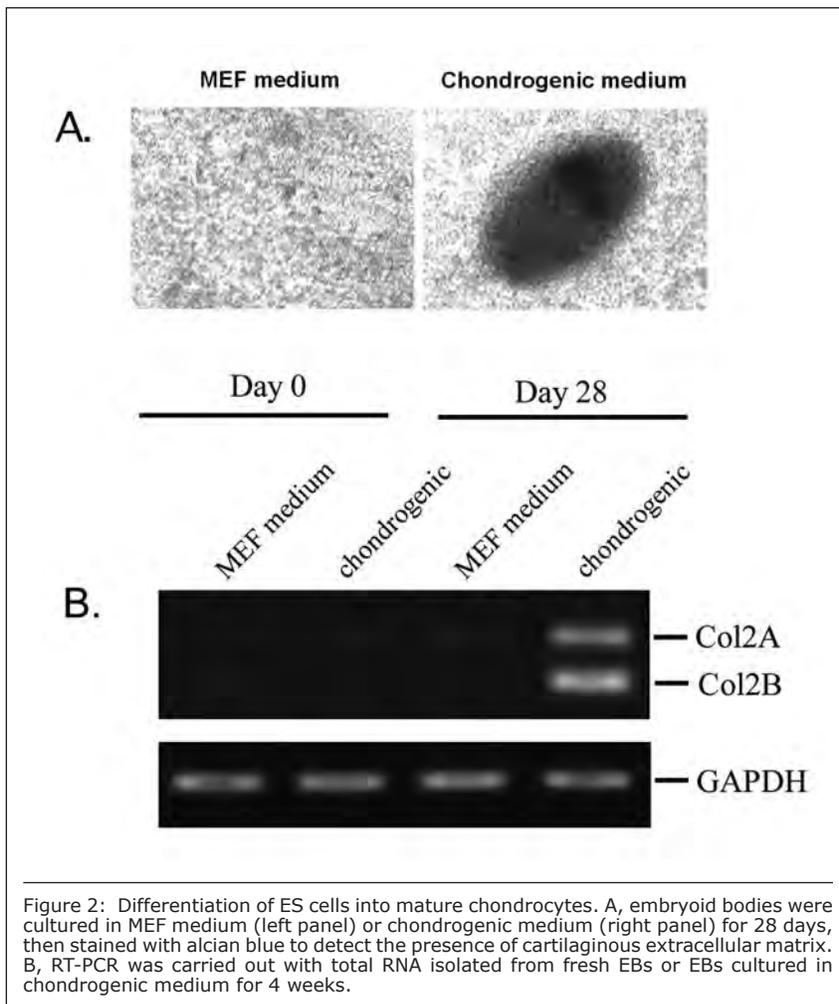


Figure 1: Embryonic stem cells (ES) have the potential to differentiate into a wide array of cell types, including chondrocytes. The formation of embryonal bodies (EB) is an essential step towards terminal differentiation *in vitro*.



chondrogenic medium, EBs first attached to the plate surface, formed nodules, and then gradually differentiated into mature chondrocytes. This change was characterized by production of cartilaginous extracellular matrix. This is confirmed by positive Alcian blue staining of nodules in chondrogenic medium but not in control MEF medium (Figure 2A). Alcian blue is a dye that stains the extracellular matrix of cartilage tissue. At the molecular level, mature chondrocytes are marked by expression of alternatively spliced type II collagen, a major component of the cartilage. To show expression of type II collagen, we carried out a reverse transcription-polymerase chain reaction (RT-PCR). Our results show that type II mRNA is indeed expressed as alternative splicing products in cells from chondrogenic medium, whereas a low level of Col2A (longer splicing product) was detected in the control cells (Figure 2B).

Discussion

The ability to generate chondrocytes from embryonic stem cell lines has attracted significant interest as a potential source of cartilage that could ultimately find therapeutic applications in humans. There are several described techniques for the derivation of chondrocytes from cultured cell lines. However, their utility has thus far been limited by poor efficiency, low yields, the use of costly growth factors such as recombinant TGF- β 3, and in the case of those utilizing human embryonic lines, legal, ethical and political obstacles to funding. In our present study, we sought to simplify the process by which embryonic stem cells are made to form embryoid bodies in chondrogenic medium that contains the less costly bovine insulin instead of TGF- β 3.

When mouse ES cells are cultured in an environment absent of LIF or MEF cells, which act to maintain the ES cells in a state of pluripotency, they will tend to spontaneously form three-dimensional aggregates called

embryoid bodies. ES cells must proceed through this stage of EB formation on their way towards chondrogenic differentiation. In our laboratory we have successfully used the hanging drop technique to generate EBs. However, the hanging drop technique is labor intensive and limited by the small volume of EBs that can ultimately be generated. Our success in obtaining EBs in suspension allows for a much larger culture volume and avoids the labor-intensive process of preparing the hanging drops. Our efficient and cost-effective technique for generating EBs also lends itself to the investigation of regulatory factors such as Sox9 in the control of ES cell differentiation into chondrocytes.

How Often Should You Exercise Your Bones?

Ted S. Gross, Ph.D., Jitendra Prasad, Ph.D., Steven D. Bain, Ph.D., and Sundar Srinivasan, Ph.D.

Introduction

It is well accepted that mechanical loading of the skeleton can serve as a powerful anabolic signal leading to increases in bone mass and enhanced bone morphology. However, the complex multi-scale mechanotransduction underlying this process creates a profound challenge for any attempt to optimize bone's response to loading. For example, while real-time signaling amongst bone cells undoubtedly contributes to the initial response of bone to loading, repeated activation of signaling pathways underlying bone mechanotransduction can lead to sustained downstream synthesis of auto-regulatory repressors that may serve to mute bone's sustained response to loading (1). We have therefore speculated that standard exercise regimens, which typically occur once every 24 or 48 hrs, are sub-optimal as the loading events following the initial bouts of loading are negatively influenced by persisting suppression of signaling pathways essential to achieve maximally augmented bone morphology.

Materials and Methods

- A complimentary mathematical modeling/in vivo approach was used

to address this problem that built on our initial agent based model (ABM) of bone cell communication of acute Ca^{2+} /NFAT signaling following mechanical stimulation of bone (2,3).

- We enhanced the ABM to include negative feedback auto regulation of the Ca^{2+} /NFAT pathway. This advancement allows, for the first time, simulation of bone's response to loading over any given period of time.

- We exposed the right tibia of female C57 mice (16 wk, n=8/grp) to mechanical loading (50 cycle/loading bout, peak normal strain: 2250 $\mu\epsilon$) for a varied number of loading bouts during a 3 wk intervention (1 or 3 bouts/wk for 3 wk). Additionally, for both protocols, the loading regimen included either 0 or 10 s of rest inserted between each load cycle (i.e., cyclic or rest-inserted loading).

- Animals received calcein labeling (day 10, 19) and periosteal bone formation rate (p.BFR/BS) was determined at the tibia mid-shaft of left (contralateral) and right (loaded) tibia via standard dynamic histomorphometry at day 22.

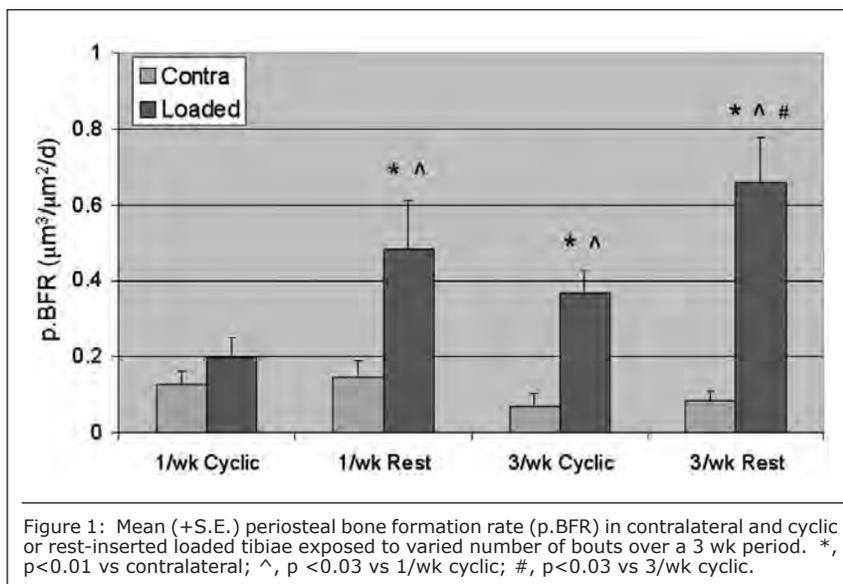
Results and Discussion

Subjecting mice tibiae to three bouts of cyclic loading separated by 7 d did not increase periosteal bone

formation rate (p.BFR) compared to non-externally loaded contralateral controls (Fig 1.). However, three 1/wk bouts of rest-inserted loading did significantly increase p.BFR (227% vs contralateral, $p < 0.01$). Nine total bouts of loading significantly increased p.BFR for both cyclic loading ($p < 0.01$) and rest-inserted loading ($p < 0.01$). While the p.BFR induced by 9 bouts of cyclic loading exceeded that induced by 3 bouts of cyclic loading ($p = 0.02$), p.BFR induced by 3 vs 9 bouts of rest-inserted loading was statistically equivalent ($p = 0.18$). Finally, we observed that 3 bouts of rest-inserted loading was equivalent to 9 bouts of cyclic loading ($p = 0.23$). These data indicate that the cellular perception and response of bone to mechanical stimuli is directly effected on two time scales, the first occurring within seconds and minutes during the brief exogenous loading bout (i.e., by including a 10 s rest-interval between each load cycle) and across days and weeks (i.e., by separating loading bouts by 2 or 7 d). As rest-inserted loading appears to require much less frequent loading bouts to achieve an anabolic response, it appears that brief rest-intervals clearly influence the cellular response for a time period that greatly extends past the time of loading. Such a differential response at the *in vivo* level is consistent with our hypothesis. As a result, we believe that modeling this response via our enhanced ABM will enable clarification of optimal loading event timing during a defined duration exercise intervention in order to maximize bone's response to mechanical loading.

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Split Foot Deformity: Report of Treatment with Modern Internal Fixation in a Family with Karsch-Neugebauer Syndrome

Sigvard T. Hansen, M.D. and Scott M. Holthusen, M.D.

Introduction

Split foot deformity is a rare anomaly and the literature is diverse in regard to treatment recommendations. No one surgeon or service has seen enough cases to develop a protocol, nor would this be easy to do in view of the considerable diversity in anatomy

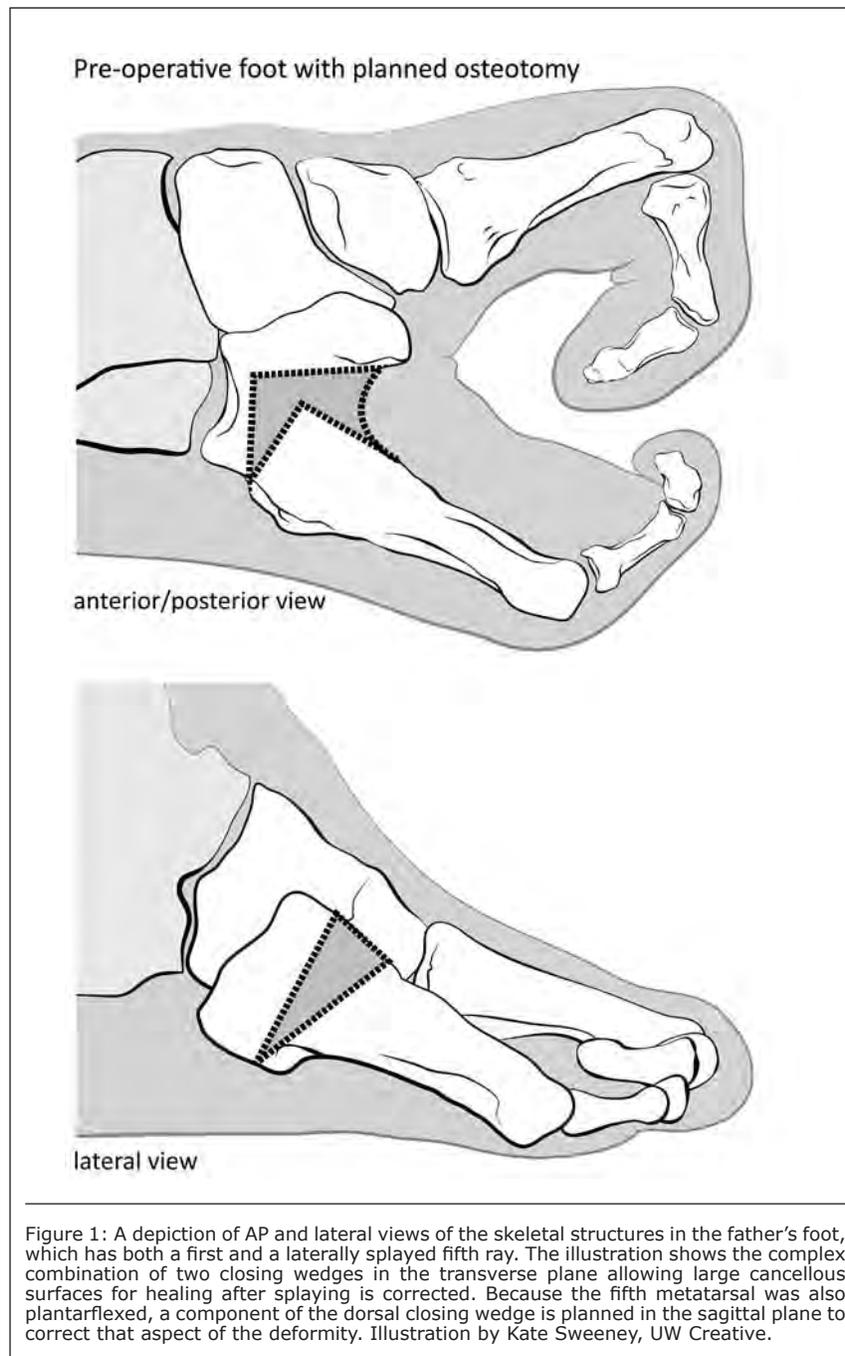
and primary diagnoses. Moreover, most reports pre-date the use of stable anatomic fixation in the foot, which has become broadly accepted only in the last 10-15 years. In this regard, the situation is similar to the initial problem with the Lapidus procedure; the rationale was sound, but Lapidus

used catgut sutures to attempt fixation of the first ray in a corrected position. This of course failed and the procedure lost credibility until the introduction of stable and reliable fixation.

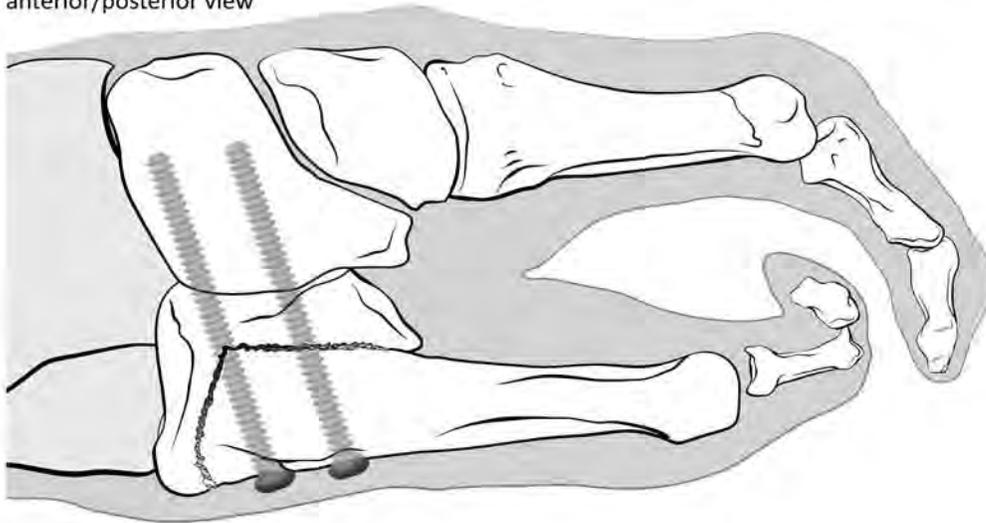
We would like to present our approach in a family with Karsch-Neugebauer Syndrome. The deformities include bilateral split hands and feet of a relatively severe type (according to Blauth's classification, type 5 in the father and type 6 in two children). This syndrome is also associated with congenital nystagmus. The father's type-5 deformity consisted of mostly intact first and fifth rays and rather marked splaying. Only the fifth metatarsals were intact in the children with type-6 deformities and they also demonstrated significant splaying lateral to the normal alignment with the calcaneus. Symptoms in both were due largely to difficulty with shoe wear caused by splaying. There was some discomfort with weight-bearing but in general the feet were surprisingly functional. This, of course, is common in patients with birth deformities as they learn to use what they have just as 'normal' people do.

Dwyer, in his rather large collected series in 1976, expressed that it was very important to correct the deformity - mostly splaying - in all planes to bring the foot into a plantigrade position. However, no internal fixation was used in his series. We agree with his principle, but assumed that it could be done better or more reliably using an appropriate osteotomy and correcting the foot in all planes using stable fixation. At the time, our cases were done without specific knowledge of Dwyer's cases.

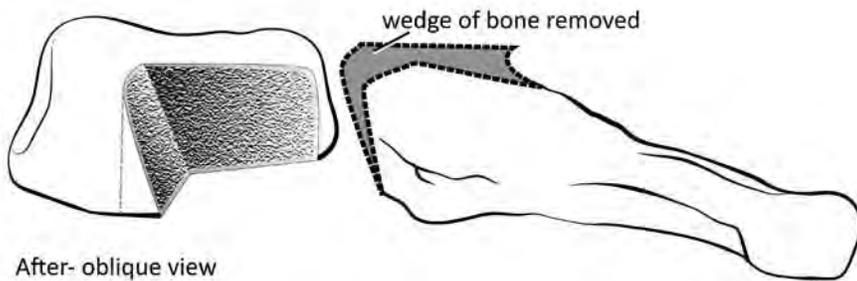
All cases, a total of five feet (two in the father, one in each of the older brothers, and one in a sister) were operated on in a similar manner by carrying out a double-wedge plane osteotomy in the congenitally fused area of the lateral foot near the cuboid-base of the fifth metatarsal. Our goal was to bring the fifth ray into alignment with the calcaneus in the transverse plane and flexed in 20 +/-10 degrees



Completed osteotomy with fixation showing correction in transverse plane
anterior/posterior view



Wedge construction for sagittal plane correction
Before- oblique view



After- oblique view

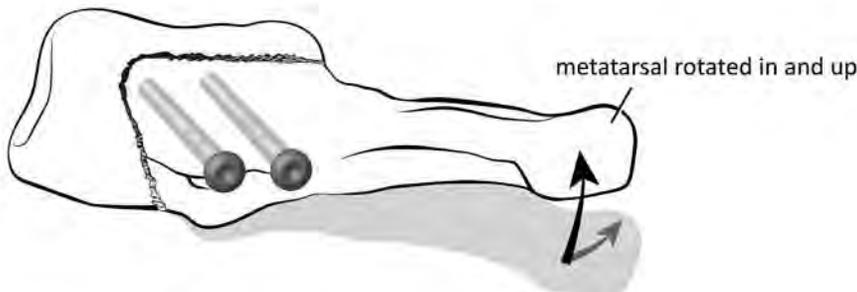


Figure 2: AP and lateral x-ray views simulate the appearance of the foot in the transverse and sagittal planes after the closing wedges are approximated and fixed. The foot, of course, is not normal (the patient did not want the toes corrected at all) but fits into a normal shoe and is very functional, even for athletic activity. Illustration by Kate Sweeney, UW Creative.

in relation to the line of the calcaneus in the sagittal plane. That is, we wanted to create somewhat of an arch but not to the degree of putting too much pressure on the fifth metatarsal head plantarly. We had to revise one of the father's feet to improve his alignment.

The osteotomy is depicted in the accompanying illustration. It has transverse and longitudinal portions designed to obtain extensive bony contact and stability with healing as

well as to provide the most anatomic alignment.

Except for misjudging the amount of plantar flexion that would work the best in our first case, all of our patients enjoyed rapid healing and are stable with resolution of symptoms secondary to splaying.

