For 107 years, the Department of Orthopaedics at University Hospitals Case Medical Center has combined first-rate medical care, personalized attention and innovative scientific research with an unwavering sense of purpose – to provide the best possible treatment for patients. This past year, the Department of Orthopaedics achieved its highest national ranking to date – No. 16 by U.S. News & World Report. UH Case Medical Center has also been named to the Honor Roll and is so designated as one of the top 18 hospitals in the United States. As we move toward the future, we remain poised to benefit the lives of patients affected by musculoskeletal disorders for generations to come.
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Among the nation’s leading academic medical centers, University Hospitals Case Medical Center is the primary affiliate of Case Western Reserve University School of Medicine, a nationally recognized leader in medical research and education. UH Case Medical Center is the 2012 recipient of the American Hospital Association–McKesson Quest for Quality Prize.
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It is only appropriate that we dedicate this edition of the Case Orthopaedic Journal to Dr. Michael Keith as his academic career has been about the pursuit of translational research and “difference-making” operations. For the reader of this publication, I ask them to consider how Mike Keith would ask the appropriate and pertinent questions that would enable these ideas to be part of mainstream orthopaedic care. He has a keen ability to formulate these important questions and has attempted to train the next generation in this skill through his mentoring. All of us have been in a conversation with the “Professor” in which we are not quite sure where these questions have come from or what he is talking about, until perhaps at the very end of the conversation or even later in the day.

When you begin as a young surgeon, one often remarks to another about the last great case and looks forward to the next challenging operation. You quickly develop your own personal checklist, which although it has many items, the first and foremost is often to gain a certain surgical proficiency and quantity. Dr. Keith has done that and much more. As Dr. Keith has been able to check items off of “his list”, we have to ask ourselves if it is still possible to accomplish so much in this ever-busier workplace. This editorial is not so much to list the accolades and accomplishments, but to highlight the points that enabled him to jump to the next problem and solution.

It is important to consider that behind every accomplished career other things have to fall into place at the right time as well. Good orthopaedic partners, biomedical engineers such as Hunter Peckham, sterile electrical circuitry, surgical fixation technology, and microsurgery came alongside as Dr. Keith was influential in the beginnings of replantation and microsurgery, restoration in spinal and peripheral nerve injury, and the early management of traumatic conditions.

He has mentored countless students, residents, and fellow colleagues. From his initial research with Dr. Peckham on chimpanzees for the Hunter rods to the formation of FDA approved devices for reanimation in tetraplegia, there have been many articles and chapters, visiting grand rounds, and a professorship in Biomedical Engineering and Orthopaedics.

When looking back at his career or in asking him, the following describe his experience: Innovator, Intellectual, Mentor, Surgeon, Colleague, Family, and Fishing.

Perhaps, in this newer era of being productive and busy, we cannot complete all things, but we can certainly strive towards our own “checklist”. I think that Mike is almost through his list. Ask him sometime, but be prepared for a long answer.

– Harry Hoyen, MD
I am proud to introduce the 10th Edition of the *Case Orthopaedic Journal*. This year marks an important milestone in our publication. The *COJ* was first published in 2004, and its editorship has been passed down through the Allen fellow lineage ever since. In the next several pages, you will find a look back on the last nine volumes of the journal as well as an update on each Editor-in-Chief. I hope you will enjoy reading what everyone is up to now.

This edition of the *Case Orthopaedic Journal* is dedicated to Dr. Michael Keith. Dr. Keith, a graduate of the Case Orthopaedic Residency, joined the upper extremity faculty at Metro in 1979. He continues to be an integral part of the faculty and epitomizes the title of clinician scientist. Despite his own account that he has stepped back some from practice, that does not appear to be the case. He continues to offer a second to none educational experience to the fourth year residents who are privileged to rotate with him. One can only hope that this may continue on ad infinitum.

Included in this year’s journal are nine excellent manuscripts submitted by our current residents, clinical and basic science faculty, and even some of our alumni. Also included are photos from throughout the year and pages dedicated to the Henry H. Bohlman, MD Professorship, the Scoliosis Research Society Lifetime Achievement Award, the Arthritis Foundation Community Leaders Awards Dinner, and the 125th Anniversary of Rainbow Babies and Children’s Hospital.

A big thank you to the editorial staff comprised of the Allen Fellows from 2009 until present. They worked tirelessly to help with the peer-review process, take photographs, copy edit, and obtain advertising for the journal. It could not have been done without a true team effort!

Sincerely,

Lorraine C. Stern, MD
Editor-in-Chief
10th Anniversary of the Case Orthopaedic Journal
A look back at the previous 9 volumes

Volume 1 – 2004
Editor-in-Chief: Jeffrey Roh, MD

Although my education and training have enabled me to treat a wide spectrum of spinal disorders from the cervical to lumbar spine, my particular area of expertise lies in the burgeoning field of Minimally Invasive Spine Surgery (MIS). I am intimately involved in training both national and international spine surgeons in the art and science of performing MIS surgery. My clinical and research interests revolve around minimally invasive surgical approaches to spine surgery. As an inaugural member of the Society of Minimally Invasive Spine Society (SMISS), I have helped to educate and train numerous spinal surgeons in Asia, Europe, Australia, North America, and South America. I hold intellectual property and patents related to minimally invasive approaches to the spine. I am the Medical Director of ProOrtho, a division of Proliance Surgeons, one of the largest groups of orthopedic surgeons in the United States. I am also a Member of the Medical Executive Committee and Chairman of the Credentialing Committee at Evergreen Healthcare. I was voted as one of the top five doctors in KING 5’s Best of Western Washington Awards in 2009, voted as one of the top orthopedic surgeons in Seattle Met Magazine in 2012, and one of the top orthopedic surgeons in Seattle Magazine in 2013.

Volume 2 – 2005
Editor-in-Chief: Erika Mitchell, MD

After a trauma fellowship at Vanderbilt University Medical Center, I continued on as a faculty member in Orthopedic Trauma there for 4 years. Since then, my research focus has been the examination of abnormal fracture healing to gain insight into normal fracture healing biology. While at Vanderbilt, I received a $1.3 million grant from the Department of Defense to study the genetic predictors of heterotopic bone formation after traumatic fracture. This study culminated in publication in JBJS and multiple presentations at the OTA and AAOS annual meetings. In 2010, I took an Orthopedic Trauma position at Loyola University in Maywood, IL. I continued to do basic science research focusing on the affect of Type 2 Diabetes on fracture healing and growth plate development. This research is ongoing and will shortly be submitted for publication. Outside of work, I coached inner city middle and high school students in rowing for the Chicago Training Center and am very proud of my recent mentee’s admission to college. Recently, I have shifted gears after being given an opportunity in Sacramento, California. While I have now left the traditional academic environment, I am focusing on creating a new clinical model that will provide expert trauma care for fractures in the community setting. Our goal is to decrease the cost of health care and improve patient outcomes by decreasing the number of transfers, length of stay and time to operative treatment by placing fellowship trained orthopedic traumatologists into the community hospital setting. In my spare time, I have taken up the ukulele and will start coaching the Division I crew team at Sacramento State after the ‘winter’ break. I don’t miss the snow one bit!