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Iatrogenic Lateral Trochanteric Wall Fractures of the Proximal Femur: A Case Report of a Technique for Managing This Perioperative Complication Associated with the Surgical Treatment of Intertrochanteric and Pertrochanteric Fractures

M. Bradford Henley, M.D., M.B.A., F.A.C.S.

The Problem

The treatment of unstable, three and four part intertrochanteric (e.g. pertrochanteric) hip fractures has undergone many changes over the past 50 years. Yet even after current treatments are used, this fracture pattern often yields many patients with functional and lifestyle limitations as well as frequent complications. Limb length inequalities (from shortening of the femoral neck), weakness, and diminished hip range of motion a limp requiring an ambulatory aid (i.e. a cane or walker) are common.

The Background

This history of internal fixation for

these fractures changed from static fixed angle devices to sliding, fixed angle devices in the 1950's when the gliding hip screw was first introduced. This was subsequently modified in 1956 by D. K. Clawson (Clawson, 1955) of the University of Washington's Department of Orthopaedic Surgery and distributed by Richards as a sliding hip screw. Little changed throughout the 1960's-1990's, though various authors advocated specific technical aspects of the procedure so as to improve the outcome of this procedure. These included an anatomical reduction (avoidance of varus/retroversion), restoration of a stable medial cortex, correct placement of the lag screw

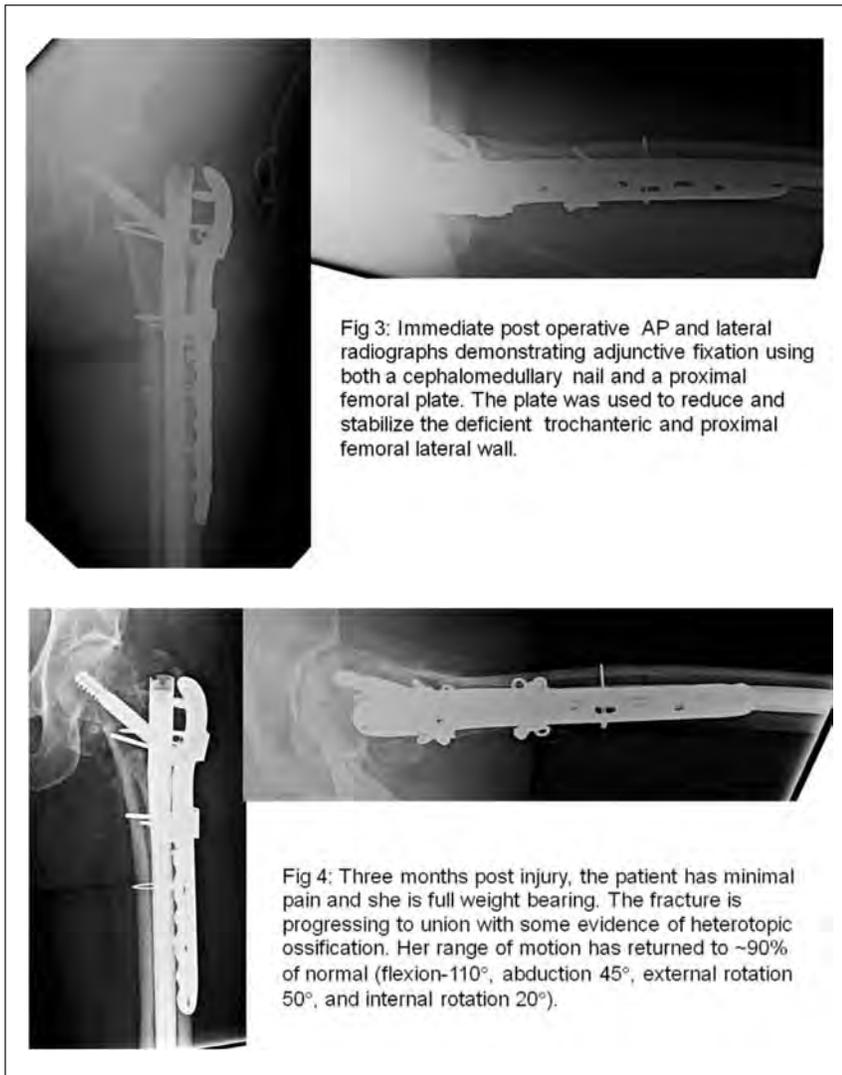
(tip-apex distance), and improving rotational stability (by adding an additional antirotation screw). In the first decade of the 21st century, surgeon's preference for treatment changed from extramedullary implants to cephalomedullary implants. Medicare data show that by 2006 more intramedullary devices were placed for these fractures, than plate/screw devices. This trend has continued through the present with 70,740 intramedullary nailing procedures being reported in 2009, compared to 24,839 plate/screw procedures. Despite this dramatic shift in treatment strategies, functional and lifestyle limitations as well as frequent complications persist. Most importantly, many orthopaedic surgeons are not prepared to deal with these problems, especially when they result in a deficient or unstable lateral trochanteric wall (Palm, Jacobsen, Sonne-Holme, & al, 2007).

The Solution

The intraoperative or postoperative complication of a lateral trochanteric wall fracture of the proximal femur is an unfortunate complication. A post operative fracture of the lateral trochanteric wall has been demonstrated to be the main predictor for a reoperation after an intertrochanteric fracture (Palm, Jacobsen, Sonne-Holme, & al, 2007). These fractures have been reported to occur after the treatment with sliding hip screw-plate devices and may also be seen after treatment with cephalomedullary nails (see Figs 1 & 2)

Various factors may lead to an iatrogenic fracture of the lateral wall. These include a large diameter reamer, imperfect entry portal for the lag screw reamer or intramedullary nail, poor fracture reduction (posterior sag and/or inaccurate restoration of femoral neck version), and anterior or posterior obliquity of the femoral head-neck compared to the guide pin or lag screw in the lateral view (Park SY, 2007). This iatrogenic fracture usually results in creating a reverse obliquity





pattern. This fracture type can usually be managed with a cephalomedullary implant alone, however with significant fracture comminution and displacement, adjunctive fixation may be safer, especially in a morbidly obese patient (see Figs 3 & 4).

Results

Percutaneous compression plates may offer helpful supplementation in the treatment of intertrochanteric fractures with intramedullary nails by maintaining the lateral proximal femoral wall so as to reduce the incidence and risk of perioperative lateral wall fractures. The combination of a suitably strong proximal femoral locking plate with a cephalomedullary implant can provide good results even in complex patients.

Reference

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Effect of Implant Anchor Density and Pedicle Screw Coefficient on Basic Surgical Quality and Outcomes Measures for Adolescent Idiopathic Scoliosis Surgery

Walter F. Kregel, M.D., Sandra Smylie, M.S., and Viviana Bompadre, Ph.D.

Introduction

Instrumentation constructs utilized for correction and fusion of Adolescent Idiopathic Scoliosis have become increasingly complex, and expensive. Some authors have shown improved correction with greater implant anchor density (Screws, hooks or wires per vertebra), while others have shown little correlation between implant density and patient-based outcomes or correction, and there is not substantial discussion of the associated costs, or effects on other outcomes measures



Case 1 and case 2

likely to be utilized by payors and regulatory agencies to determine cost effectiveness, and "grade" surgeons. We set out to examine the effect of implant density and other variables inherent to scoliosis surgery on correction, costs, and other standard quality measures.

Implant density in the main thoracic curve from T4-T12 is 12 anchors divided by 9 vertebrae = 1.33 in case 1 and in Case 2 it is 16 divided by 9 = 1.89. Pedicle Screw coefficient is the density multiplied by the proportion of anchors that are pedicle screws. For case 1 this is 7/12 X 1.33 = 0.78, and for case 2 it is 16/16 X 1.89 = 1.89. Pedicle screw coefficient numerically rates pedicle screw anchors more heavily, based on increased costs and potential risks compared to other anchors.

Materials and Methods

Retrospective review of 119 consecutive cases of PSF for AIS by 4 surgeons at Seattle Childrens

Dependant variables - Implant density, Curve Magnitude, Curve Flexibility, Levels Instrumented and fused, Surgeon

Outcomes - Correction, Complications, reoperations, infection,

EBL, Transfusion, Implant and Total Hospital Charges, ICU days, Infection, Length of stay

There was a trend but not significant correlation ($p=0.08$) of implant density to correction of the fully instrumented thoracic scoliosis curves (not shown in table). Complications were not correlated with implant density, pedicle screw coefficient (density X proportion of anchors that were pedicle screws), levels fused, curve magnitude, or surgeon. Levels involved in the fusion strongly correlated with length of stay, Operative Time, Transfusion, implant charges and hospital charges. Pedicle Screw coefficient correlated significantly inversely with length of stay ($p=0.023$), directly with operative time, and most strongly with implant costs ($p<=0.004$). Total Hospital Charges correlated most significantly with levels fused.

Blood loss, Operative Time and ICU days correlated with surgeon, as did implant density (not in table). Transfusion ($p=0.68$) and implant charges ($p=0.59$) showed trends toward correlation to surgeon.

Discussion

As cost effectiveness becomes more critical, high volume, high

Outcomes		Curve Magnitude	Levels Fused	Implant Density	Pedicle Coefficient	Surgeon
Pearson (p value)						
Clinical	Complications	.047 (.631)	-.002 (.984)	-.112 (.254)	.011 (.908)	-.094 (.337)
	Re-Operations	-.02 (.842)	-.019 (.844)	-.087 (.377)	.032 (.742)	.112 (.251)
	Infections	-.025 (.804)	-.101 (.305)	.037 (.703)	-.094 (.336)	-.111 (.258)
Surgical	ICU days	.050 (.613)	.073 (.456)	-.106 (.282)	-.019 (.849)	.197* (.043)
	LOS in Hospital	.225* (.021)	.317** (.001)	-.183 (.060)	-.220* (.023)	-.097 (.321)
	EBL, cc	.007 (.945)	.186 (.057)	0.16 (.868)	.159 (.105)	.356** (.000)
	Transfusion	-.019 (.885)	.25** (.01)	.022 (.821)	-.085 (.387)	.178 (.068)
	Operative Time	.260** (.007)	.534** (.000)	.060 (.542)	.203* (.037)	.342** (.000)
	Implant Charges	.086 (.395)	.282** (.004)	.289** (.004)	.287** (.004)	.189 (.059)
	Hospital Charges	.117 (.234)	.353** (.000)	0.88 (.371)	.135 (.168)	.170 (.081)

cost procedures will come under more scrutiny, as will the surgeons performing them. Surgeons and institutions will need to be aware of variables associated with costs and other easily measurable outcomes, that are likely to be graded by payors. For AIS surgery some variables that effect outcomes and costs are not under control of the surgeon, such as curve magnitude and levels fused, while others are clearly under control of the surgeon, such as implant density and pedicle screw coefficient. Clarity about the effects of surgical choices will help surgeons make appropriate cost-effectiveness decisions until there is unequivocal evidence of improved outcomes with more costly techniques.

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Unintended Durotomy During Spine Surgery: A Multivariate Analysis

Michael J. Lee, M.D., Amy M. Cizik, M.P.H., Geoff Baker, B.A., Mark Konodi, M.S., Richard J. Bransford, M.D., Carlo Bellabarba, M.D., and Jens R. Chapman, M.D.

Study rationale

- Incidental durotomy during spine surgery is a common occurrence with a reported incidence ranging from 3 to 16%¹⁻³.
- Risk factors identified by prior studies include: age, type of procedure, revision surgery, ossification of the posterior longitudinal ligament, gender, osteoporosis and arthritis.
- However these studies are largely univariate analyses using retrospectively recorded data.

Research Question

- Using multivariate analysis in a large registry of spine patients, what are significant risk factors for unintended durotomy during spine surgery?

Materials and Methods

- The Spine End Results Registry 2003-2004 is a database of all surgical patients from Jan 1st 2003-Dec 31st 2004. Extensive demographic, comorbidity, and complication data were defined a priori and prospectively collected.
- The Surgical Invasiveness Index was utilized to quantify extent of surgery.
- Using these data, univariate and multivariate statistical analyses were performed to identify and quantify risk factors for incidental durotomy during spine surgery.
- Relative risk values with valid confidence intervals and p values were

determined using these data.

Results

- Our multivariate analysis demonstrated that age, lumbar surgery, revision surgery, and elevated surgical invasiveness are significant risk factors for unintended durotomy during spine surgery. (Table 1)
- Of these, revision status was the largest risk factor.
- Diabetes was a significant risk factor in our univariate analysis, but not in our multivariate analysis.

Discussion

- Strengths: This is an analysis of an extensive prospectively collected data registry, which allows for multivariate analysis to determine risk factors for unintended durotomy. Prior studies have been largely qualitative in assessment.
- Weakness: One possible risk factor could not be taken into consideration: experience level of the operating surgeon at the moment of cerebrospinal fluid leak. At an academic institution, there are many team members with varying levels of experience. Retrospective review of the operative reports did not satisfactorily yield this information.
- Weakness: Though these data were prospectively gathered, much of the data are recorded as categorical variables rather than continuous variables. The recording of data in this way may not accurately reflect

the severity of some risk factors over others.

- In general, the findings of this study are in agreement with much of the existing literature. These data can be useful in pre-operative patient counseling, particularly patients who have had prior spine surgery.

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	RR	p	95% CI
Age 40-64 (ref age 18-40)	1.67	<0.016	1.12 – 2.59
Age >65 (ref age 18-40)	1.81	<0.015	1.13 – 2.94
Cervical surgery (ref: lumbar surgery)	0.39	<0.001	1.63 – 2.98
Surgical Invasiveness (ref score 0-5)	1.56	<0.038	0.99 -2.34
Revision (ref: primary)	2.21	<0.001	2.63 – 2.98

Table 1: Significant Risk Factors for Unintended Durotomy during spine spine surgery after step-wise multivariate log-binomial regression analysis.

Testing for the Presence of Positive-Outcome Bias in Peer Review: A Randomized Controlled Trial

Seth S. Leopold, M.D., Gwendolyn B. Emerson, M.D., Winston J. Warme, M.D., Fredric M. Wolf, M.D., James D. Heckman, M.D., and Richard A. Brand, M.D.

Introduction

Positive-outcome bias (POB) is defined as the increased likelihood that studies with a favorable or statistically significant outcome will be published compared to studies of similar quality that show unfavorable or "no-difference" results. While this phenomenon is not limited to the peer-review process, manuscript review is considered an important locus of POB. Because of numerous confounding factors (including differences in study quality, sample size, and clinical relevance), the existence of this kind of bias is almost always inferred, rather than proven.

We sought to determine whether POB is present during peer review by testing the following hypotheses: 1) peer reviewers would recommend publication of a "positive" version of a fabricated test manuscript over an otherwise-identical "no-difference" test manuscript version; 2) peer reviewers would identify more purposefully placed errors in the no-difference version; and, 3) peer reviewers would rate the methods section in the positive

version more highly than the identical methods section in the no-difference version.

Materials and Methods

Two versions of a fabricated "test" manuscript describing a well-designed randomized controlled trial were created and submitted for peer review to The Journal of Bone and Joint Surgery (American) and Clinical Orthopaedics and Related Research, with the partnership of the editors-in-chief of those journals.

The two manuscript versions were identical except that, in the "positive" manuscript version, the data pertaining to the principal study end point favored the primary hypothesis and the conclusion was worded accordingly while, in the "no-difference" manuscript version, the data did not show a statistically significant difference between the two study groups and the conclusion section was worded accordingly.

The Introduction sections and, importantly, the Methods sections were verbatim identical between the

two test manuscript versions. The test manuscript was created, with the help of the two participating editors-in-chief, purposefully to represent an extremely well-designed, multicenter, surgical RCT.

Seven identical errors were placed in each manuscript version, to determine whether the study outcome influenced how carefully peer reviewers evaluated the manuscripts.

The three hypotheses were tested by assessing the difference between the reviews of the positive and no-difference manuscript versions as follows: the proportions of reviewer recommendations to accept or reject the manuscript (accept/reject), the reviewers' methods quality scores (ranging between 0 and 10), and the number of purposefully placed errors in each manuscript that were detected by reviewers (ranging between 0 and 7).

The test manuscript was on the subject of antibiotic prophylaxis for clean orthopaedic surgery; the manuscript version with the positive conclusion demonstrated that the administration of an antibiotic for 24 hours postoperatively, in addition to a preoperative dose, was more effective than the single preoperative dose alone in the prevention of a surgical-site infection; the no-difference manuscript found no significant difference in surgical-site infection between the two regimens purportedly studied.

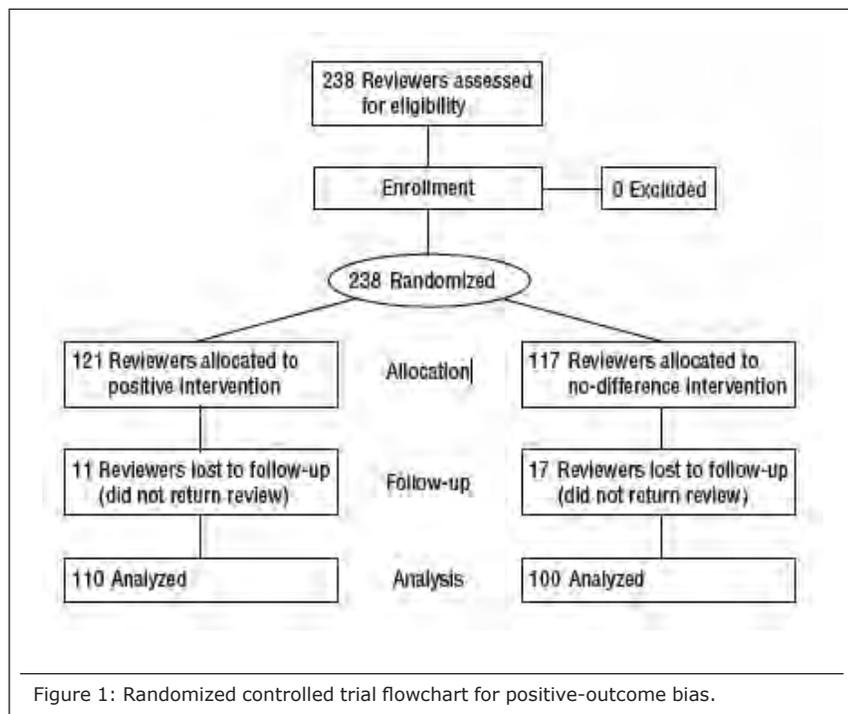
238 reviewers from the two journals were randomly allocated to review either a positive or a no-difference version of the manuscript. 210 returned reviews.

Results

All three study endpoints provided strong evidence for positive-outcome bias affecting peer review.

Reviewers were more likely to recommend the positive version of the test manuscript for publication than the no-difference version (97.3% vs. 80%; $p = 0.0001$; OR = 8.92, 95% CI = 2.56, 31.05).

Reviewers detected more errors in



the no-difference manuscript than in the positive version (0.85 vs. 0.41; $p < 0.001$), suggesting heightened reviewer scrutiny of the no-difference manuscript version.

Reviewers awarded higher methods scores to the positive manuscript than to the no-difference manuscript (8.24 vs. 7.14; $p = 0.005$), even though the methods sections in the two manuscript versions were identical.

Although the magnitude of the effect varied between the two journals surveyed (JBJS and CORR) for each endpoint, the direction of the effect was the same for both journals across all three endpoints.

Discussion

We found evidence of positive-outcome bias (POB) in the review processes of both journals studied (JBJS and CORR). The overall effect across reviewers for both journals was quite pronounced, with a positive-outcome manuscript version being nearly 9 times more likely to be recommended for publication than an identical manuscript version showing no difference in outcome. Significant differences in the frequency of error detection suggested heightened scrutiny of the no-difference manuscript compared with that of the positive-outcome manuscript, and methods scores were significantly higher for the positive version despite the methods sections being identical between the two test manuscript versions.

To the extent that POB exists, it would be expected to compromise the integrity of the literature in many important ways, including, but not limited to, the inflation of apparent treatment effect sizes when the published literature is subjected to meta-analysis. To our knowledge, although numerous studies have inferred POB by comparing denominators of studies submitted (or initiated) with those published, we identified no other experimental studies in the biomedical literature with which we could directly compare our results.

It has been proposed that bias of the sort we observed, which is similar to the "confirmatory bias" in psychology that Mahoney described in a qualitative study some 35 years ago (1), is not just a part of evidence-based medicine or peer review, but rather is part of

normal human cognitive behavior (finding what one seeks). Indeed, Mahoney reminds us that Sir Francis Bacon identified this phenomenon in the scientific process nearly 400 years ago. Certainly our own previous work and that of others has found that the "newsworthy" (defined as a positive finding) is more likely to draw a favorable response from peer reviewers (2), and indeed that work with positive outcomes is more likely to be submitted to peer review in the first place (3). It is possible that registries of prospective trials will mitigate POB at the level of manuscript submission; however, journal editors will need to consider providing specific guidance to reviewers on the subject of the review of no-difference manuscripts in order to minimize the impact of POB on manuscript acceptance. In addition, journals also should specifically encourage authors to submit high-quality no-difference manuscripts, and look for opportunities to publish them, whether in the "traditional" print versions of the journal, in online journal appendices, or in partnership with open-source media.

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Pediatric Limb Salvage Outcome Assessment

Antoinette W. Lindberg, M.D., Stephanie E.W. Punt, B.S., Jedediah K. White, B.S., and Ernest U. Conrad, M.D.

Introduction

Pediatric limb salvage has a greater impact than adult limb salvage because of patient use and longevity. Pediatric patients may be at greater risk for subsequent failure of their reconstructions. Our goals were to assess the results with pediatric limb salvage compared to adult limb salvage results and identify issues with leg length discrepancy, local tumor control, surgical complications, and function.

Methods

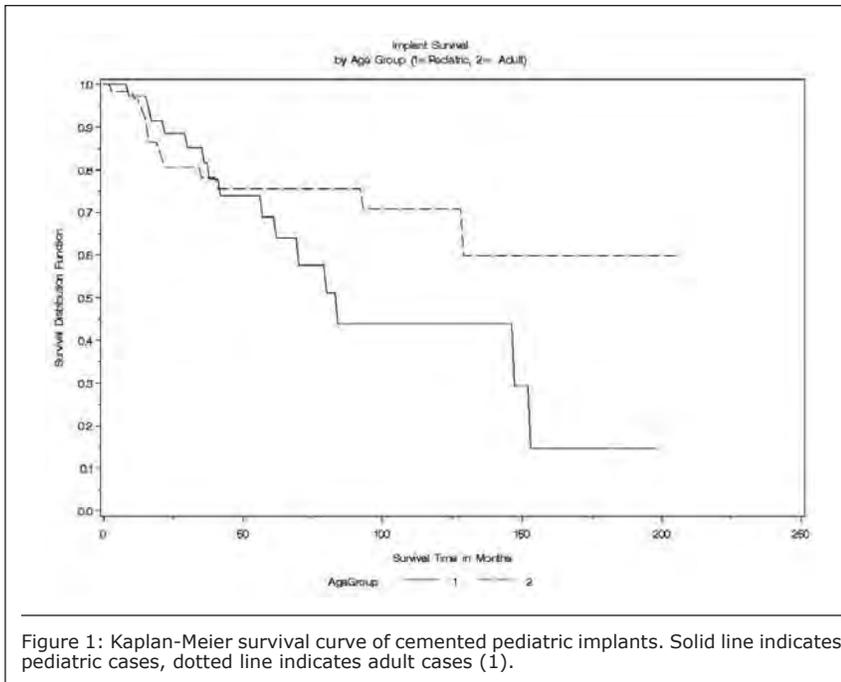
All limb salvage patients at Seattle Children's Hospital have been collected prospectively in a dedicated sarcoma registry since 1990. That registry

was queried for osseous limb salvage patients under 18 years of age. Allograft reconstruction results were compared to implant reconstruction results. Pediatric implant results were compared to adult limb salvage results. Failed limb salvage was defined as amputation and major revisions were defined by the revision of the implant stem at the osseous junction. Minimal follow up for this study was 18 months. Leg length discrepancies and final function were evaluated. Oncology implant techniques were consistent except for a change from cement to uncemented stem/fixation that occurred in 2003.

Results

136 pediatric patients from 1990-2010 were evaluated for results of an osseous limb salvage procedure. Inclusion criteria were patient age (less than 18 years of age) and clinical follow up greater than 18 months. Reconstructions included 74 allografts and 62 oncology implants in 136 patients. Average age was 13.3 years and average follow up was 7.1 years. The implant procedure involved the distal femur and proximal tibia in 48/62 (77.4%) of cases. Revision procedures in our cemented vs. uncemented cohort for the distal femur and proximal tibia occurred most commonly for aseptic loosening in cemented implants (17% vs. 7% in uncemented implants). Cemented implants had a higher failure rate than uncemented implants. Deep infection occurred in 10% of allografts and in 4% of implants. Allograft reconstructions required longer postoperative rehab and had a higher failure rate than implant (15% vs. 10%). Amputation (7/136, 5.1%) were unusual for both groups and were indicated for local tumor recurrences. Revision rates were higher in a child with a cemented stem than their adult counterparts (24% vs. 42%). Kaplan-Meier prosthetic survivorship in children was 69% and 44% at 5 and 10 years respectively for cemented stems (1). Gender and tumor size did not affect implant survival. Arthrofibrosis occurred in 10% of patients. Leg lengthening procedures achieved 75% of lengthening goals. Results are summarized in Table 1.

We are also currently using activity



	Allografts	Oncology implants
Total number	74	62
Deep infection	10%	4%
Failure rate	15%	10%
	Cemented stem	Uncemented stem
Aseptic loosening	17%	7%

Table 1: Allografts vs. oncology implants and cemented stems vs. uncemented stems.



Figure 2: This 10 year old patient has returned to playing softball over 2 years after distal femoral condyle sparing resection surgery (top row: preop xrays) (middle row: postop xrays: left: Condyle sparing intercalary allograft, right: custom prosthesis) (bottom row: postop patient playing softball).

monitors (Step Watch) and functional outcome surveys before and after surgery to clinically assess outcome in limb salvage patients. The pediatric group showed a significant correlation to daily total strides for limb salvage youth vs. normal age-matched controls (4,487 steps/day, 7,671 steps/day $p=0.0001$). Youth having a limb salvage procedure self-scored their standing, physical activity, and mobility ability (via ASkp-38) significantly less than their age-matched controls (88.3 versus 97.7 respectively, $p=0.001$) (2).

Summary

Children are at higher risk for implant failure than adults with oncologic implants about the knee. The greatest cause of surgical revision was aseptic loosening in both children and adults. Leg lengthening remains a challenge in children under 12 years old.

Assessment by Step Watch provides an accurate assessment of activity levels before and after surgery. Limb salvage adolescents have significantly lower activity (and less variation) than normal age matched controls.

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Endoscopically-aided Physeal Bar Take-down and Guided Growth for Treatment of Angular Limb Deformity

Erik K. Loraas and Gregory A. Schmale, M.D.

Abstract

Treatment of physeal arrest following infection remains a challenge. Localized endoscopic epiphysiolysis combined with guided growth is effective treatment of partial physeal arrest and limb deformity that may occur in children after infection as infants. Arrest may occur at anytime following physeal trauma, highlighting the importance of long-term follow-up.

Introduction

Partial or full arrest of the physis remains one of the most challenging problems in childhood growth, often causing length and angular deformities of the limb [1]. Osteomyelitis remains a leading cause for physeal, though arrest typically does not manifest until years later. Children may benefit from physeal bar takedown and/

or contralateral growth arrest [2]. Temporary hemiepiphysiodesis or "guided-growth" may occur with traditional Blount's staples or small plates.

The surgical approach for physeal bar takedown involves removal of the bone bridge via metaphyseal windowing. Visualization is critical for complete removal of bridging bone and conservation of healthy physeal cartilage. A dental mirror has traditionally been used for visualization, however an arthroscope is an attractive alternative [3]. This case report confirms the importance of monitoring for physeal arrest following infection, the benefits of temporary hemiepiphysiodesis in treating angular defects, and the advantages of an arthroscope used endoscopically within the bone as an "osteoscope" in physeal bar takedown.

Case Report

A previously healthy 6-month-old boy presented to the Emergency Department with a swollen, tender, and warm left leg. Blood cultures, femoral bone biopsy, and a joint aspirate grew methicillin sensitive *Staphylococcus aureus*. Treatment with antibiotics continued until serum inflammatory markers normalized. No follow-up occurred until the patient presented at eight years of age with complaints of a crooked leg and a limp. Physical exam demonstrated a valgus left knee. Fusion of the lateral femoral physis and 11 degrees of mechanical axis valgus on the left were also apparent (Fig. 1).

The angular deformity was treated by temporary medial distal femoral hemiepiphysiodesis with a two-holed plate, for correction of the valgus through future growth of the lateral femoral physis after bar excision. Resection of the lateral physeal bar was performed via an osseous window made with osteotomes and curettes under fluoroscopic guidance, with the assistance of a 4-mm arthroscope to check the thoroughness of the bar excision. Saline washed the tunnel clear of blood, but viewing was

performed "dry", after evacuation of fluid with Frazer tip suction. The scope and curette were alternately introduced and removed to accomplish the bar excision. Once a complete ring of physis could be seen, the tunnel was irrigated and drained (Fig. 2). The distal end of the tunnel was packed with fat harvested from the soft tissues of the posterior thigh through the same incision. Biopsy specimens collected at that time were negative for infection.

Nine months following surgery, the left knee valgus had fully corrected. At one year the patient had returned to full activity, and the medial distal femoral plate was removed. The family was cautioned that following plate removal the deformity may recur, and that further close follow-up was essential. Future guided growth by repeat medial distal femoral temporary or permanent hemiepiphysiodesis prior to skeletal maturity might be necessary.

Discussion

Partial arrest is common following trauma to the physis. For young patients with growth remaining, physeal bar takedown remains an option for treatment or limb deformities. Traditional visualization of the bar relies on a dental mirror. In this case, a 4 mm arthroscope was used for visualization, as an osteoscope. Advantages of the arthroscopic technique include superior illumination, the option for magnification, easy rinsing of the lens while viewing, and the possibility to capture images [3].

Guided growth via temporary hemiepiphysiodesis allows for gradual correction with few of the complication risks associated with osteotomy. Early recognition of growth abnormalities enables early intervention and potential prevention of major limb deformities. Less invasive procedures for treatment of deformities are then possible. Long-term follow-up after physeal trauma is critical to recognizing physeal arrest early.



Figure 1: Left genu valgum from a distal lateral femoral physeal bar.

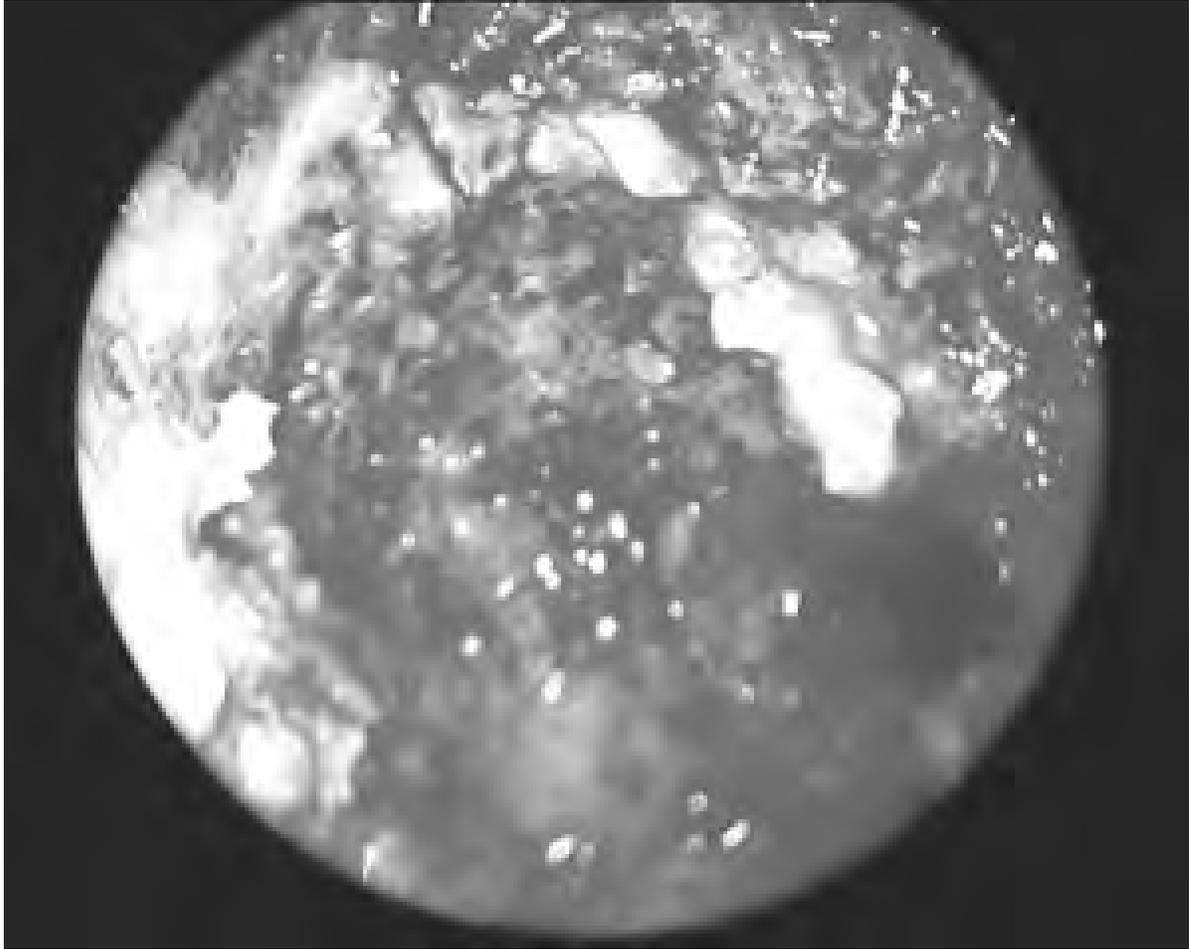


Figure 2: Direct visualization of the physis with an arthroscope: osteoscopy.

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Bone Repair with Sphere-templated (6S) Polymers

Buddy D. Ratner, Ph.D. and Paul Manner, M.D.

Introduction

Large segmental defects in bone, often induced by traumatic injury or pathologies, are difficult or impossible to surgically repair. Autologous bone grafting is the best therapeutic modality to date, but this is associated with donor site morbidity, infection and the lack of suitable bone that can be

transferred from one site to another. Cadaver bone and "metal and plastic" do not provide the regenerative healing and full functionality that would be preferred.

Materials and Methods

• Sphere templated (6S) polymers are fabricated by the process illustrated

in Figure 1. 6S is short for "sieve, shake, sinter, surround, solidify, solubilize."

• polyHEMA hydrogels with varied pore sizes were implanted in critical sized drilled defects in the distal femurs of aged rabbits, with the contralateral limb serving as a control.

• Micro-CT with 9 micron resolution and histology were used to assess defect filling at set time points.

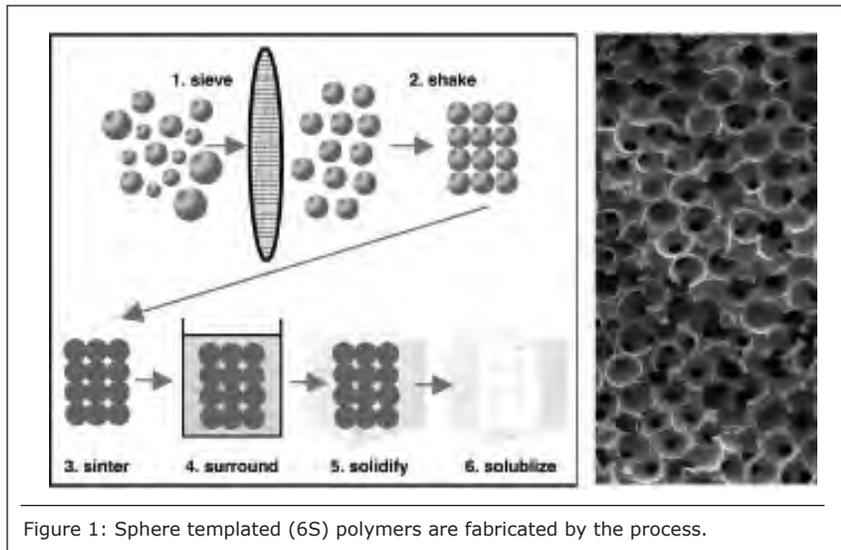


Figure 1: Sphere templated (6S) polymers are fabricated by the process.

Results

• At 4 weeks, polyHEMA with a 38 micron average pore size displayed significant improvement in filling compared to control.

• At 12-16 weeks, 38 micron polyHEMA with hydroxyapatite added showed almost complete filling of the defect.

• polyHEMA with an average pore size of 150 microns, previously thought to be ideal for bone ingrowth, showed no evidence of improved ingrowth.

Discussion

Since bone scaffold materials are generally expected to have pores larger than 150 μm , to contain a calcium-rich mineral phase and possibly to deliver cytokines such as BMP-2, this healing from a 38 μm pore size acrylic hydrogel material with no additional factors was striking, but consistent with healing in other vascularized tissue sites.

The potential for excellent healing is noted for 6S in epithelial tissues, endothelial structures and mineralized tissues. Here we focus the application of these engineered materials to specific needs for bone repair. However, why these materials perform as well as they do in healing and integration in so many anatomical sites is still unclear. The strong role of the macrophage (M \emptyset) in directing this healing is hypothesized as we find high concentrations in implanted 6S materials. More specifically, preliminary data suggests the M \emptyset is being ultimately directed to the M2 (regenerative) pathway by mechanical inhibition of M \emptyset spreading within the 6S, rather than the tissue-destructive M1 pathway.

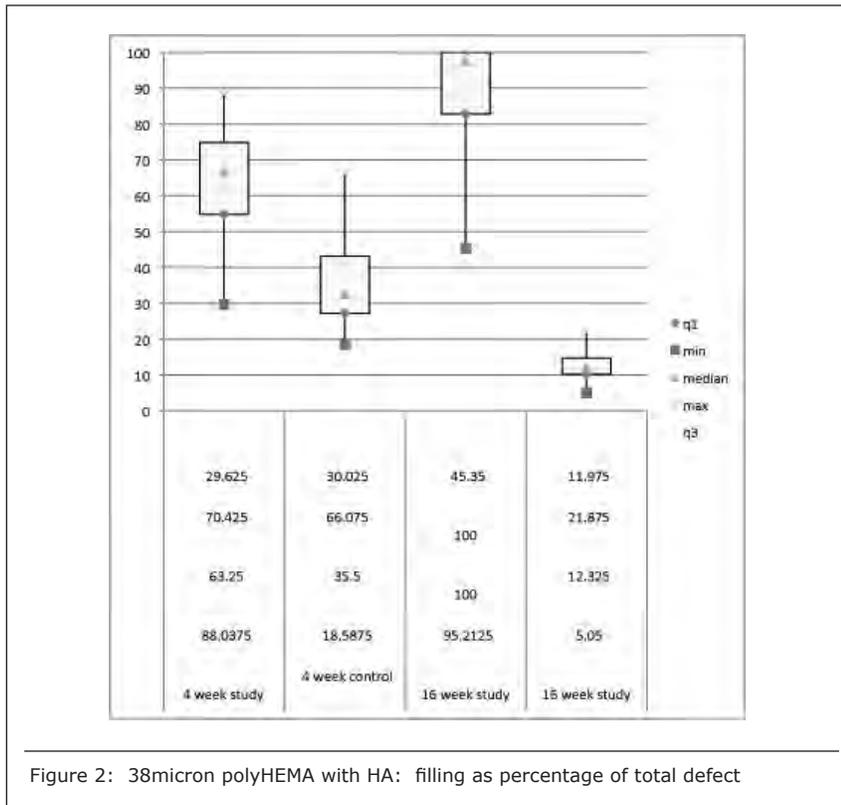


Figure 2: 38micron polyHEMA with HA: filling as percentage of total defect

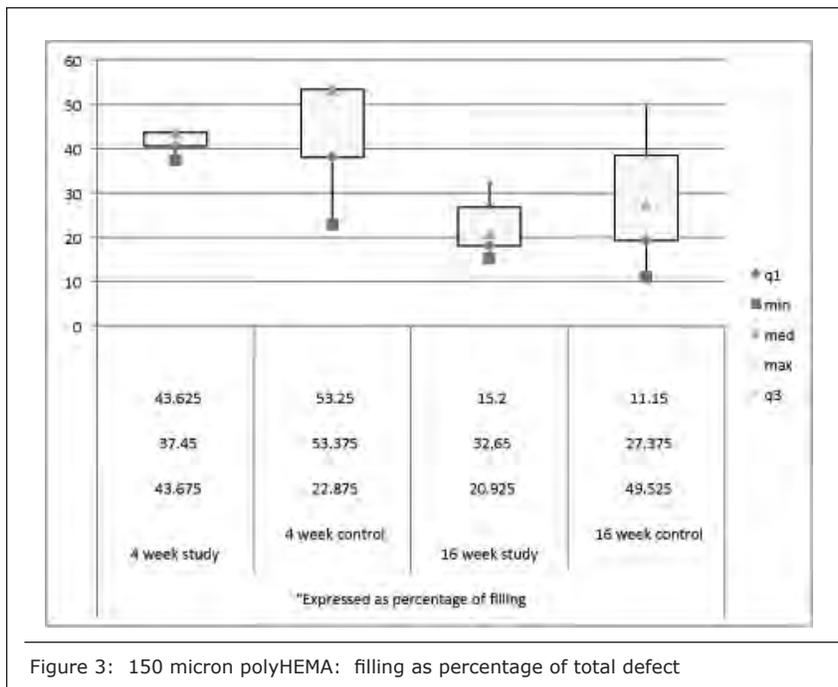


Figure 3: 150 micron polyHEMA: filling as percentage of total defect

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Non-Orthogonal Intraoperative Posterior Pelvic Imaging Impacts Iliosacral Screw Insertion

M.L. Chip Routt, Jr., M.D. and Matt L. Graves, M.D.