Volume 3 – 2006
Editor-in-Chief: Michael Lee, MD

I am currently an associate professor in spine surgery at the University of Washington Medical Center in Seattle. In addition to my busy practice of clinical, research and teaching endeavors, I enjoy spending time with the unofficial Pacific Northwest Case Western Society which includes former COJ editors Jeff Roh, Jerry Huang, Adam Mirarchi and many more. I am blessed with two young healthy children and my wife Cathy. I enjoy reading the COJ and fondly look back at my time at Case.
Volume 4 – 2007
Editor-in-Chief: Jerry Huang, MD

Following residency, I completed a hand and microvascular surgery fellowship at UCLA Medical Center followed by an AO Traveling Fellowship at Lindenhof Hospital, focusing on hand, elbow and shoulder surgery with Professor Diego Fernandez and Professor Ralf Hertl. In 2008, I joined the faculty in the Department of Orthopaedics and Sports Medicine at the University of Washington Medical Center. I am currently the Program Director for the UW Combined Hand Fellowship. I have a very busy clinical practice and stay involved in both clinical and basic science research here at the University of Washington. I am extremely fortunate to be married to my beautiful and loving wife, Brandi, with two children. Kai is 5 years old and Alexis will be turning 3 in March. We love living in the Pacific Northwest and moved into our current house a year ago.

Volume 5 – 2008
Editor-in-Chief: Matthew Smith, MD

Since graduation from Case Western Reserve University residency in 2008, I completed a sports medicine and shoulder fellowship at the University of Michigan. During my fellowship year, I conducted research in hip biomechanics that received the “Excellence in Research” award from the American Orthopaedic Society for Sports Medicine (AOSSM) in 2010. After fellowship, I joined the faculty at Washington University in St. Louis in the sports medicine division. Additionally, I serve as a team physician for the NHLs St. Louis Blues. I am part of the Multi-center Orthopaedic Outcome Network (MOON) shoulder group. Our research has received the “Neer Award” from the Shoulder and Elbow Society twice in the last three years for research identifying outcome predictors for non-operative treatment of rotator cuff tears. In 2013, I was selected for the American Orthopaedic Society for Sports Medicine traveling fellowship to Asia where I spent nearly one month visiting Japan and China. I will complete a Masters of Science in Clinical Investigation through Washington University School of Medicine in May 2014. My clinical practice encompasses surgery of the shoulder, elbow, knee and hip.

Volume 6 – 2009
Editor-in-Chief: Andrew Islam, MD

After residency, I went to the Cleveland Clinic for a fellowship in sports medicine. After fellowship, I moved to Cincinnati and joined a 12 person orthopedic group. I have a practice with a focus on shoulder arthroscopy and sports medicine. I got married in 2012 to my wife Elizabeth. We have one daughter, Isabel.

Volume 7 – 2010
Editor-in-Chief: Michael Chen, MD

I am currently employed by Mercy Health Physicians, a multi-specialty group in Cincinnati, OH. My practice consists mostly of sports medicine, focusing mostly on shoulders and knees.
Volume 8 – 2011
Editors-in-Chief: Ryan Garcia, MD & James Murphy, MD

Ryan Garcia
I am finishing my 3rd year in plastic surgery at Duke and will stay around for an additional PGY10 year in Hand Surgery with Duke Orthopedics. We live in Chapel Hill and our son just turned 1 year. I am currently looking for a job in academics in orthopedics. I will have a practice that is 50% hand surgery and 50% limb salvage with a focus on microsurgery.

James Murphy
I completed my fellowship in Adult Reconstruction at University of Pennsylvania in 2013 and started practice at Geisinger Wyoming Valley Medical Center in Wilkes-Barre, PA. I am currently a member of AAOS, AAHKS and am still actively involved in clinical research.

Volume 9 – 2012
Editors-in-Chief: Erik Schnaser, MD & Troy Mounts, MD

Erik Schnaser
I am currently doing a fellowship in adult reconstruction (total joints) at the Hospital for Special Surgery in NYC. Though I have not officially accepted a job yet, we are likely going to move back out west after the fellowship year is done. I have to thank all of the faculty at Case, Metro, and the VA as I felt well prepared in my fellowship and it has been a fantastic experience thus far.

Troy Mounts
I am currently a Spine fellow at Thomas Jefferson University Hospitals in Philadelphia, PA. I have been blessed with the rare opportunity to learn from some of the top Spine surgeons in the world. To date I have performed nearly 200 complex spine reconstructive surgeries. As a fellow I have authored multiple book chapters and am heavily involved in research. I am currently pursuing an academic career out west where I hope to bring my patients ‘back’ to health.
I am delighted to introduce the 2013 volume of the Case Orthopaedic Journal, which highlights the outstanding achievements of the Department of Orthopaedics at Case Western Reserve University School of Medicine. The Department continues its ranking as one of the top orthopaedic departments in the United States, and we take great pride in the outstanding achievements and excellent work carried out during the past year by our clinicians, scientists, residents and staff.

The Department of Orthopaedics at Case Western Reserve University consists of four medical centers, our research laboratories and, most importantly, the outstanding people who have earned our reputation for excellence. Our medical centers include:

- University Hospitals Case Medical Center, which includes Rainbow Babies and Children’s Hospital and the Seidman Cancer Center,
- MetroHealth Medical Center, our Level I trauma hospital,
- Louis Stokes Veterans Administration Medical Center here on our Case Western campus, and
- University Hospitals Ahuja Medical Center and attached orthopaedic musculoskeletal center.

Our basic science laboratories are located:

- in the School of Medicine, with our Molecular Biology division in the Biomedical Research Building,
- in the Case Western Reserve School of Engineering, in the Musculoskeletal Mechanics and Materials Laboratory, and
- at MetroHealth Medical Center and the Veterans Administration Medical Center, where our Functional Electrical Stimulation Laboratories are located.
- Additionally, our Anatomic Research Laboratory resides in the Cleveland Museum of Natural History, the home of the Hamann-Todd bone collection.

**Medical Center and Medical School Achievements**

*U.S. News & World Report* once again ranked Case Western Reserve University School of Medicine in the “Best Medical Schools” in America, and University Hospitals Case Medical Center this year was named to the exclusive Honor Roll of Best Hospitals 2013-2014 in the *U.S. News & World Report* “America’s Best Hospitals” rankings. More than 5,000 hospitals nationwide were considered, and UH Case Medical Center was one of just 18 to be placed in this Best Hospitals Honor Roll. Our hospital ranked in the top 20 in six specialties—including Orthopaedics, and once again ranked in all 12 methodology-ranked specialties, with seven of our specialties achieving their highest placement in the 24-year history of the Best Hospitals rankings. UH Rainbow Babies and Children’s Hospital was again rated as one of the “Best Children’s Hospitals in America” and was ranked in all pediatric specialties. Rainbow continues to be the only Level I pediatric trauma center in Northern Ohio.
Departmental Achievements

The Department’s excellence in clinical activities was once again recognized by U.S. News & World Report, which ranked us as one of the top orthopaedic departments in the country (#16), and Pediatric Orthopaedics placed #14. Our national leadership in musculoskeletal research was again confirmed by our continued ranking as one of the top-funded orthopaedic departments in the United States by the National Institutes of Health (NIH, #14).

Our residency program received over 625 applications this year for our seven residency positions, and the Department matched seven of our top selections. We welcome to the program Dr. Christopher Collier from the University of Chicago, Dr. Jeremy Gebhart from Case Western Reserve University, Dr. James Kyriakedes from the University of Cincinnati, Dr. Ryan Li from the University of Pittsburgh, Dr. Todd Morrison from Jefferson Medical College, Dr. Joshua Napor a from Penn State Medical School, and Dr. Douglas Weinberg from Tulane University. Our Trauma Fellow this year, based at MetroHealth Medical Center, is Dr. Michael Robertson, who completed his residency at the University of Missouri School of Medicine. Our Joint Replacement Fellow is Dr. Matthew Popa from Grand Rapids Medical Center in Michigan. The Allen Research Fellowship this year was awarded to Dr. William Morris, who is working in our Cellular Biology Laboratory in research involving osteogenic sarcoma under the mentorship of Dr. Edward Greenfield.

We also welcomed three new faculty members this year. Dr. Zachary L. Gordon has joined our Division of Spine Surgery at UHCMC. He completed his orthopaedic residency here at Case Western Reserve University and a spine fellowship at University of Pittsburgh Medical Center. Dr. Gordon is a graduate of The Ohio State University and CWRU School of Medicine.

Umut A. Gurkan, PhD, after completing his postdoctoral fellowship at Harvard Medical School in biomedical engineering and medicine, joined our Department’s faculty. His primary department is Mechanical & Aerospace Engineering. Among his research interests are “micro/nano-scale technologies for biomanufacturing complex multiscale biological systems and musculoskeletal tissues.” Dr. Gurkan received his PhD in biomedical engineering from Purdue University, and has 85 publications in medical journals and texts. He has been invited to deliver 50 national and international presentations.

Ari D. Levine, MD, returned from his trauma fellowship at Carolinas Medical Center to join our trauma faculty based at MetroHealth Medical Center. Dr. Levine completed his orthopaedic residency here at Case Western Reserve University. His undergraduate degree was earned in a combined program from Miami University of Ohio and Columbia University, and he received his medical degree from the University of Cincinnati.

Congratulations to Faculty Members and Residents

In June, Christopher G. Furey, MD, was installed as the inaugural holder of the Henry H. Bohlman, MD, Chair in Orthopaedic Spine Surgery at University Hospitals Case Medical Center. Dr. Furey, who is the Director of our Division of Spine Surgery here at University Hospitals Case Medical Center, received his undergraduate degree at Vanderbilt and is a graduate of Case Western Reserve University School of Medicine. His residency was at Tufts New England Medical Center, followed by a spine fellowship at Duke University Medical Center. Dr. Furey has a special interest in factors that determine the outcome of surgery for severe cervical spinal cord compression. He is a member of the American Academy of Orthopaedic Surgeons, the North American Spine Society and the Scoliosis Research Society, among other organizations.

He has published more than 35 journal articles and book chapters, and is also a member of the American Academy of Orthopaedic Surgeons’ Board of Councilors. The other spine surgeons in his Division include Dr. Nicholas Ahn, Dr. Jason Eubanks and Dr. Zachary Gordon.

This fall, George H. Thompson, MD, Chief of Pediatric Orthopaedic Surgery, received the 2013 Lifetime Achievement Award from the Scoliosis Research Society. This is only the 10th time this world-renowned spinal surgical society has presented this prestigious award. Dr. Thompson is an internationally esteemed pediatric orthopaedic surgeon who has made tremendous contributions to pediatric orthopaedics. The honor commemorates Dr. Thompson’s extensive career which has led to innovations in everything from surgical techniques to ways of preventing or decreasing blood loss, making operations safer for children. Because
of the techniques he has developed and published, he has changed the lives of tens of thousands of children worldwide. Dr. Thompson received the award last September in Lyon, France.

Drs. Kingsbury G. Heiple and Victor M. Goldberg received the 2013 Arthritis Foundation Community Leaders Awards. Dr. Heiple was the inaugural holder of the Charles H. Herndon Professorship at Case Western Reserve University, and the Chair of the Department of Orthopaedic Surgery at CWRU and UHCMC from 1982 to 1988. A native of Peoria, Illinois, Dr. Heiple received his medical degree from the University of Chicago and completed his orthopaedic residency at Case Western Reserve University/University Hospitals Case Medical Center. He joined our faculty in 1958 and was quickly recognized as a superb surgeon as well as an outstanding clinician-scientist and educator. For over a decade, he served as an associate editor of The Journal of Bone and Joint Surgery and also served on the American Board of Orthopaedic Surgery and was its president from 1984 to 1985. Dr. Heiple has over 80 peer-reviewed manuscripts and numerous book chapters.

Victor M. Goldberg, MD, was Chair of the Department of Orthopaedic Surgery at Case Western Reserve University and University Hospitals from 1989 to 2002. He completed his internship and surgical residency at Case Western Reserve University/University Hospitals Case Medical Center, and his orthopaedic residency at the Hospital for Special Surgery in New York. A world leader in adult reconstruction and in surgery of the hip and knee, Dr. Goldberg also has been a true clinician-scientist, with his research interests including tissue engineering of bone and cartilage, bone graft physiology and mechanisms of bone loss. He has been a significant developer of hip and knee arthroplasty implants used worldwide in the treatment of advanced arthritis. A former president of the Orthopaedic Research Society and of the Knee Society, he served as chairman of the board of trustees of the Orthopaedic Research and Education Foundation, as well as chairman of the Council of Research for the American Academy of Orthopaedic Surgeons. Dr. Goldberg continues as an active faculty member in our Department and as an attending at the VA Hospital. He serves on the editorial boards for the Journal of Arthroplasty, Clinical Orthopaedics and Related Research, and AAOS Now. He has published over 250 peer-reviewed articles, 24 book chapters and 10 books. Dr. Goldberg received three Kappa Delta Awards from the AAOS, as well as the Shands Award from the AOA and ORS, and the Otto Aufranc Award from the Hip Society.

Thanks to a generous donation by Dr. and Mrs. Goldberg as well as donations by numerous colleagues, patients and friends, University Hospitals Case Medical Center has established the Victor M. Goldberg, M.D., Lectureship in Orthopaedics. This lectureship will honor Dr. Goldberg’s numerous contributions to the Department of Orthopaedic Surgery at University Hospitals Case Medical Center. The lectureship will also further enhance our tradition of bringing together our residents and faculty with the best and brightest leaders in Orthopaedics.

Ronald Triolo, PhD, received a U.S. Army Medical Research Acquisition Activity Grant for his project “A Hybrid Neuromechanical Ambulatory Assist System.” This project will allow Dr. Triolo and his team to advance the design of a hybrid neuromechanical ambulatory assist which will be self-contained, portable and suitable for clinical testing outside of the laboratory. The goal of his research is to restore independent and functional mobility to individuals with paralysis. Dr. Triolo is the executive director and a principal investigator of the Advanced Platform Technology Center of Excellence at the Louis Stokes Department of Veterans Affairs Medical Center. Dr. Triolo also received a Department of Defense Grant for his work in functional electrical stimulation of the musculoskeletal system.

Claire M. Rimnac, PhD, the Wilbert J. Austin Professor of Engineering, and Matthew J. Kraay, MD, the Kingsbury G. Heiple and Fred A. Lennon Chair in Orthopaedics – along with their collaborators in the Multicenter Implant Retrieval Program – have been selected as the recipients of the James A. Rand Award from the American Association of Hip and Knee Surgeons for their paper entitled “Is Increased Modularity Associated with Increased Wear Debris in Metal-on-Metal Total Hip Arthroplasty Devices?”
Dr. Lindsay Bashur, a postdoctoral fellow in the laboratory of Dr. Guang Zhou and a T32 trainee supported by our Department’s NIH Training Grant, received the American Society of Bone and Mineral Research Young Investigator Award. This award recognizes young investigators who submit top-ranking abstracts to the ASBMR meeting. Dr. Bashur presented her work on the JAB1 role during limb development, as well as the role of JAB1 in osteosarcoma pathogenesis.