Introduction

Iliosacral screw insertion relies on intraoperative posterior pelvic fluoroscopic imaging. The purpose of our study is to identify the details of intraoperative posterior pelvic imaging and its correlation with preoperative computed tomography scans. The geometry of iliosacral screw insertion using a non-orthogonal system is similarly assessed.

Material and Methods

Radiographics of standardized pelvic computed tomography scans in ten consecutive adult patients with unstable pelvic ring injuries

were analyzed. None had sacral dysmorphism. All patients were treated using iliosacral screws as a component of their fixation constructs. During screw placement, standard posterior pelvic inlet and outlet imaging techniques were used, and the degrees of fluoroscopic tilt from the perpendicular were measured and recorded. The injury pelvic computed tomography scans were evaluated to quantify sacral osteology details relevant to intraoperative imaging.

Results

There is considerable sacral bony and lumbosacral structural variety.

The preoperative sagittal sacral CT image measurements correlated with intraoperative imaging details. The average degree of inlet tilt was 25 (range 20-33). The average degree of outlet tilt was 42 (range 30-50). The average arc between inlet and outlet tilts was 63 degrees (range 62-76).

Discussion

Based on these findings, intraoperative posterior pelvic imaging is non-orthogonal. This has impact on the surgeon during iliosacral screw insertion since manual maneuvers to correct directional aiming insufficiencies must accommodate the non-orthogonal imaging. As a result, cranial-caudal aim changes according to the outlet image and anterior-posterior aim changes on the inlet image will produce unwanted changes on the other image. The preoperative CT mid-axial sagittal CT imaging helps the surgeon to: (1) identify sacral morphology, (2) plan the specific degree of intraoperative imaging tilts needed to ideally view the posterior pelvis, (3) anticipate potential intraoperative aiming issues due to the non-orthogonal imaging. Based on these findings, we urge surgeons to carefully study the preoperative pelvic CT scan, especially the sacral sagittal mid-axial view, in order to: (1) better understand that patient's unique sacral osseous details, (2) to plan more thoroughly preoperatively, and (3) correlate these details with the intraoperative imaging for safer screw insertions.

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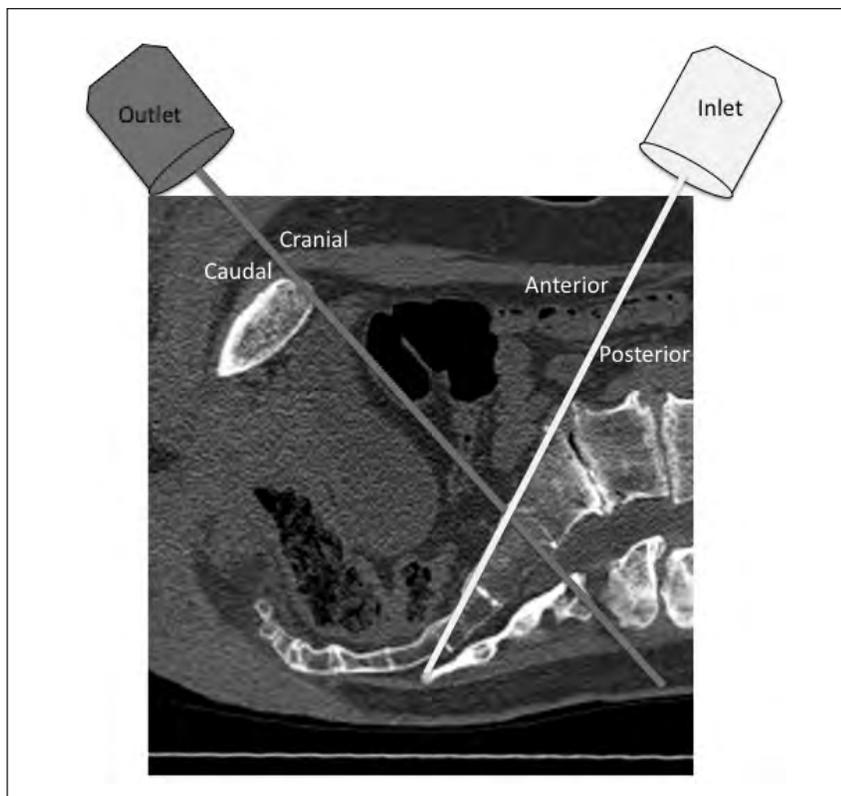


Figure 1: This mid-axial sagittal sacral CT scan image demonstrates the sacral morphology for this patient. The lighter line represents the degree of anticipated fluoroscopy tilt from the perpendicular necessary intraoperatively for routine posterior pelvic inlet imaging. The inlet imaging beam is oriented tangentially to the anterior vertebral bodies of the upper sacral segments by "stacking" of these upper sacral vertebral segments. The dark line represents the degree of tilt to achieve the standard outlet image. The outlet image superimposes the cranial symphysis pubis and second sacral vertebral segment. For this patient, the angle formed between the inlet and outlet lines measures less than 90 degrees. During ilio-sacral screw insertion, an anterior aim correction according to the inlet image would produce inadvertent caudal aim change on the outlet image due to the non-orthogonal orientation of the imaging. Similarly, a cranial aim correction according to the outlet image would inadvertently result in a posterior aim change.

Prospective Comparison of Functional Outcomes Following Ankle Arthrodesis and Ankle Arthroplasty

Bruce J. Sangeorzan, M.D., Marisa R. Benich, B.S., Sigvard T. Hansen, M.D., Jane Shofer, M.S., Avigal Segal, M.S., Eric Whittaker, M.S., and William R. Ledoux, Ph.D.

Introduction

We earlier published that ankle arthritis has an impact on a person's function and on health status as hip arthritis. There are two major treatments for end stage ankle arthritis: fusion or arthrodesis in which the bones are bonded together; and ankle arthroplasty in which an artificial joint replaces the arthritic one. There is uncertainty about the optimal treatment of end stage ankle arthritis. Both physicians and patients are in need of good quality evidence comparing arthroplasty to the "gold standard" of arthrodesis to guide treatment decision.

Material & Methods

- We prospectively studied more than 200 patients undergoing two different treatments - ankle replacement and ankle fusion - for end stage ankle arthritis to see how effective the treatment was in

improving pain and functional activity.

- The patients were not randomized. Treatment was selected by discussion of the patient and treating physician. Either ankle arthrodesis (n=81) or ankle arthroplasty (n=122) was performed based on the wishes of the patient or the advice of the surgeon.

- Patients wore a StepWatch3™ Activity Monitor for 14 days to count the total steps, periods of high, medium and low step activity and the minutes per day each person walked

- Patients completed the Musculoskeletal Functional Assessment (MFA) and SF-36 (to measure bone and joint health and overall health status respectively) preoperatively and at 3, 6, 12, and 24 months postoperatively.

- Linear mixed effects regression was used to determine if there were significant changes in outcome measures across all study visits and if these changes differed by surgery type.

Results

Patients in both groups had significant improvement in comfort and function. Step activity at a high level (> 40 steps per minute) did increase across the overall study period (p=.0032) with a majority of the increase occurring between baseline and 12 months after surgery. Neither surgery significantly improved the total number of daily steps over the course of the study but did improve the time spent at high activity levels. While self-reported function did not differ significantly by surgery type, MFA scores decreased strongly for both surgeries, indicating increased function (p<.0001). Postoperative improvement at 24 months, indicated by change in MFA score, was stronger for arthroplasty than arthrodesis (p=.035). Furthermore, patients overall reported improvement in the areas of bodily pain (p<.001), social functioning (p<.001), and physical functioning (p<.001) as indicated by increasing scores on the SF-36.

Discussion

This is the first prospective single center study in which the same experienced surgeons performed both treatments. Both ankle arthrodesis and ankle arthroplasty improved pain, increased patients' function at a high activity level and also patients' self-reported function. At one year, trends suggest that patients undergoing arthroplasty improve function to a higher level compared to patients undergoing arthrodesis. At two years there were no differences in function. Data analyses are ongoing as more patients continue to complete follow-up 24 months postoperatively. Possible subtle differences between arthroplasty and arthrodesis and more importantly, the durability of the outcomes deserve further investigation.

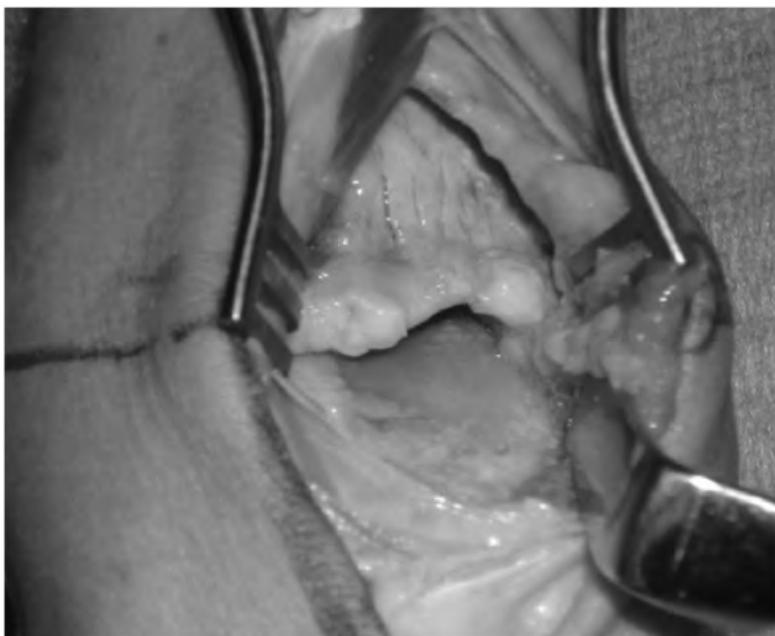


Figure 1: An ankle joint with all the cartilage worn away.



Figure 2: An AP radiograph of an arthritic ankle.



Figure 3: An AP radiograph of an ankle treated with an ankle fusion.



Figure 4: An AP radiograph of a patient treated with an ankle arthroplasty.

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Quantum Systems Engineering in Service of Regenerative Medicine

John A. Sidles, Ph.D.

A Research Highlight

A University of Washington research highlight for 2011 was the award of the Gunther Laukien Prize to Department of Orthopaedics Professor John Sidles, jointly with IBM researchers John Mamin and Dan Rugar. The Laukien Prize is given each year by the Experimental NMR Conference (ENC) to recognize "cutting-edge experimental NMR research with a high probability of enabling beneficial new applications." It is recognized as the single most prestigious research award associated to fundamental research in magnetic resonance.

The work which received the Laukien Prize was for the theoretical conception (by Prof. Sidles) and reduction to experimental practice (by Prof. Sidles jointly with IBM) of what is nowadays called quantum spin microscopy, specifically, that variety of quantum spin microscopy called magnetic resonance force microscopy (MRFM).

"Physicians Are Defined by the Tools at their Disposal"

The research path leading to the Laukien Prize began in 1991, at a 6:00 am UW Orthopaedics Conference. The conference was led by then-Chair

of Orthopaedics Rick Matsen, and the cases reviewed that morning were tough ones: bone tumors, HIV infections, severe orthopaedic trauma, complications attendant to diabetes, and a variety of autoimmune diseases including rheumatoid arthritis. Dr. Matsen reminded the residents of the general principle that "Physicians are defined by the tools at their disposal," and he then stated the obvious: medicine could not offer definitive cures to most of that morning's patients. Dr. Matsen then pointed to Prof. Sidles, and said gravely: "It is the job of Professor Sidles to provide us with better tools." The UW research initiative that has led to the Laukien Prize was conceived by Prof. Sidles during the next hour.

See Every Atom in Healing Tissues

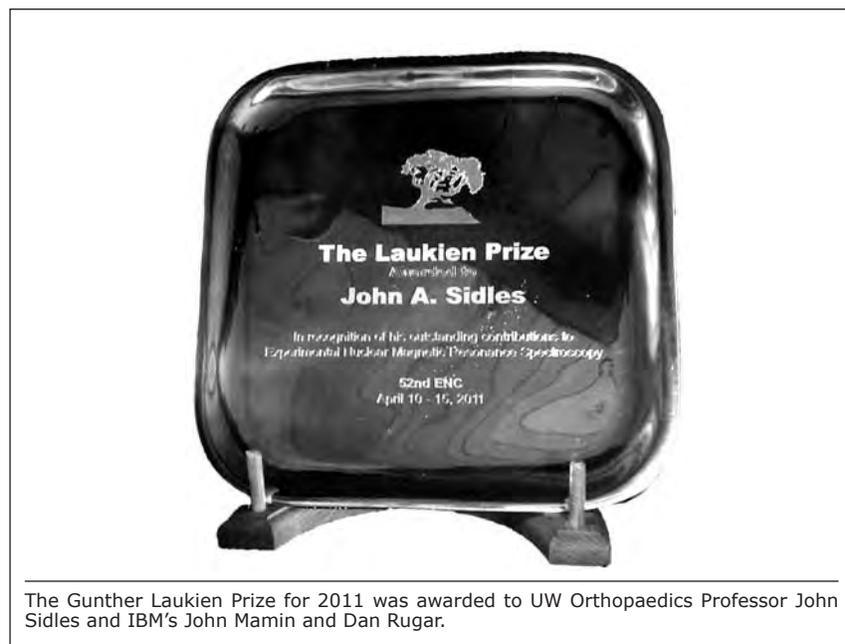
Professor Sidles conceived that the pace of medical research could be accelerated, and its risks retired, by realizing one of the oldest dreams of science: three-dimensional, in-depth, atomic-resolution biological microscopy of healing tissues. As described in a recent *Proceedings of the National Academy of Sciences* (PNAS) article "Spin microscopy's heritage, achievements, and prospects" [3],

a previous generation of scientists, including John von Neumann and Richard Feynman, had worked hard on this problem ... without success. Prof. Sidles' contribution was to conceive (in succession) three breakthrough capabilities for achieving von Neumann's and Feynman's objective.

The First Breakthrough: Moore's Law Performance Scaling

The first great challenge associated to atomic-resolution biomicroscopy was "How will the required sensitivity be achieved?" This challenge was met by the breakthrough marriage of medical magnetic resonance imaging (MRI imaging) and atomic-force microscopy (AFM); an approach that has become known as magnetic resonance force microscopy (MRFM). This is the work for which the Laukien Prize was awarded. The key physical idea is that as force microscopes are made smaller and colder and cleaner (less dissipative), their sensitivity becomes steadily greater, such that atomic-resolution imaging is achievable, both in theory [1] and in practice [2]. Working together, Prof. Sidles and Prof. Joe Garbini (of Mechanical Engineering) founded the UW Quantum Systems Engineering (QSE) Lab, and with funding from the NIH, the NSF, and the Defense Department, they have created multiple generations of MRFM instruments, in collaboration with an ever-growing list of MRFM researchers around the world.

A key performance metric in MRFM is "How many proton magnetic moments are required to send one bit-per-second of information through the microscope?" (the above-mentioned PNAS article [3] describes this metric in detail). In the first MRFM devices, back in 1992, this smallest-sample number was about one billion protons ... very far from the goal of single-proton imaging. By 2005 a succession of smaller-colder-cleaner MRFM devices had improved this sensitivity metric to one hundred proton moments: a sensitivity improvement of ten million. This represents 23 doublings of MRFM sensitivity, equivalent to a



The Gunther Laukien Prize for 2011 was awarded to UW Orthopaedics Professor John Sidles and IBM's John Mamin and Dan Rugar.



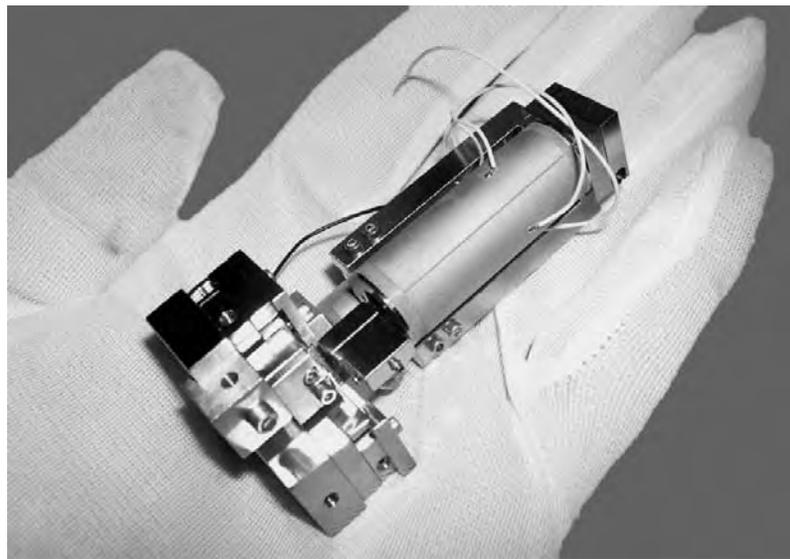
Gunther Laukien Prize winners John A. Sidles (#4 from left), John Mamin (#6 from left) and Daniel Rugar (#7 from left); with Bruker CEO Frank Laukien (#2 from right), Prof Ernst, chair of prize committee (#1 from right), and former Laukien Prize winner Daniel Weitekamp (#5 from left), together with Bruker management and members of the award committee.}

doubling-time of six months: this rate of sensitivity improvement is faster even than the Moore's Law scaling of computer capabilities (computers double in capability at the amazing pace of one doubling per eighteen months; MRFM has sustained a pace of improvement three times faster).

The Second Breakthrough: Quantum Pullback Theory

Beginning in 2005, atomic-resolution biomicroscopy encountered its second great challenge: "What

is the quantum dynamics of the sample spins?" This challenge arose as MRFM experiments began to resolve quantum fluctuations in the sample spins. Progress in MRFM sensitivity stalled while researchers struggled to extract imaging information from these fluctuating signals. A key theoretical breakthrough was the merging of recent advances in quantum information theory with the quantum theory of magnetic resonance, as described in our UW group's survey article "Practical recipes for the model order reduction,



MRFM microscopes are not large devices; they fit comfortably within the palm of the hand.

dynamical simulation, and compressive sampling of large-scale open quantum systems" [4]. This article was the first to describe practical mathematical methods for simulating quantum dynamical processes within the large-gradient, spatially inhomogeneous spin systems that are characteristic of quantum spin biomicroscopy.

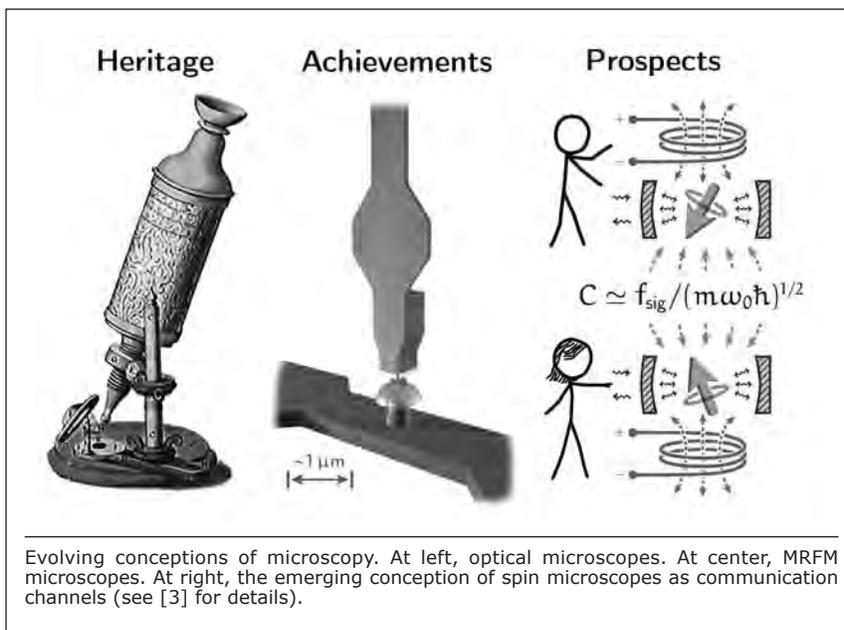
The Third Breakthrough: NMR Coherence Lasers

Research in quantum spin microscopy now is focussing upon a third fundamental challenge, which we foresee is the final challenge before medical applications begin: "By what practical means can the signal coherence be sustained during imaging?" Our approach was summarized at this year's ENC Conference, upon the occasion of the Laukien Prize award, in the presentation "Quantum spin microscopy's emerging methods, roadmaps, and enterprises" [5]. In essence, this third breakthrough combines the nanotechnology of the first breakthrough (smaller-colder-cleaner devices) with the dynamics of the second breakthrough (pullback onto low-dimension state-spaces) to create a new class of imaging methods that we call *NMR coherence lasers*. Here laser is understood to be a mnemonic for *local accumulation of system entropy reduction*.