Dr. Michael Reich received first-place honors in the Cleveland Orthopaedic Society’s resident essay contest for his research “Genipin Crosslinking As a Potential Alternative Method for Sterilizing Bone Allografts.”

Dr. Shane Hanzlik won the trainee award for the Best Basic Science Paper at the annual meeting of the International Society of Hip Arthroscopy. Dr. Chad Fortun also was a finalist for this award. Dr. Jay Solomon won first prize at the Cleveland Clinic Foundation’s 13th Annual Cutting Edge in Upper Extremity Surgery meeting, with his project “Open Reduction Internal Fixation of the Radial Head versus Radial Head Replacement in Terrible Triad Injuries of the Elbow.” This project was in collaboration with Drs. Harry Hoyen, Kevin Malone, and Heather Vallier. Dr. Jonathan Streit took second place in this research contest, which is held in honor of the late Dr. Alan Wilde, for his project titled “Medialized versus Lateralized Center of Rotation in Reverse Shoulder Arthroplasty: A Radiographic Analysis.” Dr. Streit was also selected by the American Orthopaedic Society for Sports Medicine to attend the 2013 AAOS/ OREF/ ORS Clinician Scholar Career Development Program.

In total, over the last year the members of the Department published over 55 peer-reviewed manuscripts and they were invited to present their work in over 97 occasions at national and international meetings.

This year’s chief residents, who graduated in June, were another outstanding class. They are advancing on to fellowships in their subspecialty areas of choice, and we welcome them into the Case Western Reserve/Charles Herndon Alumni Association and wish them all the best in their future careers.

- Scott Kling, MD – sports medicine, University of Pittsburgh Medical Center, Pittsburgh
- Ethan Lea, MD – orthopaedic trauma, University of California, Davis
- James Learned, MD – orthopaedic trauma, University of Washington Harborview Medical Center, Seattle
- Troy Mounts, MD – spine surgery, Rothman Orthopaedic Institute at Jefferson, Philadelphia
- Erik Schnaser, MD – adult reconstruction and joint replacement, Hospital for Special Surgery, New York

Once again, it has been a privilege to lead this fabulous orthopaedic department, in its 106th year. This year’s report highlights the high-quality work that typifies the faculty, residents and staff of this outstanding Department.
Although the MetroHealth faculty and staff continue to provide exceptional medical and surgical care for all in need in Northeastern Ohio as they have always done, much has changed at Metro. Many roles have changed, some new faces have been added; and, unfortunately, we have had to say good-bye to others.

The greatest change for me is that after almost 30 years of practicing at both University and Metro, I have now settled into a full-time position at MetroHealth Medical Center. After a somewhat prolonged search, I took on the chairmanship on September 1 of this year. This relieved both Drs. Cooperman and Patterson of their interim chairmanship and allowed them to move on to new roles. I have inherited a very strong and healthy department and I am excited to build on their prior successes and continue to expand and grow the department. I will continue to be active within the AO as Chairman-Elect for AO Trauma International.

Dr. Patterson now puts full effort into his role as Executive Director of the Surgical PCU at MetroHealth. In addition to all of his administrative duties, he continues to remain active clinically as both a trauma surgeon and as an arthroplasty surgeon in addition to his active role as teacher and mentor to the residents, fellows, and medical students. Unfortunately, we had to say goodbye to Dr. Cooperman, who retired after many years of exceptional service to both MetroHealth and Rainbow Babies and Children’s. He has retired and now has a part-time position at Yale Medical Center providing his unique style of wisdom and knowledge. Though he certainly will be missed, his impact will never be forgotten.

The trauma service remains busy, challenging the exceptional skills of our faculty. We were fortunate to hire Dr. Ari Levine as our seventh (yes, seventh!!) fellowship-trained orthopaedic traumatologist. Ari is a past resident of ours who just completed an orthopaedic trauma fellowship at the Carolinas Medical Center. He was a welcome sight after an extremely busy trauma season and he is already getting very busy.

Dr. Heather Vallier remains busy both with care of the trauma patients and also with her research. As the head of research and education, she remains prolific with her publications and presentations. She recently advanced to the rank of Professor and is on the Board of Directors of the Orthopaedic Trauma Association (OTA).

Dr. Sontich continues to expand the limits of the use of the Taylor Spatial Frame by taking on the most difficult cases of trauma, nonunion/malunion and infection. His expertise and skills remain a vital component of our trauma service. His expertise is recognized nationally with multiple invited presentations and responsibilities and as the President of the Ohio Orthopaedic Society.

Dr. Roger Wilber continues his practices at both University Hospitals and MetroHealth Medical Center. As the head of the Pelvic and Acetabular section, he continues to perfect his surgical skills and improve outcomes of the most complex pelvic and acetabular injuries in addition to having a very busy arthroplasty service. All of his national and international lecturing has recently achieved him the honor of being named the chairman of the AO North American Musculoskeletal Trauma Education Committee (NAMTEC).
Dr. Megan Brady, who in addition to being an active orthopaedic traumatologist, is also the head of the Orthopaedic Fragility Service. She has partnered with multiple medical specialties to give specialized care to this ever-expanding population. She is also developing a busy foot and ankle practice and has expanded the orthopaedic footprint to include the new Middleburg Heights office.

The Orthopaedic Trauma Service has been fortunate to have a string of exceptional fellows who are a vital component of our busy trauma team. Our most recent fellow, Dr. Jeffrey Earhart, has joined a trauma practice in Rockford, Illinois. Our current fellow, Dr. Michael Robertson, is in place and working hard.

Dr. Tim Moore is now a member of the newly formed Neurosciences Department headed up by Dr. Michael Steinmetz. In spite of this minor change of title and location of his office, he is still an orthopaedist at heart and provides critical services to our patients and teaching to our faculty, residents, and medical students.

With the retirement of Dr. Dan Cooperman and the demands at Rainbow Babies and Children’s, Dr. George Thompson, Dr. Ray Liu and Dr. Christina Hardesty have stepped in to provide essential services for the busy pediatric orthopaedic practice at MetroHealth Medical Center. Dr. Liu is rapidly developing a very busy pediatric deformity practice and Dr. Hardesty remains busy with spinal deformity and general pediatric orthopaedics.

The Hand and Upper Extremity Service, made up of Drs. Michael Keith, Harry Hoyen, Kevin Malone, Todd Bafus, and Stephen Lacey, continues to take on all the most difficult hand and upper extremity cases in Northeastern Ohio. Drs. Keith and Hoyen continue to work closely with Dr. Hunter Peckham with research on Functional Electrical Stimulation. Dr. Harry Hoyen remains remarkably busy with his clinical practice and his national teaching and presentations. Dr. Kevin Malone, in addition to his busy clinical practice, is active with teaching the residents. He has taken on increased administrative responsibilities with running the Orthopaedic Education at MetroHealth Medical Center. Our newest addition, Dr. Todd Bafus, is already very busy working both at MetroHealth Medical Center and also at the Wade Park VA Hospital.

Dr. John Feighan continues to provide essential expertise and service in complex foot and ankle problems as chief of the Foot and Ankle Service. He is also actively mentoring Dr. Megan Brady as she develops her foot and ankle interests.

Outside the department of orthopaedics, there have been several other changes within the MetroHealth System. We have a new CEO, Dr. Akram Boutros, who came to us from New York City. Though he just started in August, he has already made a significant impact on improving and advancing MetroHealth’s ability to pursue its mission. MetroHealth is also starting to expand outside its main hospital at West 25th street. A brand new state-of-the-art office opened in Middleburg Heights this past year and plans are being made for a new facility in the Brecksville area. Orthopaedics has also expanded to an office in Lyndhurst. This creates a very exciting opportunity for orthopaedics, allowing us to further offer our expertise to a broader population of people in Northeastern Ohio. The former Deaconess Hospital is now called MetroHealth Old Brooklyn Health Center and is the home for PM&R, FES, and acute rehab.

Though much has changed, the heart and soul of Metro has not. Its mission and people remain the same and Metro continues to be a wonderful place to work. It is a true honor for me to be full time at Metro and continue to promote and expand the mission of the hospital and the department of orthopaedic surgery.
The orthopaedic surgery section at the Cleveland Veterans Affairs Medical Center (VAMC) has had another year of growth in both outpatient and surgical care. This growth has been fueled by strong demand of returning veterans, improvements in our operations, and dedication of our staff. Brian Cmolik, MD (Cardio-Thoracic Surgery) became the new Chief of Surgical Services and he has been a staunch supporter of veterans orthopaedic care.

First and foremost, I would like to thank the residents and fellows for their hard work and dedication to the veterans. Through more efficient practice planning we have been able to honor most resident leave requests while simultaneously boosting clinical and surgical productivity. This year also marked the re-launch of our adult reconstruction fellowship and we welcomed Matthew Popa (MD, CWRU 2008) to the team from Grand Rapids Michigan.

I am proud of the contribution provided by our established faculty including Thomas McLaughlin, MD (sports medicine, arthroscopy), Patrick Getty, MD (orthopaedic oncology), Randall Marcus, MD (adult reconstruction, foot & ankle), Victor Goldberg, MD (adult reconstruction, total joints), and John Makley, MD (orthopaedic oncology). I am especially appreciative of our upper extremity specialists Robert Gillespie, MD (shoulder & elbow), J “Rob” Anderson, MD (Hand & Elbow), and Todd Bafus, MD (Hand & Upper Extremity). This trio provides superb coverage for all upper extremity concerns from hand and micro surgery to shoulder arthroplasty. Mike Vento, MD has been a valuable faculty member by providing non-operative staffing and E-consultations which have lead to improved performance measures by the section. We are grateful for ongoing clinical support from our two physician assistants: Greg Field, PA-C and Terry Bauer, PA-C. In addition, the nursing support provided by Barbara Dennstedt, RN-BSN and Carliss Towns, RN-MSN has improved our efficiency and patient relations. I would like to express special recognition and gratitude to Barb Dennstedt, RN for taking major steps in perioperative risk stratification, MRSA prevention, and case planning. Her work has contributed to patient satisfaction and improved clinical outcomes in arthroplasty patients. On the basic science level Ron Triolo, PhD, Professor of Orthopaedics and Biomedical Engineering, received a $502,718 grant from the U.S. Army Medical Research Acquisition Activity for his work on “A Hybrid Neuromechanical Ambulatory Assist System.” Likewise Kath Bogie, DPhil has been a leading researcher in the Functional Electrical Stimulation (FES) center and published on physiologic measurements of tissue health.

The current Residency Training Program is divided into two rotations each with a PGY-5 chief resident and PGY-3 resident. Their time is split roughly 50/50 between outpatient clinics and surgical services. In the 2012-2013 academic year we performed over 7600 outpatient clinic visits which is an 11% year over year increase and 23% increase over the last two years. During the same period we performed 615 operative cases representing a 5% year over year increase and a 19% growth in surgical volume since I became section chief.
I am delighted that this issue of the COJ is dedicated to Mike Keith. He has always been extremely supportive of academics and always has interesting and insightful suggestions.

Each year, one or two of our residents are selected as Allen Fellows, who join a research lab for a full-time, year-long, experience. The 2013-2014 Allen Fellow is Will Morris, MD, who is working with Patrick Getty and me on a new therapeutic approach for osteosarcoma. Will already has preliminary data that the new drug blocks osteosarcoma progression in vitro. Next year’s Allen Fellows will be Chris Collier, MD and Doug Weinberg, MD. Chris will work with Patrick Getty and me on the osteosarcoma project and Doug will work with Ray Liu on a variety of projects related to pediatric orthopaedics.

The 2013 Allen Fellowship Visiting Professor was Seth Leopold, MD, who is a Professor in the Department of Orthopaedics at the University of Washington and is the new Editor-in-Chief of Clinical Orthopaedics and Related Research. Seth’s talks were on critical reading of the literature and on writing for peer-reviewed journals. Both talks included lots of very helpful suggestions.

Since last year’s COJ, Hani Essber, MD has joined the CWRU/NIH Musculoskeletal Training Grant. Hani is a post-doctoral trainee also working on the osteosarcoma project with Patrick Getty and me. Some of you may know Hani from his rotation in pediatric orthopaedics with Allison Gilmore during medical school. Last spring, the training grant hosted the first Northeast Ohio Musculoskeletal Research Retreat. It featured a wonderful series of oral and poster presentations by trainees and their mentors from all of the institutions in the area. We are planning to alternate these retreats yearly with the long-standing CWRU Musculoskeletal Research Days. We are therefore currently planning the 2014 Research Day and looking forward to hosting another retreat in the spring of 2015.

Finally, I’d like to announce that the new small animal µCT has arrived and should be up and running by the time this issue of the COJ reaches you. Purchase of this machine was made possible by funds from the State of Ohio Third Frontier Program, as part of a regional orthopaedic research program headed by Walt Horton at NEOMED. I anticipate that the new µCT will allow all of us to make new strides in understanding skeletal anatomy, development, injury, and repair. I’d like to thank all of you who assisted with securing the funds and selecting the optimal model to purchase.
We would like to congratulate Dr. Christopher Furey, who was appointed the second holder of the Henry H. Bohlman, MD Professorship this past summer. The Henry H. Bohlman, MD Professorship was established in 2008 as an endowed chair in spine surgery. It was funded in large part by the late Dr. Bohlman’s past residents and fellows as well as by his patients and friends. Dr. Bohlman was the inaugural holder of the chair.

Dr. Bohlman, who passed away in 2010, joined the faculty at Case Western in 1972 after completing medical school at the University of Maryland and residency at Johns Hopkins as well as serving some time as a major in United States Air Force. Among Dr. Bohlman’s many academic accomplishments, perhaps the one he is best well known for is pioneering the anterior approach to cervical spine surgery. At the time of his passing, Dr. Bohlman had authored over 120 papers, 45 book chapters and had been invited to lecture over 300 times. He was on the editorial board of *Spine, The Journal of Bone and Joint Surgery* and *Neurosurgery* and had served as president of the Cervical Spine Research Society and Federation of Spine Associations. Dr. Bohlman was awarded the Association of Bone and Joint Surgery Nicolas Andry Award for outstanding achievement in the field of orthopaedics and the North American Spine Society Leon Wiltse Award for contributing greatly to the art and science of spinal disorder management.

Under his tutelage, Dr. Bohlman trained over 110 spine fellows at University Hospitals who now carry on his legacy. Dr. Bohlman was also an avid wine collector and his fellows formed the Wine and Spine Society that met annually at the AAOS meeting.