Optical lasing reduces light fluctuations and concentrates light energy, and by a broadly analogous quantum mechanism, NMR coherence lasing reduces spin fluctuations and concentrates spin signal energy. For both kinds of lasing the practical consequence is a large gain in signal strength and imaging speed. Should the present round of MRFM experiments perform according to quantum pullback theory---and in particular, should the new NMR coherence lasing methods prove effective in signal enhancement---then the objective of atomic-resolution microscopy will be achievable with the present generation of MRFM sensing devices.

The New Profession of Quantum Systems Engineer

Engineers no less than physicians "are defined by the tools at their disposal." The toolset associated to the preceding three breakthroughs (in nanotechnological sensing, in



Evolving conceptions of microscopy. At left, optical microscopes. At center, MRFM microscopes. At right, the emerging conception of spin microscopes as communication channels (see [3] for details).

quantum simulation capability, and in the control of coherence) defines a new profession: *quantum systems engineer*. The three defining attributes of a quantum systems engineer are: (1) When technical challenges arise that are associated to system dynamics, quantum systems engineers are prepared to address these challenges immediately. (2) Quantum-optimized systems will perform decisively better than systems not so optimized. (3) The study of quantum systems engineering, with its integrated blend of natural mathematical concepts, fundamental physics, and high-level systems integration, creates professionals whose skills are uniquely well-suited to the requirements of 21st century enterprise.

Foundations for 21st Century Medical Enterprises

Quantum systems engineering provides three new foundations for 21st century medical enterprises. First, there is von Neumann's and Feynman's great and noble objective of surveying with atomic resolution every atom in the cells of living tissues [3]. To appreciate the grandeur and scope of von Neumann's and Feynman's objective, we reflect that if the entire universe were shrunk to the size of the human body, then the spacing between individual stars (about two light-years) would shrink to the size of the spacing between individual atoms (about 0.1 nanometers). Thus von Neumann's and Feynman's objective is comparably

ambitious to surveying every star in the sky ... an objective that the astronomy community nowadays pursues with commitment, confidence, vigor and success. Second, quantum systems engineering provides us with a sober, quantitative appreciation of technological paths by which atomic-resolution MRFM imaging is likely be achieved in the immediate future. And third, quantum systems engineering helps us to appreciate that the strategic consequences attendant to von Neumann's and Feynman's great enterprise---a systematically comprehensive structural survey of the atomic-scale architecture of living human cells---will prove comparably transformational to the strategic consequences of previous great science-and-technology enterprises, such as the space program, the Human Genome Program, and the sky survey programs.

Sustaining the UW Commitment to Healing

The University of Washington Medical School seeks to sustain two distinctive competencies simultaneously: (1) providing state-of-the-art medical care in a teaching environment, and (2) creating new treatment methods and demonstrating their end-result efficacy. We envision a coming generation of 21st century physicians who are "redefined by the new tools at their disposal" and who respect these simultaneous competencies as follows. First,

when patients present with healing challenges---no matter how severe---21st century physicians will offer truly regenerative healing options. Second, 21st century healing methods will be dramatically and decisively effective ... not only in selected patients, and not only for special conditions, but comprehensively. Third, training in 21st century medicine will be grounded in a comprehensive and integrated understanding of healing processes at every scale, extending from symptoms and diagnosis of patients presenting in the clinic, to the molecular dynamics of that patient's healing processes. It is this integrated medical vision that we take to be the chief practical consequence of von Neumann's and Feynman's great enterprise, to "see every atom" within living organisms.

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Making Old Bones Feel Young Again

Sundar Srinivasan, Ph.D., Brandon J. Ausk, M.S., Jitendra Prasad, Ph.D., Dewayne Threet, Steven D. Bain, Ph.D., Thomas S. Richardson, Ph.D., and Ted S. Gross, Ph.D.

Introduction

The increasing incidence of osteoporosis worldwide requires anabolic treatments that are safe, effective, and critically, inexpensive given the prevailing overburdened health care systems. While vigorous skeletal loading is anabolic and holds promise [1,2], deficits in mechanotransduction accrued over age [3,4] markedly diminish the efficacy of readily complied, exercise-based strategies against osteoporosis in the elderly [5,6]. Our approach to explore and counteract these age-related deficits was guided by cellular signaling patterns activated during mechanical stimuli. Specifically, we developed an agent-based computational model of real-time Ca²⁺/NFAT signaling amongst networked cells in situ within

bone [7]. The model successfully described periosteal bone formation induced by a wide variety of loading stimuli in young and aged animals [4,8]. Importantly, the model predicted age-related deficits within the Ca²⁺/NFAT pathway underlying the diminished bone formation at senescence, and suggested that restoration of these deficits would substantially enhance bone formation. Given the mechanism of action of low-dose Cyclosporin A (CsA) in the context of these specific deficits [9,10], we hypothesized that supplementing mechanical stimuli with low-dose CsA would substantially enhance bone formation in the senescent skeleton.

Materials and Methods

- The right tibia of senescent

female C57BL/6 mice (22 Mo, n = 24) received mechanical loading using the noninvasive murine tibia-loading device.

- Loading was calibrated to induce 1700 $\mu\epsilon$ peak (longitudinal normal) strain for 50 cycles/d (1-Hz), three days/wk (M, W, F), for 3-wk.

- Animals were assigned to one of three groups and received vehicle (0.0 mg/Kg, n = 8) or CsA at 0.3 mg/Kg (n = 8) or 3.0 mg/Kg s.c. (n = 8), 30 mins prior to each loading bout.

- As a comparison, young female C57BL/6 mice (4 Mo, n = 13) received a loading protocol (but not CsA) inducing equivalent normal strains as in senescent mice.

- Animals received calcein labeling (day 10, 19) and periosteal bone formation rate (p.BFR/BS)

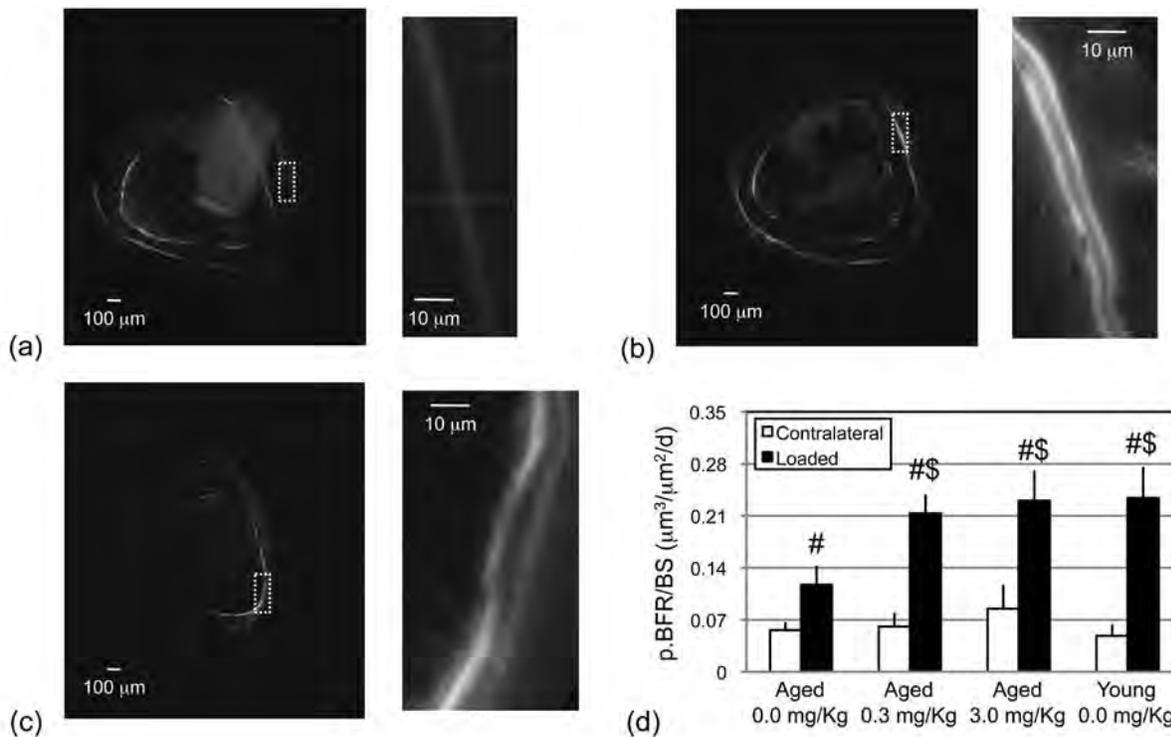


Figure 1: Loading supplemented with CsA restores bone formation at senescence to levels observed in young. Florescent images of representative tibiae mid-shaft from a senescent mouse subject to loading (a), supplemented with CsA (b), and from a young mouse subject to loading (c). Periosteal bone formation rates (p.BFR/BS) in aged animals (0.0 mg/Kg), or animals supplemented with CsA (0.3, 3.0 mg/Kg) and from young animals (d). $p < 0.05$ # vs contralateral and \$ vs vehicle treated animals.

was determined at the tibia mid-shaft of left (contralateral) and right (loaded) tibia via standard dynamic histomorphometry at day 22.

Results and Discussion

We found that in contralateral bones (not subject to exogenous loading), p.BFR/BS was not significantly different between aged animals without or with CsA supplements or compared to young animals (Fig 1b; $p = 0.56$). Furthermore, loading induced p.BFR/BS ($p = 0.04$) was significantly lower in vehicle treated senescent mice compared with young mice (Fig 1b). In contrast, loading supplemented with CsA at both 0.3 and 3.0 mg/kg significantly enhanced p.BFR/BS ($p < 0.01$ for both dosages) compared to that in vehicle treated senescent mice and to levels not different from that in young animals (Fig 1b, $p > 0.55$).

In effect, the low-dose CsA supplements tested here completely rescued loading induced bone formation in senescent animals. We consider this result to be especially promising as CsA in combination with readily complied, mild physical exercise could represent an extremely low-cost anabolic option to augment bone mass in the elderly (estimated at less than \$1 US/month [11]). If optimized, and efficacy is borne out in clinical trials, this intervention involving mild exercise supplemented with low-dose CsA would represent an inexpensive, anabolic treatment option that could be readily implemented in elderly populations at risk in developed and developing countries alike.

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Musculoskeletal Medicine from Larva to Butterfly

Carol C. Teitz, M.D.

Introduction

As noted by the AAOS in 2007, training in musculoskeletal disorders is a priority for medical schools across the US¹. Ten to twenty-eight percent of problems seen by primary care providers are musculoskeletal². As noted in the 2007 AAOS report, "delayed diagnoses, inappropriate referrals to MSK specialists, and unnecessary use of therapeutic and diagnostic modalities increase the costs of care for these patients."¹ In order for patients to get the best possible care and for orthopedic surgeons to have practices full of operative candidates, we must educate our medical students to recognize musculoskeletal disorders, know how to treat basic problems and injuries, and know which patients are suitable for surgical referral. In addition, we would like to entice more medical students into considering careers in orthopedic surgery. A sequence of experiences is most likely to meet these goals.

Larva

Many medical students are first attracted to consider a career in medicine by either a personal medical experience or an opportunity to shadow a practicing physician. The first impression is often a lasting impression. In order to encourage pre-medical students to even consider a career in orthopedic surgery, we need to provide opportunities for these students to shadow us in our daily work. Furthermore, medical schools, including the UW School of Medicine (SOM), will not consider an applicant who has not had exposure to the doctor-patient interaction in the form of shadowing³.

Pupa

The UW SOM has been at the forefront of musculoskeletal education in the classroom since the founding days of the Department of Orthopaedics and Sports Medicine. Dr. D Kay Clawson (Orthopaedics), along with Dr. Cornelius Rosse (Biological Structure) founded the Musculoskeletal Core Course which has remained an integral part of our

required curriculum and is now under the stewardship of Dr. Greg Schmale. This course includes musculoskeletal anatomy, clinical correlations, living anatomy, an on-line musculoskeletal radiology tutorial, and introduction to common problems affecting the musculoskeletal system. Students are also taught key parts of the musculoskeletal physical exam both in the Musculoskeletal Core Course as well as in their Introduction to Clinical Medicine course in the second year.

Caterpillar

In order to gain additional exposure to orthopaedic problems, students have a number of clinical options. They can take preceptorships or clerkships. Preceptorships for first and second year medical students (who, depending on timing, may or may not have completed the Musculoskeletal Core Course) consist of 30 hours of exposure to a clinician's practice over one academic quarter. This typically takes the form of a 4-hour session once per week. A 2-week long full time preceptorship is also available to 3rd and 4th year students. Clerkships for third and fourth year students, which provide 4 weeks full-time exposure to both orthopedic office and operative practice, are available in adult orthopaedics, pediatric orthopaedics, sports medicine, trauma, orthopaedic oncology, spine, shoulder and elbow, and joint replacement at UW Medicine affiliated hospitals as well as at 2 Spokane affiliates. In addition, a popular clerkship among students planning a career in primary care is the Outpatient Orthopaedic Clerkship in which 3rd and 4th year students spend 4 weeks attending only clinics in a variety of orthopaedic specialty clinics such as hand, sports, spine, and joint replacement.

Butterfly

Ideally, if we have done our jobs, and shared not only our knowledge of the musculoskeletal system but also our enthusiasm for fixing musculoskeletal problems and returning our patients to maximal function, we will attract

medical school graduates who want to become orthopedic surgeons. Our residency program, ably led by Dr. Doug Hanel, continues to provide excellent training in both the clinical and research realms of our field. As should be obvious from the other articles in this issue, the UW Department of Orthopaedics and Sports Medicine is an exciting place to work and train.

Graduates of both our undergraduate and graduate educational programs should be well trained to care for patients presenting with musculoskeletal complaints.

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Brain Trauma and Car Crashes: Developing a Threshold for Injury

Allan F. Tencer, Ph.D.

Study Rationale

Concussion injury has gained considerable attention with much effort focused on wartime explosive and sports contact injuries to the brain. The head injury criterion (HIC) was developed for assessment of direct contact of the skull and is used for example in automotive crash studies (1). However, no equivalent criterion is accepted for mild loss of

consciousness (LOC) which could indicate concussion symptoms. A valid criterion based on exposure to rapid acceleration-deceleration is the first step in developing methods to reduce exposures and trauma.

Research Question

Can a relationship be developed between short term exposure to rapid acceleration/deceleration and the risk

of mild LOC?

Methods

Since there are no valid laboratory models of human exposure to acceleration resulting in LOC, we chose to study and model actual frontal motor vehicle crashes from which accelerations of the head during the collision could be matched with NHTSA test collisions of the same vehicle using instrumented crash dummies.

The CIREN (crash injury research and engineering network, National Highway Traffic Safety Administration) database was accessed.

This database contains extensive reconstructions of actual collisions. CIREN data also contains detailed medical records of the victims.

A series of head-on (+/- 30 deg from the long axis of the vehicle) collisions were obtained from the CIREN database.

The data included vehicle make, model and year, occupant age and weight, restraint system usage and other injuries as assessed by the overall AIS (abbreviated injury score).

The crashes were assigned to one of two groups, those in which the occupant sustained a mild loss of consciousness (LOC) and those without LOC.

Each collision was matched to a NHTSA standardized crash test performed at 36 mph into a barrier (Figure 1). From the crash test data (part of the new car assessment program or NCAP) the head acceleration data for the dummy in the test was determined.

For each of the actual crashes in the two groups, the crash was matched to the NCAP test by make and model of the vehicle, and the severity of the crash, which is determined from the Delta V or the speed change of the vehicle during the collision.

Small corrections were made for slight differences in the principal direction of force (PDOF) and the Delta V of the actual collisions compared with the NCAP test which is direct head-on at 36 mph.

A logistic regression analysis was



Figure 1: Actual crash vs NHTSA frontal crash test.

	N	Head X acc'n	Belts used	gender male (%)	age (years)	weight (lbs)	height (ins)	ISS
MEAN no LOC	78	40.5	71%	52%	43.8	198.4	67.5	14.7
std dev		19.5			15.5	78.8	4.0	10.1
MEAN LOC	29	58.3	68%	50%	41.6	161.4	66.8	19.1
std dev		26.5			19.1	39.9	5.2	7.4
p value		<0.0001	NS	NS	NS	0.006	NS	0.059

Table 1: Comparison of the LOC and non-LOC groups.

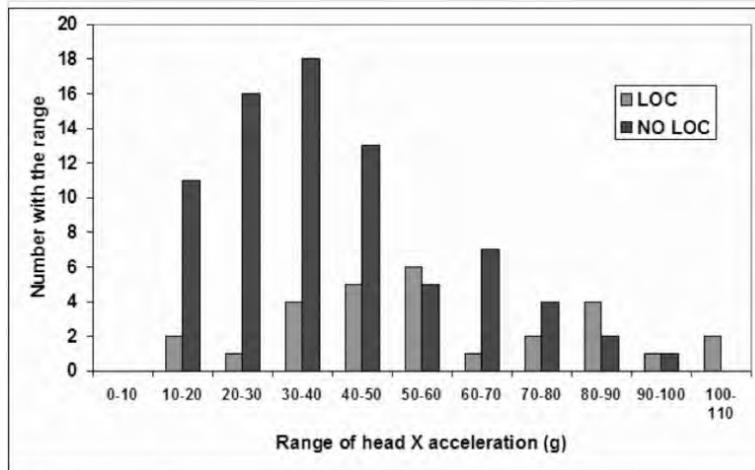


Figure 2: Distribution of head acceleration exposures in the two groups.

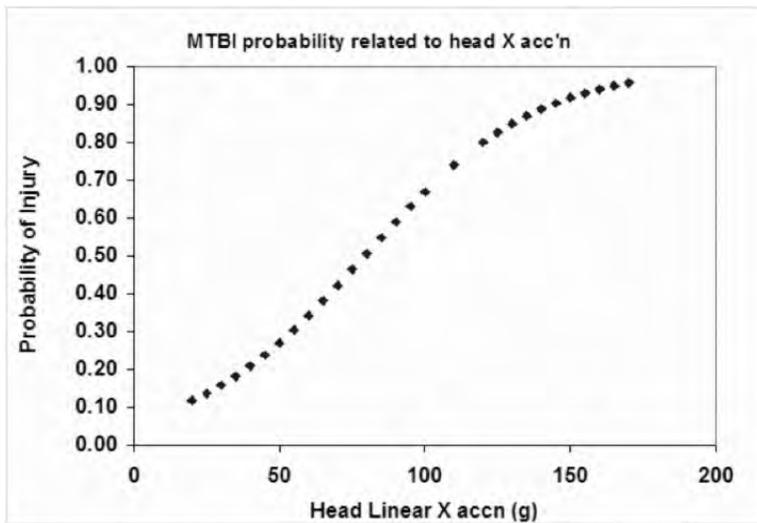


Figure 3: Logistic regression of probability of mild LOC and head acceleration exposure.

then performed to develop an exposure curve which gives a probability of LOC occurring in relation to the peak acceleration to which the occupant's head was (most likely) exposed during the collision.

Results

As shown in Table 1, there were 78 collisions studied in the non LOC group and 29 in the DAI group.

No significant differences were noted in age, height, gender, seat

belt use, or ISS score between the two groups. The LOC group was significantly lighter in weight than the non-LOC group.

The overall acceleration exposure was significantly greater in the DAI group (58.3 g v 40.5 g).