Dr. Furey is an Associate Professor of Orthopaedics at the Case Western Reserve University School of Medicine and the Chief of the Spine Division at University Hospitals. He earned his undergraduate degree at Vanderbilt and his medical degree at Case Western. Dr. Furey completed a general surgery internship at University Hospitals and his orthopaedic surgery residency at Tufts. Following his residency training, Dr. Furey completed his spine fellowship at Duke and then returned as faculty to University Hospitals in 2000.

Dr. Furey has authored over 35 papers, 4 book chapters and has been invited to present his work over 85 times at local, national and international meetings. He is currently a member of the American Academy of Orthopaedic Surgeons Board of Councilors and a board member of United Cerebral Palsy of Greater Cleveland. Dr. Furey also served as the president of the Cleveland Orthopaedic Society from 2008-2009, on the Executive Board of Directors of the Ohio Orthopaedic Society form 2009-2011 and on the spine and biomedical engineering subcommittees of the Academy.
The Scoliosis Research Society (SRS) honored Dr. George Thompson, the Chief of the Department of Pediatric Orthopaedic Surgery at Rainbow Babies and Children’s hospital, with a Lifetime Achievement Award for his work in pediatric spinal disorders in September of 2013 in Lyon, France. He was only the 11th recipient of this prestigious award. The SRS Lifetime Achievement Award honors a member for distinguished service to the Society as well as significant contributions to spinal deformity care. This award commemorated Dr. Thompson’s extensive career, which has led to innovations in everything from surgical techniques to ways for preventing or decreasing blood loss, making operations safer for children. He has been involved in the SRS for his entire career, holding many committee positions and serving as its president for an unprecedented two years when the president scheduled to succeed him died suddenly. Dr. Thompson graduated from Oklahoma State University (BS in Physiology) in 1966 and the University of Oklahoma School of Medicine in 1970. He did a surgical internship and orthopaedic surgery residency at the University of California Los Angeles Medical Center (1970–1972, 1974–1977) followed by a fellowship in pediatric orthopaedics at the Hospital for Sick Children in Toronto, Ontario (1978) under the supervision of Robert B. Salter, MD, FRCSC. He then joined the faculty at Case Western Reserve University (1979–present). He is currently the Co-Chair of the Salter Society; Co-Editor of the Journal of Pediatric Orthopaedics; President/CEO of the SICOT Foundation; and member of the Medical Advisory Board, Shriner’s Hospital for Children. He is the Past-President of the Ohio Orthopaedic Society (1997–1999), Pediatric Orthopaedic Society of North America [POSNA] (2002–2003), and Scoliosis Research Society [SRS] (2006–2007; 2007–2008). He is the immediate Past-Deputy Editor of Pediatric Orthopaedics for the Journal of Bone and Joint Surgery (2003–2005). He has received numerous honors and awards, most notably the American Orthopaedic Association (AOA) North American Traveling Fellowship (1979), an endowed chair (2006), and the POSNA Arthur H. Huene Award (2008). He has published 153 peer-reviewed articles, 86 chapters in textbooks and edited four textbooks. He has presented more than 700 regional, national and international lectures.

"Dr. Thompson is one of the most hard working and respected people nationally and internationally in the field of pediatric orthopaedics and spine deformity surgery. Dr. Thompson has spent his entire career committed to University Hospitals Rainbow Babies and Children’s Hospital. His mission has been, and remains to be, to provide the highest level of care for children throughout this region, train the next generation of doctors, spearhead cutting edge research, and share his knowledge and skill throughout the world.” – SRS Press Release
For more than 125 years, history has been repeating itself at University Hospitals Rainbow Babies & Children’s Hospital.

From a fateful Thanksgiving Day in 1887 – when nine young women set out to establish a facility in Cleveland dedicated solely to caring for children that would later evolve into the current hospital – to this very moment, our dedicated caregivers have operated on the edge of innovation to promote the health and wellness of children. Year after year, our team has researched cures, developed novel therapies and engaged families in the care and cure of their baby or child – establishing UH Rainbow Babies & Children’s Hospital as a world-renowned pediatric medical center.

Spurred on by the Rainbow Babies & Children's Foundation's transformational gift of $32.5 million in November 2012 to commemorate the hospital's 125th anniversary, Rainbow embarked on a year-long anniversary celebration in 2013 with various events and publications. The celebration peaked on July 13 when more than 2,500 UH and Rainbow employees were treated to a special night at Progressive Field when the Cleveland Indians triumphed over the Kansas City Royals. The entire evening included highlights and features of Rainbow and our legacy including: a pre-game parade, a free vintage 1902 Tribe jersey giveaway with the Rainbow anniversary logo on the sleeve, appearances by hospital mascot Bo the Take Care Bear, Rainbow patients throwing out the 1st pitch, special game day signage around Progressive Field commemorating the anniversary, a Rainbow anniversary video played pre-game on the jumbo scoreboard, and sponsored fireworks at the end of the game.

The celebratory events included the development of a special website that highlights Rainbow’s medical and innovative milestones available at RainbowBabies.org/timeline. Rainbow's legacy includes numerous medical firsts including the efforts of Drs. Charles Herndon and Clyde Nash in the 1960’s who collaborated to provide numerous innovations in the clinical treatment of patients with scoliosis. This legacy continues on today under the excellent leadership of George Thompson, MD, Chief of Pediatric Orthopaedics and recent recipient of the Scoliosis Research Society’s Lifetime Achievement Award.

Dr. Ray Liu and his wife, Dr. Caryn Tong, arrive with their daughter Emily Liu at the celebratory Indians Game.

Bo the Take Care Bear takes in the festivities on the field.

Dr. Ray Liu and his daughter Emily participate in the pre-game parade.
ALUMNI UPDATES

Dr. Michael Archdeacon has been named Chair of the Department of Orthopedic Surgery at the University of Cincinnati’s College of Medicine, effective November 1, 2013. He has served as interim chair since August. Dr. Archdeacon has served as vice chair in the Department of Orthopedic Surgery since 2007 and medical director since 2002. He was chief of staff at the UC College of Medicine from 2008 to 2012, and currently he is the medical director for operative services. Dr. Archdeacon is a professor of orthopedic surgery and adjunct professor of biomedical engineering as well as the director of the division of musculoskeletal traumatology. He will now also hold the Dr. Peter J. Stern Endowed Chair of Orthopedic Surgery.

Dr. Andrew Pollak has been named the new Chairman of the Department of Orthopaedics at the University of Maryland. He will also serve as Chief of Orthopaedics at the University of Maryland Medical Center. Dr. Pollak was previously Professor of Orthopaedics at the School of Medicine and Chief of Orthopaedics and head of the Division of Orthopaedic Traumatology at the University of Maryland R. Adams Cowley Shock Trauma Center. He has been serving as interim chair of the department since October 2012. In addition, Dr. Pollak will also serve as System Chief of Orthopaedics for the University of Maryland Medical System coordinating orthopaedic efforts across its 12 member hospitals.

Dr. Anthony M. Harris has been named Interim Chair of the Department of Orthopaedic Surgery and Rehabilitation at the University of Florida, Jacksonville. He is currently an assistant professor in the Department of Orthopaedics and the Chief of the Division of Orthopaedic Trauma Surgery.

Dr. Matthew Smith received the 2013 American Orthopaedic Society for Sports Medicine Traveling Fellowship. He was one of three fellows who traveled to Asia for 4 weeks this past spring visiting different sports medicine centers in Japan and China. Dr. Smith is currently an assistant professor in the Department of Orthopaedic Surgery at Washington University in St. Louis, Missouri.
PHOTOS FROM THROUGHOUT THE YEAR

2013 Graduation Dinner
Kirtland Country Club

1st Row: Cynthia Nguyen, Edward Greenfield, Eugene Tsai, Patrick Getty, James Learned, Scott Kling, Erik Schnaser, Randall Marcus, Troy Mounts, Ethan Lea, John Wilber, Jeffrey Earhart, Lorraine Stern, Guang Zhou, Sheeba Joseph

2nd Row: Steven Reichard, Nicholas Ahn, James Kyriakedes, Anna Wallace, Christopher Collier, Jonathan Streit, Michael Karns, Jason Solomon, Chad Fortun, Thomas McLaughlin, Ashraf Youssef, Jason Eubanks, Glenn Wera, Brian Victoroff, Harry Hoyen, Adrienne Moraff

3rd Row: Sunny Patel, Roger Wilber, Dwight Davy, John Shaffer, Christina Hardesty, William Petersilge, Christopher Bechtel, Joshua Napora, Todd Morrison, Ryan Li, Todd Bafus, Megan Brady, Kevin Malone, Michael Reich, Christina Cheng

Herndon Dinner
The University Club of Chicago

Mr. Jason Wallace, Dr. Anna Wallace, Drs. Michael and Sylvia Abdulian.

Dr. Jeff Soldatis, Dr. Ray Duffett, Dr. Thomas McLaughlin, Dr. Daniel Cooperman.

Dr. Barry Samson, Ms. Lynette Bennett, Dr. Enrique Boada, Dr. Bruce Henderson, Mrs. Jan Henderson.

Dr. Jonathan Belding, Mrs. Jamie Belding, Mrs. Kate Fortun, Dr. Jason Solomon, Dr. Chad Fortun, Dr. Jonathan Macknin.

Dr. Jay Janicki, Dr. George Thompson, Dr. Robert Frederick.

Dr. Patrick Getty, Dr. Glen Feltham, Dr. Michael Archdeacon, Dr. Ben DiGiovanni.
Northeast Ohio Musculoskeletal Research Retreat, April 6, 2013

Drs. Greenfield and Marcus.

Dr. Christopher Bechtel presents his work.

Dr. Guang Zhou presents his work.

Drs. Andrew Tsai and Christina Cheng review Dr. Tsai's research poster.

Drs. Greenfield, Tsai and Cheng with Ms. Val Schmedlen.

Dr. Greenfield introduces the end of day awards.
Trout Club took on a new destination this year, Pine Lake Trout Club in scenic Chagrin Falls. In fact, this was the original location of Trout Club before it was relocated to Deep Springs Trout Club in Chardon.

Sheeba Joseph, Andrew Tsai, Cynthia Nguyen and Will Morris enjoy the surroundings at the new trout club location.

The outgoing chiefs prepare their presentation. From left: Scott Kling, Erik Schnaser, James Learned, seated – Ethan Lea.

Glenn Wera and Troy Mounts catch up before the food is served.

Drs. Hardesty and Thompson unknowingly get photobombed by Erik Schnaser.

Meanwhile, at another table, the PGY-4’s prepare to roast the chiefs. (From left: Chad Fortun, Lorraine Stern, Jon Belding, Jay Solomon, seated – Anna Wallace.)
Intern Picnic
South Chagrin Reservation

This year we changed locations to the South Chagrin Reservation of the Cleveland Metroparks. Although we did not have the usual “beach” volleyball court, there was a big game of frisbee and a playground that was enjoyed by the children in attendance.

Drs. Rob Anderson and Brian Victoroff enjoy some discussion with Drs. Jay Solomon, Jon Belding and Lorraine Stern as well as Mrs. Jamie Belding. Meanwhile, Jane and Eve Belding take a rest from the swings.

Dr. Ron Desai fills the role of sous chef preparing the chicken kabobs for the grill, a welcome addition to the usual fare of hot dogs and hamburgers.

Everyone enjoying the food and shade in the picnic area.
On October 25, 2013, the Great Lakes Region chapter of the Arthritis Foundation in Northeast Ohio held their annual Community Leaders of the Year Awards Dinner at the Marriott Downtown at Key Center. This year they honored eight past academic chairmen of local orthopaedic departments to celebrate the legacy of orthopaedic care, education and innovation. Among those honored were our own Dr. Kingsbury Heiple and Dr. Victor Goldberg, past chairmen at University Hospitals Case Medical Center, as well as Dr. Clyde Nash, past chairman at MetroHealth Medical Center. Several other faculty members and alumni were in attendance to honor these three men for their contributions to orthopaedic surgery.
AAOS Research Capitol Hill Days

Orthopaedic surgeons, patients, and researchers visited Capitol Hill on February 28, 2013 to raise awareness about the debilitating and costly musculoskeletal diseases and disorders affecting millions of Americans and emphasize the need for research funding. Dr. Erik Schnaser and Dr. Megan Brady represented Case Western, along with alumnus Dr. Michael Archdeacon. A patient of Dr. Archdeacon’s, Mr. Andrew Meyers, rounded out the delegation. They met with local politicians including Congressman Dave Joyce, Congresswoman Marcia Fudge, Senator Sherrod Brown and Senator Rob Portman.

Cathy Ostrander’s Retirement

Mrs. Cathy Ostrander retired from the Department of Orthopaedics after 34 years of service in December of 2013. She began in the department as the secretary to Dr. Victor Frankel and then became the secretary for Dr. Victor Goldberg. After Dr. Goldberg’s retirement, she became Dr. Glenn Wera’s secretary. She looks forward to spending more time with her grandchildren during her retirement. She will truly be missed!

Picture from Mrs. Ostrander’s retirement lunch. From left: Rick Megasi, Kelly Wells, Connie Poe-Kochert, Celeste Sanders, Julie Bunkelman, Sonya Owens, Phyllis Lie, Charese Hurt, Cathy Ostrander, Carrie Schneider, Kathy Griswold.
UH ATTENDINGS

Nicholas Ahn  Robert Anderson  Susannah Briskin  Jason Eubanks  Steven Fitzgerald  Christopher Furey

Patrick Getty  Robert Gillespie  Allison Gilmore  Victor Goldberg  Donald Goodfellow  Zachary Gordon

Christina Hardesty  Amanda Weiss Kelly  Matthew Kraay  Stephen Lacey  Raymond Liu  Randall Marcus

Shana Miskovsky  William Petersilge  Michael Salata  John Shaffer  Joe Son-Hing  George Thompson

Brian Victoroff  Glenn Wera  Roger Wilber
FACULTY AND RESIDENTS

METROHEALTH ATTENDINGS

Todd Bafus
Megan Brady
John Feighan
Christina Hardesty
Harry Hoyen

Michael Keith
Stephen Lacey
Ari Levine
Raymond Liu
Kevin Malone

Tim Moore
Clyde Nash
Brendan Patterson
John Sontich
Heather Vallier

John Wilber
Roger Wilber
VAMC ATTENDINGS

Robert Anderson

Todd Bafus

Patrick Getty

Robert Gillespie

Victor Goldberg

John Makley

Randall Marcus

Thomas McLaughlin

Michael Vento

Glenn Wera
CURRENT RESIDENTS

PGY-5 Residents

Jonathan Belding, MD  
MD, Case Western Reserve University  
BA, Colgate University

Chad Fortun, MD  
MD, Case Western Reserve University  
BS, University of Wisconsin - La Crosse