A plot of acceleration exposures, Fig 2, shows the distribution of LOC between the two groups.

The plot in Fig 3 indicates that a 50% probability of mild LOC occurs at a peak short term acceleration of the head of 80g.

Discussion

It has been difficult to determine acceleration exposures which can induce mild LOC since this involves subtle damage to the axonal tissue or blood vessels of the brain. Therefore indirect methods have been used.

King, et al (2003) approached the problem by studying mild concussive events from NFL football games, then reconstructing the impacts using helmeted dummies at the velocities measured in the videos and recording head accelerations. From that study, a 50% probability of injury at an exposure of 79g, very similar to the result of this study.

Conclusions

A 50% risk of mild loss of consciousness occurs with short term exposure of about 80g of head acceleration.

Mycobacterium Tuberculosis of the Spine

Theodore A. Wagner, M.D.

The Problem

As the Chairman of the Global Outreach Committee for the Scoliosis Research Society, I have spent time traveling to international sites for spinal surgery in Indonesia, India, Bangladesh and Syria. In each location clinics were full of patients with the ravages of TB of the spine and joints. The continued epidemic of this infection affected both genders and both the pediatric and adult ages.

The Background

- TB is an ancient disease but a new person is infected every second on this planet and 3 million persons die every year [8,000 per day]
- A 1/3 of the world population is infected and 5-10% develop active disease.
- 90 percent of those with active disease live in the non-industrial countries
- TB is the leading killer of women and greater than all maternal morbidity
- TB is the leading cause of death in the HIV population
- TB accounts for 1/4 of all the preventable deaths in the developing world
- The up trend of TB since 1985 is associated with HIV, the emergence of Multiple Drug Resistant M. Bacterium [MDR-TB], and the intense migration of people
- 5% of those with active TB have musculoskeletal disease
- 50% of those with musculoskeletal TB have spinal involvement

Case 1: Untreated Tuberculosis

An example of a 20 year old male with a history of untreated TB with spinal involvement incurred at age twelve in Bangladesh. The spinal column is severely deformed and the patient highly compromised and will face a high-risk procedure to attempt correction.

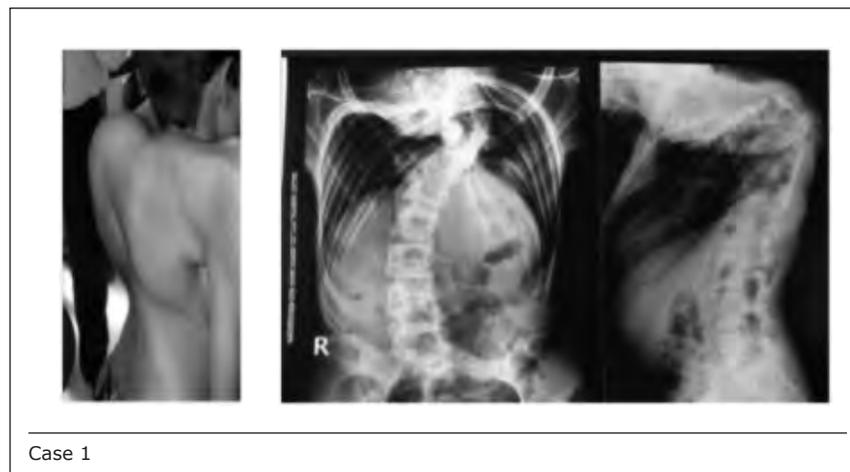
The Solution

- The preferred treatment of TB is early diagnosis and chemotherapy. However spinal onset is subtle and often goes on to severe deformity. Thoracic kyphosis with or without neurologic deficit is the most common site followed by lumbar and cervical.
- The surgical treatment of the resultant chronic deformity without an abscess has been debated constantly since several studies conducted in Hong Kong in the mid 1970s. The recommendation remains to correct the kyphosis by subtracting or shortening the posterior elements and posterior instrumentation of the spine. With an active anterior abscess, anterior debridement and fusion may be the first stage. Pedicle subtraction osteotomies with instrumentation offers another possibility for chronic cases of deformity.
- At University of Washington (Seattle Children's Hospital, Veterans Administration Hospital, Harborview Medical Center and University of Washington Medical Center) an average of 12 to 15 cases of musculoskeletal T.B. on the surgical service per year.

- Half of these cases involve immigration from Asia or Africa.

Case example

- Eleven year old female immigrant from Somalia with a progressive upper kyphotic deformity of her thoracic spine.
- History of night sweats, weight loss and drainage from her left ear lead to start of trial TB therapy in Kenya.
- Presented at SCH with left ear deafness and biopsy positive for TB.
- CT/MRI of spine revealed a large para-vertebral abscess and T5/6 collapse.
- A combined high left thoracotomy, debridement and placement of a Titanium cage with rib graft was performed in conjunction with posterior segmental instrumentation and fusion.
- She was maintained on a 4 drug





Case Example

regime for 6 months.

- In the 2 year follow-up patient is now healthy and an accomplished high school student with normal thoracic posture.

Increasing Safety in the Reconstruction of Unstable Sternoclavicular Joint Injuries

Winston J. Warme, M.D. and Anastasios Papadonikolakis, M.D.

Introduction

- Sternoclavicular joint (SCJ) dislocations are rare injuries that can be associated with numerous complications related to the injury itself, reduction maneuvers or the reconstructive procedures required to stabilize the joint¹.

- Anterior dislocations can lead to cosmetic deformity, allow scapular protraction, pectoral shortening and shoulder girdle weakness, as seen with clavicular malunions. Posterior dislocations have been associated with major vascular, tracheal, esophageal

and nerve injuries¹⁻⁴.

- Drilling through the medial aspect of the clavicle and manubrium is usually required for SCJ stabilization⁴. Given the underlying mediastinal structures, this is a dangerous and daunting undertaking.

- In order to increase patient safety we developed a novel method of drilling that increases safety and allows for a controlled SCJ reconstruction.

Technique

Two holes are then created in the medial aspect of the clavicle, and

two parallel holes are made in the manubrium behind the subchondral plate of the articular surface using the Acufex PCL drill set (Smith & Nephew, Andover, MA). A semitendinosus tendon autograft or allograft is passed through these holes in a figure of eight fashion (Figure 1). For the posterior SC joint dislocations, the drill holes are made by placing the PCL Tibial Aimer through the surgical field onto the posterior cortex of the medial aspect of the clavicle (Figure 1). The guide wire is drilled, the PCL aiming device is removed and then the PCL Elevator/Wire Catcher is placed over the reversed guide wire, exiting the posterior cortex of the clavicle (Figures 1B). The tunnel is then reamed to the desired diameter using the PCL reamer, typically 6 mm, based on the measured graft width. To further increase safety the posterior cortex is reamed by hand. The surgeon's index finger is placed over the posterior cortex of the clavicle or manubrium for increased protection during this process.

This procedure is repeated on the manubrium creating two tunnels parallel with the clavicular holes (Figure 2). The graft is passed in a figure of eight fashion, tied and sutured to itself with permanent suture.

Postoperatively, the patient uses a sling for 6 weeks. After this, full motion is gradually regained over the subsequent 6 weeks. Strengthening is allowed at 3 months and return to heavy work, or sports at 6 months.

Discussion

We have successfully used this technique in 8 patients without any complications. All the patients to date have healed uneventfully, remained stable and returned to their normal lifestyle. A formal study is under way to track the long term outcomes and comparative effectiveness of this intriguing new surgical technique.

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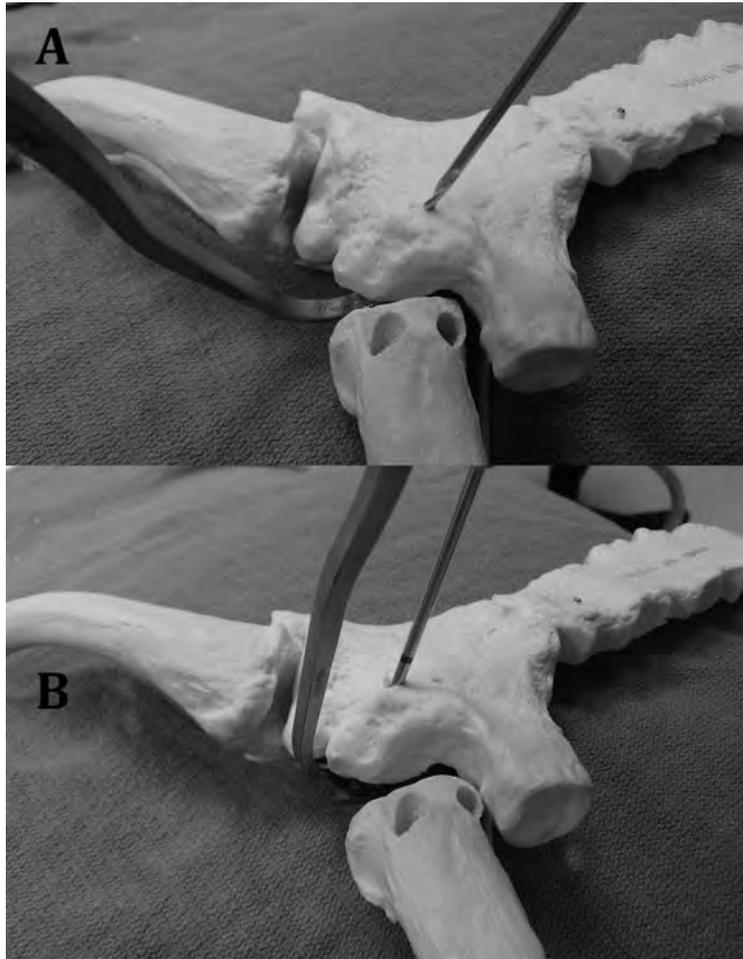


Figure 1: The manubrial cortices are thinner and less dense than the more robust clavicular cortical bone. Drilling is performed with the PCL aiming device resting on the posterior cortex of the manubrium (A). The guide wire is then reversed with the blunt end inserted in the shallow area of the PCL guide wire catcher (B). The reamers are then used to complete the drilling over the guide wire. The guide wire catcher prevents uncontrolled advancement of the guide wire while the reamers spin over the guide wire.



Figure 2: The graft is tied and sutured to itself with the SCJ reduced (A,B,D). The graft is passed through the holes with the use of the smooth 18 gauge wire loops with bent ends that are inserted into the holes (C). In posterior SC dislocations the graft is inserted in a configuration such that two parallel strands are located on the posterior aspect of the SC joint (B). In anterior SC dislocations, only the anterior cortex of the clavicle is drilled and the parallel strands are positioned anteriorly (D).

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Reliability of Magnetic Resonance Imaging in Measurement of Tibial Tubercle – Trochlear Groove and Patellar Tendon – Trochlear Groove Distances

Jason J. Wilcox, M.D., Brian J. Snow, M.D.¹, Stephen K. Aoki, M.D.², Patrick E. Greis, M.D.², Man Hung, M.D.², and Robert T. Burks, M.D.²

Introduction

An increase in the tibial tubercle –trochlear groove distance may predispose an individual to lateral patellar instability. This distance has been measured using both clinical and radiographic parameters, with axial CT images being the gold standard. Axial MR images offers many of the same advantages when measuring the TT-TG distance, while also allowing better soft tissue evaluation and without exposing this typically younger population to radiation. Though the reports of using MR images for this purpose are growing, there is a relative paucity of evidence that it is as accurate and reliable as when using CT images.

Materials & Methods

- Study Design: Cross Sectional Study
- 50 consecutive knee MRI's reviewed independently by four

observers

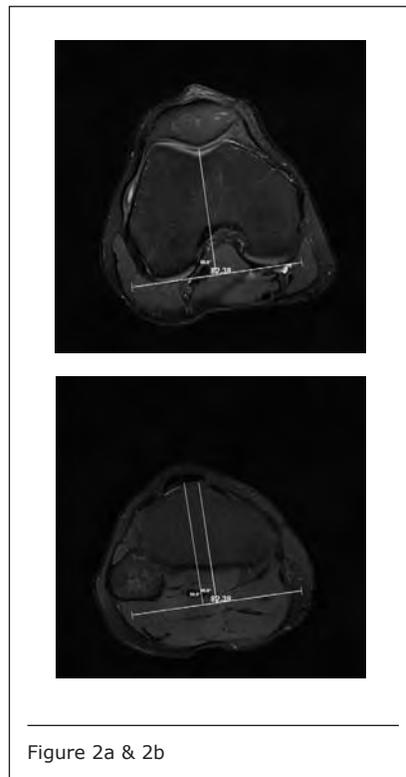
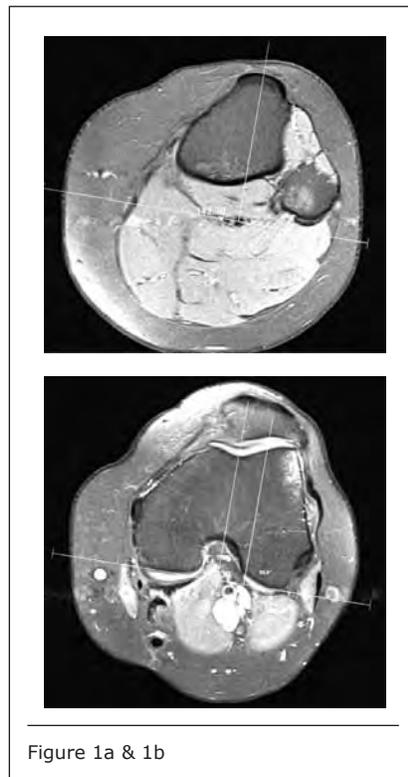
- Distance between tibial tubercle and osseous nadir of trochlear groove was measured (Figure 1a & 1b)
- Distance between the center of the patellar tendon and the cartilaginous nadir of the trochlear groove was measured (Figure 2a & 2b)
- Each measurement was repeated by each observer per knee at a minimum of 30 days to limit bias
- Inter- and Intra-observer reliability, average difference from the mean per observer, number of knees per observer where the measurement differed from the mean by 2mm or greater, and limit of reproducibility were calculated.

Results

- Table 1: The inter-observer reliability of the TT-TG and PT-TG distances were both excellent, but using the soft tissue landmarks (PT-

TG) were found to be statistically more reliable ($p = 1.3 \times 10^{-9}$)

- Table 2: The intra-observer reliability of the TT-TG and PT-TG distances were also excellent, but the use of soft tissue landmarks were again found to be more reliable ($p = 0.009$)
- The average difference from the mean per observer were both smaller in absolute value and had lower standard deviations, indicative of decreased variability
- When using bony landmarks, there were 44 instances where an individual's mean for a knee was greater than 2mm from the groups' mean. When using soft tissue landmarks, this occurred three times ($p = 2.2 \times 10^{-9}$)
- The difference between two observers to detect a true difference above measurement error would need to exceed 5.5mm when using bony landmarks versus 4.1mm when using soft tissue landmarks ($p = 3.4 \times 10^{-4}$)



Discussion

- The decision to transfer a patient's tibial tubercle due to lateral patellar subluxation is often influenced by the patient's tibial tubercle to trochlear groove distance
- The difference between what is considered a normal and an abnormal distance is separated by a few millimeters, suggesting the need for an accurate and reliable tool when measuring this distance
- There is increasing evidence that this measurement is being made using axial MR images despite a paucity of evidence as to its accuracy and reliability as contrasted to CT images.
- Our study suggests that both methods are reliable when measuring this distance, but the measurements are significantly more reliable when using soft tissue landmarks.

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Measurement	TT-TG	PT-TG
I	0.918 (CI ₉₅ 0.835 - 0.956)	0.973 (CI ₉₅ 0.958 - 0.983)
II	0.911 (CI ₉₅ 0.760 - 0.959)	0.981 (CI ₉₅ 0.971 - 0.989)
Total	0.913 (CI ₉₅ 0.811 - 0.953)	0.977 (CI ₉₅ 0.968 - 0.983)

Table 1: Inter-observer reliability. The ICC with 95% confidence interval.

Observer	TT-TG	PT-TG
1	0.964 (CI ₉₅ 0.936 - 0.979)	0.987 (CI ₉₅ 0.977 - 0.992)
2	0.969 (CI ₉₅ 0.945 - 0.982)	0.968 (CI ₉₅ 0.934- 0.984)
3	0.935 (CI ₉₅ 0.867 - 0.966)	0.964 (CI ₉₅ 0.937 - 0.980)
4	0.961 (CI ₉₅ 0.931 - 0.978)	0.973 (CI ₉₅ 0.953 - 0.985)
Total	0.961 (CI ₉₅ 0.948 - 0.970)	0.972 (CI ₉₅ 0.963 - 0.979)

Table 2: Inter-observer reliability. The ICC with 95% confidence interval.

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¹ Brian J. Snow, M.D. is in private practice in Texas.

² Stephen K. Aoki, M.D., Patrick E. Greis, M.D., Man Hung, M.D., and Robert T. Burks, M.D. are affiliated with the University of Utah

Emerging Role for Type III Collagen in Osteoarthritis

Jiann-Jiu Wu, Ph.D., Mary Ann Weis, B.S., Lammy Kim, B.S., and David R. Eyre, Ph.D.

Study Rationale

The collagen fabric of human joint cartilage consists largely of type II collagen that matures from a cross-linked heteropolymeric fibril template of types II, IX and XI collagens. In adult joints, type III collagen is deposited in varying amounts on this original collagen network. However, the role of type III collagen in OA is not clear.

Objective

The purpose of this ongoing study is to determine the significance of type III collagen deposition in articular cartilage of normal and osteoarthritis joints.

Material and Methods

- Type III collagen was purified from human and bovine joint cartilages by pepsin digestion, salt fractionation and molecular sieve fractionation.
- Monoclonal antibodies were used to probe type II collagen chains in extracts of adult human and bovine articular cartilage for covalently attached type III collagen.
- Molecular sieve-purified type III collagen preparation from pepsin-solubilized articular cartilage was digested with trypsin.
- Cross-linked peptides were

purified by immobilized metal ion affinity chromatography and HPLC.

- Purified cross-linked peptides were identified by mass spectrometry and by N-terminal protein sequence analysis.
- Cartilage from a human knee joints removed at replacement surgery was used to study the extraction of collagen type III by stromelysin-1 (MMP3) and other proteases.

Results

- Type III collagen was identified in pepsin-solubilized material from adult articular cartilage samples by SDS-PAGE, in-gel trypsin digestion and microbore LC/mass spectrometry with database matching and by N-terminal protein sequence analysis.
- Western blot analysis using mAb to probe type II collagen chains in extracts of adult human and bovine articular cartilage for covalently attached type III collagen N-telopeptide revealed that the $\alpha 1(\text{III})$ N-telopeptide domain can be detected attached to $\alpha 1(\text{II})$ chains.
- Type III collagen was readily extracted by stromelysin (MMP3) digestion of human articular cartilage under native conditions suggesting that it is accessible as a cross-linked polymer external to type II collagen

fibrils. (MMP3 is a notably prominent marker in OA synovial fluids.)

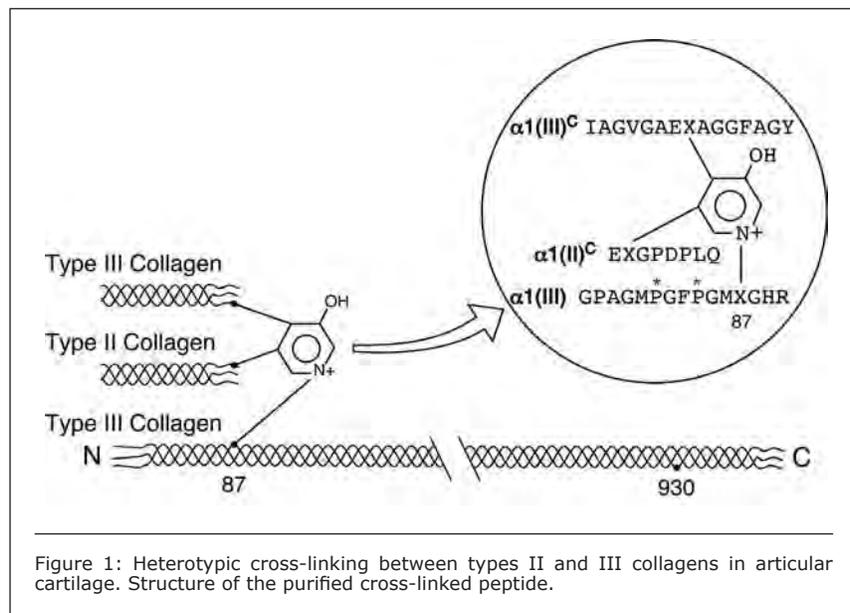
- Tandem mass spectrometry identified a pyridinoline cross-linked peptide in that had originated from a site of linkage between types II and III collagens (Fig.1).
- Fig. 2 illustrated the concept of collagen type III polymeric filaments interwoven with and cross-linked to the existing collagen type II fibrillar network and its susceptibility to depolymerization and selective extraction by MMP3 cleavage.

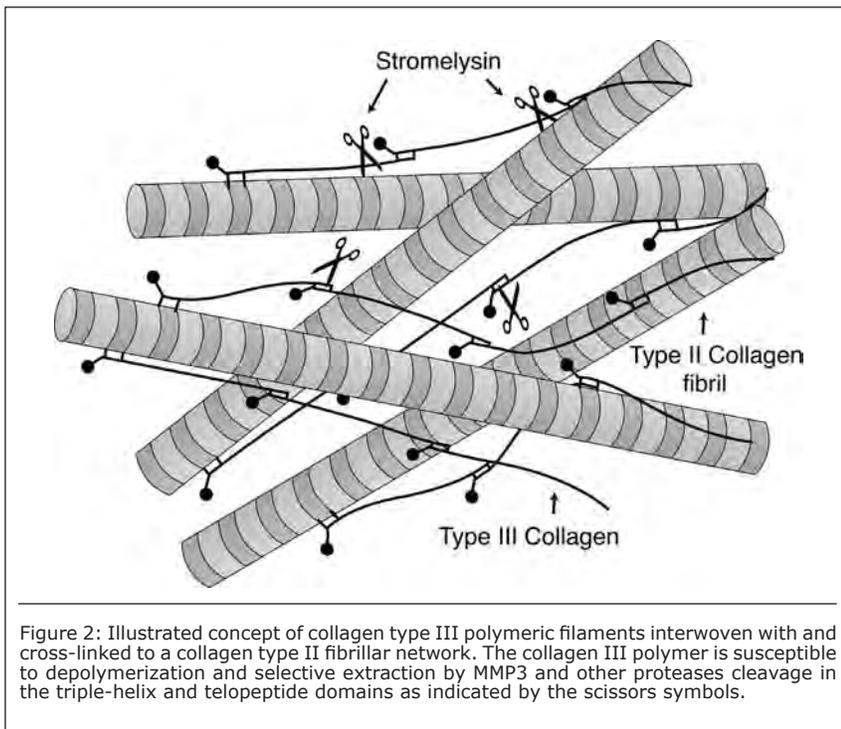
Discussion

- The results reveal that type III collagen molecules accumulate in mature human articular cartilage where they are cross-linked to each other and to the surface of type II collagen fibrils. The amount varies between individuals, sampling site and tissue microanatomy presumably dependent on history of injury and wear and tear during normal joint function, trauma and perhaps aging.
- It is known that type III collagen becomes prominent during fibrous repair responses in skin and other tissues, suggesting that it is synthesized as a modifier of existing fibril networks in response to tissue and matrix damage.
- Collagen III content was recently shown to be significantly higher in superficially undamaged cartilage from OA hip joints compared with age-matched, non-OA, hip fracture control tissue (2010 ORS Abstract #1019). There is potential, therefore, for degradation products of type III collagen to be developed as an early biomarker of joint cartilage pathology in osteoarthritis.

Conclusion

Type III collagen molecules with unprocessed N-propeptides are present in the extracellular matrix of adult human and bovine articular cartilages as covalently cross-linked polymers extensively cross-linked to type II collagen. The results suggest a structural role for type III collagen in cartilage as a covalent modifier





that may add cohesion to the existing collagen type II fibrillar network which is known to swell and soften as part of the early chondrocyte response to matrix damage in OA.

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Harborview Orthopaedics

Medical Center Focus

As part of the larger UW Medicine system-wide implementation of the Patients First initiative, HMC has focused on increasing patient satisfaction using standardized survey responses. Additionally, there is a focus on physician behavior in particular: politeness, introductions on rounds, and making rounds at regular intervals, rigorous compliance with hand washing protocols, etc. The medical center is also focused on metrics that are used as proxies for quality and those that are shown to the public. This impacts orthopedics as relating to: timing and appropriateness of antibiotic administration, DVT prophylaxis, hand-washing, hospital acquired infections and unscheduled hospital readmissions. A focus on first case start times has increased the burden on the surgeons to be in the OR long before surgical start time and reduced efficiency of morning teaching conferences, business meetings and rounds. Finally Harborview Medical Center is trying to build its financial foundation on more than just orthopedics and neurosurgery. Vascular surgery, ophthalmology and urology are adding faculty members and resources. This is good for the hospital but it has impacted operating rooms on busy weekends.

Dr. Krieg has been appointed to the WA state trauma committee to keep us abreast of trauma policy issues and advise the state on orthopedic issues.

Clinical Care

We are delighted to announce the addition of Michael Brage, MD to the department. Dr. Brage will work primarily in the Sigvard Hansen Foot and Ankle Institute. He joins our foot/ankle group after an extended search for a new partner who embodies the excellence defined by Sigvard T Hansen Jr., for whom the Foot & Ankle Institute is named. He has expertise in a broad range of complex foot and ankle reconstruction. We have also been able to make changes to our resident rotations and are now able to offer a solid Foot & Ankle experience before our residents have to make a Fellowship decision. We hope to add an additional Assistant Professor level physician on the foot service in the near

future so that we can better cover all the UW Medicine's needs.

We are continuing to explore expansion of our Fracture & Trauma service by one additional surgeon and considering integrated options to manage fractures across all UW Medicine facilities. We are hoping to use HMC's newly established clinical outreach program, headed by Sean Nork, the Transfer Center and the Internet to increase public awareness of our unparalleled Fracture and Trauma Service offerings, especially in the area of complex intra-articular fracture treatment. Our outreach program also provides valuable educational offerings in partnership with our colleagues in the WAMI region. Harborview continues to host our Summit in Seattle annual event. Based on last year's tremendous success we plan on a similar event this year with special focus on upper extremity and Hand injuries.

In light of growing demand for Hand surgery throughout our system, we are now recruiting a Hand faculty position and we are actively interviewing. Spine, Hand / Upper Extremity and Foot & Ankle services remain busy with their elective outpatient visits. Modest drops in trauma volumes reflects the recession and the fact that more area hospitals are hiring orthopedic surgeons and perform fracture care locally instead of transferring patients to HMC. Overall Harborview Clinical volumes are up but not to the projected budget for the Fiscal Year. Recently we have started posting records of patient care volumes in the operating room to raise our communal awareness. Our goals for the immediate future are to expand our Orthopaedic services to the community and our WAMI regions and share our educational expertise with our partners near and far.

Teaching

Starting in August 2011, we will have fewer ACES with a reduction of one trauma ACE and one Foot ACE. We will add an R5 to the foot service. The HMC compliment is Trauma: 3 UW chiefs, 3 UW R2, 3 UW R3, one half Madigan chief, one third Madigan R3; spine one R2, 2 R4, ; hand one R4, one R2; foot one R4 adding one R5. In addition to the Monday morning



Michael E. Brage, M.D.

sessions, each service has a monthly Morbidity and Mortality conference, a surgical indications conference and a Journal Club.

Research

Harborview is a participating center in the METRC, a combined civilian and Military clinical trial network funded by the Department of Defense. The focus is on severe extremity injury, infection, limb impairment and loss, and on downstream disability. Trials will be prospective, and randomized and there is a national registry of injuries. Initial projects compare bone graft to BMP, IV antibiotics to orally administered antibiotics, Antibiotic impregnated plates to standard care and limb salvage to amputation. Multiple clinical case series are done each year. We will begin an NIH funded multicenter clinical trial comparing ankle fusion to ankle replacement this summer.

Children's Orthopaedics

New Partners and Clinical Pathways for The Future

Pediatric Orthopedics at Seattle Children's was extremely fortunate to add Dr. Mark Dales, Dr. Carol Mowery, and Dr. Suzanne Steinman to our department as of June 1, 2011. Dr. Dales is an accomplished pediatric orthopedist specializing in pediatric spine, trauma, and general pediatric

orthopedics. Dr. Mowery will cover general pediatric orthopedics and assist with developing the regional outreach program. Dr. Steinman is a pediatric orthopedist who recently finished her training at the Texas Scottish Rite Hospital and completed a six month pediatric hand fellowship. Dr. Steinman also helped developed and will assist with the pediatric upper extremity

program and general pediatric orthopedics. All three new partners are well known to the department as long time Seattleites and are thrilled to be returning to Seattle Children's as staff members.

The clinical programs at Seattle Children's continue to flourish with the development of pediatric spine and sports programs. Dr. Wally Kregel



Seattle Children's Orthopaedics 1907 to Today: 104 Years of Caring



Left to right: Drs. Carol Mowery, Mark Dales, and Suzanne Steinman

has recently completed a highly successful and innovative spine implant vendor review that has identified value stream assessment of spine implants and surgery. In addition, the sports program continues to thrive with the continued success of the Seattle Children's Athletic trainers care of the Seattle Public School sports teams. The addition of a beautiful new Bellevue Children's facility has allowed better service to Eastside patients. The outpatient pediatric orthopedics visits for 2010 equaled approximately 35,000 patient visits.

The Pediatric Orthopedics Department and Seattle Children's have initiated a program for Clinical



Pathways at Seattle Children’s for orthopedic patients. Dr. Michael Goldberg spearheads that effort both at Seattle Children’s and nationally with the AAOS. Dr. Goldberg’s efforts are to establish “safety checklists” and standard order sets with the assistance of Dr. Kit Song in a pilot study for patients with elbow fractures, femur fractures and scoliosis. These local efforts will interact with recent AAOS guidelines for similar diagnoses and will establish routine clinical metrics to be integrated as standard clinical work. We hope and expect clinical pathways will contribute to our clinical research programs and provide standard outcome metrics for all pediatric and orthopedic patients.

This work is part of our “Continual Process Improvement”(CPI) to achieve standard work with patient care. Standard outcome metrics

produced by this work will contribute to the development of future clinical research projects and improve clinical efficiency. Other current CPI projects in orthopedics focus on patient safety and treatment costs and expenses. All projects are coordinated through the strategic planning process for Orthopedics directed by Drs. Jennifer Becker and Chappie Conrad.

University of Washington Medical Center

State of the Union: University of Washington Medical Center

The University is a busy center for tertiary orthopaedic care. We are projected to perform 3700 surgical cases in fiscal year 2011. This slight decrease from FY 2010 is primarily due to a temporary reduction in faculty. We are in the process of recruiting a new hand surgeon and are excited to have recruited two new surgeons. Michael Brage, MD, recruited in conjunction with Harborview Medical Center, is a Harborview trained foot and ankle surgeon and will be spending a day a week at the UWMC. Michael's was a dual recruitment and his wife, Lisa Judge, MD, will be practicing anesthesiology at the Puget Sound VAMC. Joining Dr. Brage in foot care is Rock Moulton, DPM. In the several months Rock has been with us he has already developed busy outpatient clinics focusing on nonoperative management of disorders of the foot.

Our new orthopaedic tumor recruit is Darin Davidson, MD. Darin is dual

fellowship trained in both pediatric orthopaedics and musculoskeletal oncology. Darin will be starting in September and will be Chappie Conrad's full-time tumor partner at the UWMC. Due to these additions the UWMC has projected a 5% increase in surgical volume for FY 2012. Darin's wife Stacy Chartrand, DVM is also a doctor, she is a veterinarian and some of the faculty with pets have already been consulting with her.

The average length of an inpatient stay on the 6SE orthopaedic floor continues to decrease and is now 3.58 days thus far for FY 2011. Remarkably, this is down nearly 15% from the already low 4.16 days in 2009. Over the same period of time our orthopaedic case mix index, a national measure of complexity of care, has increased from 1.84 to 1.95. This is one of the highest measures of complexity in the University Health Systems Consortium, a group consisting of the nation's premier academic medical centers. Despite this high case mix index, our

observed-to-expected infection and mortality rates remain lower than expected. These achievements are in no small part due to the hard work of Sue Theiler, the nursing director of 6SE and Michael Lee, the medical director and Chief of the UWMC spine service.

We have busy outpatient surgical practices at the Roosevelt Bone and Joint Center, the Sports Medicine Clinic, and the Eastside Specialty Center. Jerry Huang, MD continues to direct the UWMC Hand Service and has a presence at both the Bone and Joint Center and the Eastside Specialty Clinic. Dan Patzer, PAC assists Jerry in managing this busy service while we are recruiting a partner for Dr. Huang. We are most fortunate to have John Sack return from his temporary retirement to help out Dr. Huang in the hand section. Dr. Sack is one of the "founding fathers" of hand surgery in Seattle. Seth Leopold, MD and Paul Manner, MD run total joint clinics at the BJC and the ESC. Pat Maxwell, RN is our accomplished manager of



One of our residents, Grant Lohse, M.D., won the UWMC Service Excellence Award. Left to Right: Vice Chair Howard Chansky, M.D., UWMC Spine Service Head Michael Lee, M.D., Nurse Manager of 6SE Sue Theiler, R.N., Lohse, and UWMC Executive Director Stephen Zieniewicz.

the Eastside Clinic and we rely on her experience to help refine processes at all of our outpatient clinics. Similarly, Karin Holmberg manages the Bone and Joint Center. Karin has been devoting considerable time to turning our electronic medical record EpicCare into a physician-friendly system. Drs. Leopold and Manner have been actively involved in developing a UWMC total joint presence at Northwest Hospital. This transition is anticipated to occur in early 2012. Howard Chansky, MD rounds out the total joint service and sees general orthopaedic problems at the Bone and Joint Clinic. Three extremely experienced physician assistants, Tim Coglon, Pete Hall, and Dan Stamper, support the total joint service by providing excellent and timely care.

John "Trey" Green, MD leads the Sports Medicine section. His surgical partners are Carol Teitz, MD (Dr. Teitz is also the Dean of Admissions for the UW School of Medicine), Chris Wahl, MD and Roger Larson, MD. John O'Kane MD is the UW Head Team physician and primary care doctor. John works in close partnership with the surgeons and also lends his nonoperative musculoskeletal expertise to weekend warriors and high performance athletes. The Sports section could not function without the skills of Suzanne Slaney, the lead orthopaedic PAC, and Nicole Patrick, PAC. Claudia Happe-Hartsell, RN brings years of experience to managing the Sports Medicine Clinic and her energy and skill continues to move the SMC forward.

Dr. Matsen and Winston Warme, MD constitute our shoulder and elbow service with the assistance of Alex Bertelsen, PAC and Jill Eggers-Knight, PAC. Jill is a new addition to our department and she brings years of experience in general orthopaedics. She will focus on the Shoulder and Elbow Service but will also develop a general orthopaedic triage clinic. Our Spine Service remains in the capable hands of Michael Lee, MD, Jens Chapman, MD and Ted Wagner, MD and Eching V. Bertelsen, PA. Connie Ly, PAC, a recent graduate from the UW Medex program, has been gaining experience by assisting the spine team, the shoulder and elbow service and the joint service! We are in the process of recruiting a new PA to also work with the spine team.

There are a wide variety of research interests at the University of Washington Medical Center and these are strongly reflected in the publication of this year's research report. The Orthopaedic Robotics Laboratory is under the directorship of Peter R. Cavanagh, PhD, who is also our Vice Chair of Research. This laboratory is the first of its kind in our department and the lab has become a hub of activity as several faculty members and residents have started collaborative projects with Dr. Cavanagh. Clinical projects under the tutelage of Dr. Cavanagh include fixation of wrist fractures, ACL injuries and tibial anatomy, remote monitoring of total joint clinical outcomes and the biomechanics of total knee replacement.

Under our Chairman elect, Jens Chapman MD, we are continuing to build capacity at the University of Washington Medical Center. We anticipate a further increase in the number of inpatient procedures, as well as outpatient clinic visits. We anticipate that the recruitment of new faculty will soon begin. We hope to further increase access to our clinics in keeping with the principles of the UW "Patients First Initiative". Partnering with our Rehabilitation Medicine colleagues will be most important in this regard. Nelson Hager, MD is a physiatrist and the medical director of the Bone and Joint Center. He has partnered with Dr. Chansky to enhance access to a wider variety of patients at the Bone and Joint Center. Nelson has also brought an active ultrasonography and diagnostic/therapeutic injection program to the BJC.

Veterans

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

The Puget Sound Veteran's Administration Medical Center (VA) is a popular rotation for the orthopaedic residents. We have a general tertiary care orthopaedic practice at the VA and we see patients from the entire northwest including Alaska as well as states outside of the Northwest. We see a wide variety of both general orthopaedics, as well as complex or revision orthopaedic problems. This past year we performed 1,162 cases and remained one of the busiest VA orthopaedic programs in the country. There have been recent budgetary and policy issues that have limited operating room time for FY11 and we are hoping that normal operations will soon be restored.

Our University of Washington residents continue to rate the VA rotation as one of their favorites. While closely supervised, they are given graduated responsibility throughout their training at the VA. Our goal at the VA is to train residents that are dedicated to caring for patients with potentially difficult socioeconomic issues, as well as residents who if they so choose, would be able to graduate from our residency and achieve a high level of expertise in a general orthopaedic practice. Until the recruitment of our former resident Jason Wilcox, we never had the steady presence of a fellowship trained sports surgeon at our facility. The residents and veterans are both benefitting from Dr. Wilcox's subspecialty training. Partnering with Dr. Wilcox in running the long Thursday clinics, Ted Greenlee MD, continues to lend us his invaluable experience, particularly his knowledge of the natural history of conservatively treated fractures.

Steve Casowitz and Dustin Higbee are physician assistants and are the backbone of our surgical service. Orville Seschillie PA, Sue Grischott, NP, Monette Manio, RN and Annette Testa, LPN, manage our busy outpatient clinics and our surgical scheduling. Fred Huang MD, a former resident that practices at Valley Hospital continues to maintain a presence at the VA and focuses on sports problems at the



A bird's eye view of Puget Sound Veteran's Administration Medical Center.

VA. It is no exaggeration to say that the orthopaedic service at the Puget Sound VA could not function without Anne Dinsmore, RN. Anne is the head of orthopaedic nursing and she is a favorite of the residents and patients. As much as she works directly with residents and patients, she does even more behind the scenes to ensure that our cases run smoothly. Finally, Richmond Sanders is the Administrative Officer for Orthopaedics. Richmond has done a remarkable job of imposing order on potentially chaotic outpatient clinics and ensuring that our clinical documentation is up to VA standards. He has become a jack-of-all-trades and amongst many other tasks is leading the efforts to implement our digital templating system.

The Puget Sound VA Medical Center itself is undergoing a major expansion with the addition of a new research building, as well as extensive additions to the clinical tower and soon the addition of above and underground parking facilities. In addition, plans are being developed to expand the hours of the operating rooms and well as potentially moving some outpatient surgical cases to the American Lake campus. All of this should improve the quality and quantity of care for our veterans, their families and the quality of the work environment.

Residency

A Very Good Year in the Life of An Orthopaedic Residency: Our Year in Numbers

In this era of ubiquitous metrics of so many aspects of life and given the rising popularity of FAQ's I thought it would be most compelling for our readership to present the following numeric summary of our residency over the past academic year 2010-11:

Part 1: Who are our residents?	
Residents per year	8
Years to complete residency	5
Applicants for 8 first year positions:	555
Interviews granted	60
Number of positions accepted	8
Step 1 Average Board Scores	248/ 99th percentile

Part 2: What did our residents do during this past year?	
Hours worked per week (Average)	60
Call days per resident per year (Average)	100
Average cases per resident upon graduation	2145
Hours of formal conferences / year	240
Faculty participating in formal conferences	45
Grand rounds presented by residents / year	10
National meetings attended by residents / year	8

Part 3: How did our residents do last year?	
Peer reviewed publications by residents last 12 months	14
Orthopaedic In Training Examination ('OITE') scores	
Program Percentile rank	92
Extramural funding per graduating resident (Thank you Alumni !)	\$4,500
Probationary / disciplinary actions	0 / 40
Residents successfully completing Part 1 of National Boards on first attempt	98%
Graduating residents doing fellowships (last five years)	39/40

Part 4: (on a lighter note) Extramural accomplishments	
Successful Mount Rainier Summits	5
10K's and Half Marathons run	8
Vertical Feet Skied	A lot
Fish Caught on a Fly	Not so many
Marriages	3
Babies Born	2
Babies on the way	4
Grand Baby for the Residency Director	1 (priceless)

Summary statement: As the numbers reflect, we attract a group of exceptionally motivated and gifted young people into our Residency. We have every reason to be proud of the increasing academic accomplishments of our residents. They have taken a truly impressive high road to secure their quality education during increasing restrictions placed on surgical experience gathering through work hour restrictions. Our OITE and Board scores have risen to new heights reflective of the dedication to excellence exhibited from all our residents throughout each year. Our residents are matching with prime post-residency fellowship training spots across all disciplines throughout North America and are pillars of their communities wherever they end up practicing. Speaking on behalf of our Residency Program and our Faculty I wish to thank our alumni for supporting the current generation of residents in their educational needs, especially during our economically hard times with considerable budgetary restrictions every donation to our Friends of Orthopaedic Residency Education (FORE) counts. Our special thanks goes to our program coordinator Angela Weiss and our Educational Coordinator Amanda Schwanz, along with Ms. Teresa Jewell, who capably filled in during Amanda's maternity leave. Lyle Sorensen has been a very active Alumni Association president and engaged our residents with the award-winning Washington Orthopaedic Association and its members. Please join me in wishing our graduating class 2011 well for their future and welcoming our incoming year of PGY -1s and 2's!



Figure 1a-e : Orthopaedic Grand Rounds: our new Mini Symposium format has been very well received with a high-quality content format presented by a combination of speakers usually including one resident, who also serves as organizer, and two or more panelist faculty, including community members. The May 4th 2011 event was such a highlight event featuring Drs. Grant Lohse, PGY 4 and Chris Sybrowsky, PGY-5 presenting differing viewpoints on duty hour restrictions with Dr. Larry Robinson, Vice Dean for GME and Clinical Affairs and Dr. Jim Krieg, Associate Professor discussing the background and outlook of these regulations. Moderated by Dr. Henley, Professor, Drs. Cory Lamblin, PGY-3 and Emily Squyer, PGY-3 had collected questions from their respective residency years and presented these to the panel at the conclusion of this packed event.



Figure 2 a-c: Surgical dissection labs: A key emphasis has been placed on enhancing our residents' surgical technique training in our ISIS labs during weekly sessions using cadaver sawbones and virtual training. New regulatory requirements have placed a higher burden on the Department to acquire specimens and instruments for training. Support from Industry and Alumni as well as the hospitals is essential to maintain our high standards of skills training.



Figure 3: Monthly resident meetings. Our residents have a monthly meeting with the Program Director, the Residency Coordinator, the Chair and members of the Education committee. These meetings have been very productive in troubleshooting and airing concerns before they become problems.



Figure 4: Our Residency interviews reflect the integral role of an engaged resident body in the success of a program. Multiple residents voluntarily representing all years participate in the interview processes in a variety of ways. Our program coordinators Angela Weiss and Amanda Schwanz deserve great credit for keeping our program a top destination for residents around the country.

Message from the Director

Ken Karbowski, M.P.H.

Our department is about to conclude another solid year from an overall operational view. We have special reason to celebrate advancement of our Research enterprise - in 2010 we once again doubled the level of research expenditures achieved in 2008, just as we had in 2009. For this great accomplishment, thanks goes to our behind-the-scenes staff who keep our enterprise running so smoothly: Karl Engdahl (Assistant Director for

funding for resident research projects, enhanced research rotations for residents considering careers in academia, more thorough tracking of faculty research activity, and enhanced research website features. These leadership initiatives, developed largely by Drs. Cavanagh and Chapman, along with our Residency Director Dr. Doug Hanel, could only be implemented through the concerted efforts of our accomplished team of administrative staff.

I would also like to thank the Department's Computing



Left to right: Tom Zorich and Karl Engdahl, Meagan Loftin, Gholam Fazelinia and Nidhi Shah, and Ken Karbowski.

Finance and Human Resources) (thank you for twenty great years in our department), Tom Zorich (Grants Manager) and Meagan Loftin (Assistant to Dr. Peter Cavanagh, our Vice Chair for Research) collectively bring nearly 40 years of experience to our research administration team. Through their hard work and organizational know-how, they've enabled us to manage growth that has, in proportion, vastly exceeded our staffing. This growth consists not only of increases in direct research expenditures, but also program enhancements and expansion designed to foster greater support and mentorship for residents and faculty alike. These new and improved elements of our program include, but are certainly not limited to, the establishment of seed

Support Group under direction of Gholam Fazelinia, Michael Burdett, John Eickerman and Nidhi Shah whose work is equally instrumental to the success of our research enterprise, and who continuously push the envelope to keep our research informatics infrastructure and Departmental website functionality as current and user friendly as possible. Their efforts, which are frequently invisible to many of us on the user side, are most worthy of our recognition.

We look forward to creating a framework for further substantial growth of our Department while maintaining best possible operational efficiencies through our Administration.



Teaching Conferences

At the University of Washington Department of Orthopaedics and Sports Medicine, education is central to our mission. Our faculty members work with residents over 5 years to educate in the field of orthopaedics. Besides one-on-one collaboration in surgery, clinics, and research, our faculty collaborate with residents, fellows, and visitors at our many conferences. Please see below and for more information visit our website: www.orthop.washington.edu

		Monday through Sunday		
	7:00 - 7:15 AM	HMC Spine Check Out Conf		
		Saturday through Sunday		
	7:30 - 8:00 AM	HMC Trauma Check Out Conf		
MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
1st Monday 6:00 - 7:00 AM All Faculty Meeting	Every Tuesday 6:00 - 7:00 AM Hand Faculty Lectures	1st Wednesday 6:15 - 7:15 AM Orthopaedic Grand Rounds	1st Thursday 6:30 - 7:30 AM UWMC M&M Meeting (for Resident/ACEs/Faculty)	Every Other Friday 6:45 - 7:30 AM PGY2 Trauma Conference
1st Monday 7:00 - 8:00 AM All Resident Meeting		2nd - 5th Wednesday 6:00-7:00 AM SCH Faculty/Provider Meeting	1st Thursday 6:30 - 7:30 AM Sports Med M&M Conf	1st Friday 6:30 - 8:00 AM SCH Pre-Op/Post-Op Care Conf
1st Monday 7:00 - 9:00 PM Spine Journal Club	Every Tuesday 9:00 - 10:00 AM Eyre Research Group Mtg	2nd Wednesday 6:30-8:00 AM Montlake Faculty Meeting	Every Thursday 6:30 - 7:30 AM SCH Resident Teaching Conf	Every Other Friday 6:45 - 7:30 AM PGY2 Hand Conference
Every Monday 6:30 - 7:30 AM Hand Fellows Journal Club		2nd Wednesday 7:00 - 9:00 AM HMC M&M Meeting (for Resident/ACEs)	2nd Thursday 6:30 - 7:30 AM UWMC OITE Review (for Residents only)	2nd Friday 6:30 - 7:30 AM SCH Resident Lecture
2nd Monday 6:30 - 7:30 AM Ortho IT Forum		Every Wednesday 7:30 - 8:30 AM 2nd - VA M&M Meeting All Other - Pre-op Conf/ Journal Club	Every Thursday 7:30 - 8:30 AM Spine Research (for Spine Faculty/ACEs)	
2nd Monday 11:00 AM - 12:00N UWMC Sarcoma Protocol Mtg		2nd - 5th Wednesday 7:00 - 9:00 AM SCH Pre-Op/Post-Op Care Conf		
Every Monday 7:30 - 8:30 AM ACEs Meeting	3rd Tuesday 6:45 - 8:00 AM Sports Med Provider Mtg	3rd Wednesday 6:30-8:00 AM UWMC Ortho/Radiology/MRI/ Arthroscopic Correlation (for Resident/ACEs)	3rd Thursday 6:30 - 7:30 AM UWMC Indications Conf (for Resident/Faculty)	Every Friday 7:15 - 8:15 AM HMC Spine Indications Conf
Every Monday 7:00 - 9:50 AM UWMC All Residents Conference		3rd Wednesday 7:00 - 8:00 AM Spine Grand Rounds	Every Thursday 8:30 - 9:30 AM HMC Spine X-Ray Conference (for Resident/ACEs/Faculty)	3rd Friday 6:30 - 7:30 AM SCH Resident Lecture
Every Monday 7:30 - 8:30 AM VA All Residents Conference		4th Wednesday 6:30-8:00 AM UWMC Upper Extremity Indications or Journal Club (for Resident/ACEs)	4th Thursday 6:30 - 7:30 AM UWMC Evidence-Based Ortho Journal Club (for Resident/Faculty)	4th Friday 6:30 - 7:30 AM SCH Resident Lecture
Every Monday 10:00 - 11:00 AM Cavanagh Research Group Mtg		4th Wednesday 6:45-8:30 AM HMC Faculty Meeting		
Every Monday - Except Holidays 4:00 - 6:00 PM HMC Trauma X-Ray Conference (for Resident/ACEs/Faculty)		4th Wednesday - alternate Case Presentations/Journal Club 7:00 - 9:00 AM HMC Journal Club (for Resident/ACEs)	Only When Monday is a Holiday 4:00 - 6:00 PM HMC Trauma X-Ray Conference (for Resident/ACEs/Faculty)	
Every Monday - Except Holidays 5:00 - 6:00 PM HMC F&A X-Ray Conference (for Resident/ACEs/Faculty)		4th Wednesday 7:30 - 9:00 AM Sports Academic Conference	Only When Monday is a Holiday 5:00 - 6:00 PM HMC F&A X-Ray Conference (for Resident/ACEs/Faculty)	
		5th Wednesday - Only when there are 5 Wed. in a month 7:00 - 9:00 AM HMC Journal Club	5th Thursday 6:30 - 7:30 AM UWMC Faculty Presentations (for Resident/Faculty)	

Graduating Residents



Aaron Chamberlain, M.D.

After residency, Aaron will complete a fellowship in Shoulder and Elbow surgery at Washington University in St. Louis, MO. Upon completion of his fellowship he plans to return west to begin practice.



Cory Lamblin, M.D.

Following residency, Cory and his wife Jean will be moving to Taos NM, where he will spend one year as a sports medicine fellow. He plans to pursue career opportunities in the mountain west region. Ultimately, Cory plans to develop a sports and trauma practice and hopes to stay involved in education of residents and medical students.



Brian Daines, M.D.

Following residency, Brian will complete the Rocky Mountain Joint Replacement Fellowship in Denver. He and his family will move to Carbonale, Illinois where he will begin private practice at the Southern Illinois Orthopaedic Center.



Edward Moon, M.D.

After graduation, Edward will complete a hand fellowship at the Hospital for Special Surgery in New York City. Upon completion, he plans to join a practice somewhere close to his family either in the Midwest or the West Coast.

Graduating Residents



Derek Rains, M.D.

Following residency, Derek will complete an Orthopedic Sports Medicine Fellowship at Panorama Orthopedics in Golden, CO. He plans to return home to the Pacific Northwest for practice following the completion of his fellowship.



Christian Sybrowsky, M.D.

Christian will pursue a one-year fellowship in sports medicine and arthroscopy at the University of Iowa. Following his fellowship, he plans to practice general orthopaedics.



Peter Scheffel, M.D.

Pete will attend the University of Utah to complete his fellowship in sports medicine. Afterwards, he plans on practicing sports medicine/general orthopedics somewhere in the West.



Brett Wiater, M.D.

Following residency, Brett will complete The Hand and Microvascular Surgery Fellowship at The University of California, San Diego. After that, Brett and his family have no definitive plans.

Incoming Residents



Timothy Alton

Timothy Alton is from Oregon City, Oregon. He attended college at Willamette University and medical school at Wake Forest University. Away from his residency, he enjoys running, skiing, hiking, camping, golf, college football and spending time with his wife.



Daniel Holtzman

Daniel Holtzman, from Los Gatos, California, attended Pomona College. He attended medical school at the University of California, San Francisco. Trauma, sports medicine and cell biology are his clinical and research interests. In his free time, he enjoys music/concerts, movies, baseball (Go Giants!), football and golf.



Kenneth Gundle

Kenneth Gundle is from Portland, Oregon. For his undergraduate education, he attended Stanford University; for medical school, he attended Harvard. His orthopaedic interests include anatomy, outcomes research and the history of orthopaedics. He likes to spend his spare time traveling, cooking delicious meals, reading broadly, cheering on the Portland Trailblazers, keeping up his Japanese, and spending time with his fiancée and family (including the dogs).



Paige Mallette

Paige Mallette, from Telluride, Colorado, attended college and medical school at the University of Colorado. When away from the University of Washington, she enjoys skiing (especially bluebird powder days), hiking, cruisering and pro kadima at the beach.

Incoming Residents



Courtney O'Donnell

Courtney O'Donnell is from El Segundo, California. She completed her undergraduate education at the University of California, San Diego and medical training at the University of California, Los Angeles. She is most interested in pediatrics. Outside of her clinical interests, she spends her time on racing her bike, backpacking, running, skiing, yoga, her family and country music.



Amanda Roof

Amanda Roof is from Harrison City, Pennsylvania. For her college, she attended Bucknell University. She attended Drexel University College of Medicine (previously Hahnemann University) for her medical training. Orthopaedic pediatrics and oncology, and wilderness medicine are her areas of medical interest. She likes traveling with friends and family, anything outdoors including football/volleyball/softball, trying new food/restaurants, baking and arts & crafts.



Daniel Patton

Daniel Patton is from Columbus, Wisconsin. He attended college at Andrews University and medical school at Loma Linda University. His major fields of orthopaedic interest are the developing world, trauma, pediatrics and upper extremity. In his spare time, he enjoys triathlons, kiteboarding and adventure.



Laura Stoll

Laura Stoll is from Sandpoint, Idaho. She attended Western Washington University for her undergraduate degree and Master's in biochemistry, and the University of Washington for medical school. When away from work, she likes skiing, anything on the water, backpacking, football, reading, and eating good food with friends and family.

ACEs

FOOT/ANKLE



Kelly L. Apostle, M.D.



Scott M. Holthusen, M.D.



Monica A. Zilkoski, M.D.

SPINE



Myles J. Luszczyk, D.O.



Jeremiah J. Maddox, M.D.



Anuj Varshney, M.D.

TRAUMA



Richard B. Barber, M.D.



Anna N. Miller, M.D.



John W. Munz, M.D.



Soren L. Olson, M.D.



Lorra M. Sharp, M.D.



Mark A. Steeves, M.D.

ACEs

SHOULDER/ELBOW



Mark E. McKenna, M.D.



Anastasios Papadonikolakis, M.D.

ONCOLOGY



Jennifer S. Barr, M.D.

PEDIATRICS



Antoinette Lindberg, M.D.



Neil C. Vining, M.D.

Fellows

HAND



Amirhesam Ehsan, M.D.



Eugene Farng, M.D.



Daniel J. Marek, M.D.



Peter S. Kim, M.D.

Research Grants

National Institutes of Health

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

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

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

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

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

Design Criteria for Therapeutic Footwear in Diabetes
Peter R. Cavanagh, Ph.D., D.Sc.

Disuse Induced Osteocyte Hypoxia
Ted S. Gross, Ph.D.
Steven D. Bain, Ph.D.
Sundar Srinivasan, Ph.D.

Neuronal Modulation of Focal Bone Homeostasis
Ted S. Gross, Ph.D.
Steven D. Bain, Ph.D.

Skeletal Dysplasias
David R. Eyre, Ph.D.
Russell J. Fernandes, Ph.D.

T-Cell Mediation of Focal Bone Loss Induced by
Transient Muscle Paralysis
Ted S. Gross, Ph.D.

National Aeronautics and Space Administration

A Quantitative Test of On-Orbit Exercise
Countermeasures for Bone Demineralization Using a
Bedrest Analog
Peter R. Cavanagh, Ph.D., D.Sc.

National Space Biomedical Research Institute

Monitoring Bone Health by Daily Load Stimulus
Measurement During Lunar Missions
Peter R. Cavanagh, Ph.D., D.Sc.

An Integrated Musculoskeletal Countermeasure Bat-
tery for Long-Duration Lunar Mission
Peter R. Cavanagh, Ph.D., D.Sc.

Enhancing the Efficacy of Musculoskeletal
Countermeasures Using Computer Simulation
Peter R. Cavanagh, Ph.D., D.Sc.

Extent, Causes, and Counter measures of Impaired
Fracture Healing in Hypogravity
Peter R. Cavanagh, Ph.D., D.Sc.

Veterans Affairs Rehabilitation Research and Development Service

Dynamic Foot Bone Motion: Evaluation of Reconstruc-
tive Procedures
Bruce J. Sangeorzan, M.D.

Reducing Internal Stresses in Deformed Diabetic Feet
Bruce J. Sangeorzan, M.D.
Peter R. Cavanagh, Ph.D. D.Sc.

Surgically Reestablishing Foot Shape in Severely
Deformed Flatfeet
Bruce J. Sangeorzan, M.D.

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

VA Merit Review Functional Analysis of EWS/FLI-1
Howard A. Chansky, M.D.

A.O. North America

An Observational Study Assessment of Surgical
Techniques for Treating Cervical Spondylotic
Myelopathy (CSM)
Jens R. Chapman, M.D.

An Observational Study Comparing Surgical to
Conservative Management in the Treatment of Type II
Odontoid Fractures Among the Elderly
Jens R. Chapman, M.D.

AO North America Orthopaedic Trauma Fellowship
Bruce J. Sangeorzan, M.D.

AO Spine North America Fellowship
Carlo Bellabarba, M.D.

Facet Kinematics in a Limited vs. Subtotal
Microdisectomy
Michael J. Lee, M.D.

A.O. Spine International

Enhancing Pedicle Screw Fixation in the Lumbar Spine
Utilizing Allograft Bone Plug Interference Fixation
Michael J. Lee, M.D.

Algos Preclinical Services, Inc.

Development of a Fracture Pain Model
Steven D. Bain, Ph.D.

American Society for Surgery of the Hand

Hand Surgery Resident & Fellow Fast-Track
Seed Grants
Douglas P. Hanel, MD

Research Grants

Ascension Orthopedics, Inc.

Safety and Effectiveness Study of Ascension's PyroCarbon Radial Head Compared to Ascension's Metal Radial Head to Treat Arthritis, Fractures of the Radial Head, Relief of Symptoms After Radial Head Resection, or Revision of a Failed Radial Head Implant
Jerry I. Huang, M.D.

Boston Medical Center

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

DePuy Spine, Inc. (Johnson & Johnson, Inc.)

Clinical Spine Fellowship Grant
Theodore A. Wagner, M.D.

DePuy Spine Travel Grant
Douglas P. Hanel, MD

Johns Hopkins University

The Major Extremity Trauma Research Consortium
Bruce J. Sangeorzan, M.D.

National Science Foundation

University of Washington Engineered Biomaterials
Paul A. Manner, M.D.

Omega Medical Grants Association

Omega Shoulder and Elbow Fellowship Program Grant
Winston J. Warne, M.D.

Omega Trauma Fellowship
David P. Barei, M.D.

Orthopaedic Research and Education Foundation

Clinical Efficacy and Cost Implications of Acute BMP-2
David P. Barei, M.D.

OREF Residency Enhancement Grant AAOS
Douglas P. Hanel, MD

OREF Trauma Fellowship Grant
David P. Barei, M.D.

Orthopaedic Research & Education Foundation Fellowship Grant
Ernest U. Conrad III, MD

Orthopaedic Trauma Association

Development of Fracture Specific MFA
Bradford M. Henley, MD

COTA Trauma Fellowship
David P. Barei, M.D.

Ostex International, Inc.

Molecular Markers of Connective Tissue Degradation
David R. Eyre, Ph.D.

Paradigm Spine LLC

A Multi-Center, Prospective, Randomized, Clinical Trial Comparing Stabilization with Coflex vs. Pedicle Screw Fixation and Fusion after Decompression for at Least Moderate Lumbar Spinal Stenosis
Jens R. Chapman, M.D.

Smith & Nephew, Inc.

University of Washington Arthroscopy, Research and Training (ART) Lab
Christopher J. Wahl, M.D.

SYNTHES

Clinical Experience with Hindfoot Arthrodesis Nail for the Surgical Treatment of Ankle and Hindfoot Pathologies
Sigvard T. Hansen Jr., MD

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

Regulation of Bone Repair by Physiologic Loading
Steven D. Bain, Ph.D.
Ted S. Gross, Ph.D.

Spine End-Results Research Fund
Jens R. Chapman, M.D.

Synthes Grand Rounds
Richard J. Bransford, M.D.

The Boeing Company

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

US Army Research Office

Digit Regeneration in Mammals
Christopher H. Allan, MD

UW Team-Advance on Single Nuclear Detection and Atomic-Scale Imaging
John A. Sidles, Ph.D.

Department Publications 2010-2011

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