Shane Hanzlik, MD  
MD, University of Nevada  
BS, University of Nevada

Jonathan Macknin, MD  
MD, University of Pennsylvania  
BA, University of Pennsylvania

Jason Solomon, MD  
MD, University of Medicine and Dentistry of New Jersey  
BS, The College of New Jersey

Lorraine Stern, MD  
MD, George Washington University  
BS, George Washington University

Anna Wallace, MD  
MD, University of Tennessee  
BA, University of Tennessee

PGY-4 Residents

Kelvin Lim, MD  
MD, Loma Linda University School of Medicine  
BS, Walla Walla University

Stephen Reichard, MD  
MD, Wake Forest University School of Medicine  
BA, University of North Carolina

Jonathan Streit, MD  
MD, University of Michigan  
BS, University of Notre Dame

Eugene Tsai, MD  
MD, Columbia University College of Physicians and Surgeons  
BS, Northwestern University

Ke Xie, MD  
MD, University of Cincinnati  
BA, Northwestern University

Ashraf Youssef, MD  
MD, University of Virginia  
BS, University of Michigan
CURRENT RESIDENTS

PGY-3 Residents

Christopher Bechtel, MD
MD, New York University School of Medicine
BS, University of Notre Dame

Michael Karns, MD
MD, University of Cincinnati
BS, University of Dayton

Cynthia Nguyen, MD
MD, Baylor University
BS, UCLA

Michael Reich, MD
MD, Vanderbilt University School of Medicine
BA, Washington University

Claire Shannon, MD
MD, University of Rochester
BS, University of Western Ontario

PGY-2 Residents

Andrew Chen, MD
MD, University of North Carolina
MPH, Johns Hopkins University
BS, University of North Carolina

Christina Cheng, MD
MD, SUNY Buffalo
BS, Cornell University

Ronak Desai, MD
MD, Rush University
BS, Illinois Institute of Technology

Sheeba Joseph, MD
MD, Case Western Reserve University
BS, Case Western Reserve University

Sunny Patel, MD
MD, Case Western Reserve University
BA, University of Pennsylvania

Andrew Tsai, MD
MD, University of Minnesota
MSc, Carnegie Mellon University
BS, Carnegie Mellon University

Allen Fellow

William Morris, MD
MD, University of Texas, Southwestern Medical Center
BA, University of Southern California
CURRENT INTERNS – CLASS OF 2018

Christopher Collier, MD
MD, University of Chicago
BA, Miami University

Jeremy Gebhart, MD
MD, Case Western Reserve University
BS, Slippery Rock University

James Kyriakedes, MD
MD, University of Cincinnati
BS, Miami University

Todd Morrison, MD
MD, Jefferson Medical College
BS, Trinity College

Joshua Napora, MD
MD, Penn State University
BSE, Duke University

Ryan Li, MD
MD, University of Pittsburgh
BA, Case Western Reserve University

Douglas Weinberg, MD
MD, Tulane University
BA, Cornell University
Dr. John Wilber was named President Elect of AO International.

Dr. Roger Wilber was named Chairman of the AO North American Musculoskeletal Trauma Education Committee (NAMTEC).

Dr. John Sontich was elected President of the Ohio Orthopaedic Society.

Dr. Michael Reich won first place in the Cleveland Orthopaedic Society Resident Essay Contest for his paper entitled “Genipin Crosslinking as a Potential Alternative Method for Sterilizing Bone Allografts.”

Dr. Jason Solomon took the 1st place Resident Research Award and Dr. Jonathan Streit took the 2nd place Resident Research Award at the Cleveland Clinic Foundation’s 2013 New Technology in Upper Extremity Conference. Dr. Jonathan Streit was also selected to attend the 2013 AAOS/ORS/OREF Clinician Scholar Development Program held at the AAOS headquarters in Rosemont, IL.

Dr. Steven Reichard was named a 2013 Resident Scholar of the American Orthopaedic Foot and Ankle Society.

Dr. Jeremy Gebhart’s abstract entitled “Correlation between sacropelvic parameters and femoroacetabular impingement in cadaveric specimens” was chosen as a “Top Ten Poster” at the 2013 International Society of Hip Arthroscopy (ISHA) Annual Meeting.

Dr. Lorraine Stern was named the 2013 American Orthopaedic Association Resident Leadership Forum participant. She also received the AO North America Resident Research Grant for the 2013-2014 funding year.

Dr. Jonathan Belding attended his daughter Eve Belding’s kindergarten class at the Laurel School where he instructed the students in a casting workshop. Each student got to help cast the extremity (or tail) of their favorite stuffed animal.
Abstract
Osteosarcoma is the most common type of bone cancer and the second leading cause of cancer-related deaths in pediatric patients. Despite conventional treatments such as surgery and chemotherapy, long-term survival rates for patients diagnosed with osteosarcoma have not improved over the last 30 years, likely due to drug-resistant metastasis and disease recurrence. An emerging concept in cancer research is that within a heterogeneous tumor there is a small subset of cells called “cancer stem cells” that are responsible for drug resistance, tumor recurrence and metastasis. This brief review summarizes our current knowledge about cancer stem cells in osteosarcoma, including their potential as a new target for osteosarcoma treatment.

Osteosarcoma
Osteosarcoma, the most common primary bone sarcoma, mainly occurs in children and adolescents. Osteosarcomas usually develop in areas of rapid bone growth or turnover in the long bones, such as the distal femur, proximal tibia, and proximal humerus. In the United States, approximately 600 cases of osteosarcoma are diagnosed per year, making osteosarcoma the fifth most frequent malignancy in 15- to 19-year-olds. Osteosarcoma can also occur in adults over 65 years of age who have rapid bone turnover due to conditions like Paget’s disease. Patients with localized osteosarcoma have a 5-year survival rate of 70% with chemotherapy in combination with surgery. Approximately 30-40% of osteosarcoma patients, however, eventually develop metastases, most commonly in the lungs. The long-term survival rate of osteosarcoma patients with metastases is only 20-30% and has not improved much over the past 30 years. A better understanding of the origin and progression of osteosarcoma is essential for the development of new diagnostic and treatment strategies to increase the long-term survival rate.

The exact causes of osteosarcoma are not completely understood. Growing evidence, however, suggests that osteosarcoma arises from mesenchymal cells, which, like osteoblasts, have the ability to produce osteoid. Osteoblast differentiation from mesenchymal cells is a tightly regulated process that is critical for proper bone formation (Figure 1A). Several transcription factors, such as Runx2, Osterix, and Sox9, are essential for proper osteoblast differentiation. Consequently, if the transcriptional network controlling the lineage differentiation of mesenchymal cells into osteoblasts is disrupted, then tumorigenic precursor cells are likely formed, potentially leading to the development of osteosarcoma (Figure 1B).

Furthermore, inactivating mutations of tumor suppressor genes p53 and pRb are also intimately involved in osteosarcoma development. p53 is a well-known tumor suppressor that is mutated in more than half of primary human tumors. p53 also plays an important role in osteoblast differentiation. Indeed, p53-/- mice exhibited increased bone mass and bone formation, and p53-/- osteoblasts showed accelerated differentiation and up-regulated expression of osteogenic transcription factor Osterix. Moreover, the inhibition of p53 function mediated by oncogenic factor Mdm2 is a prerequisite for Runx2 activation and proper skeletal formation. In recent years, the Osterix-Cre transgenic mouse model, which targets osteoblast precursor cells during development, has been used to generate novel mouse models for osteosarcoma. When both p53 and pRb were deleted using the Osx-Cre mice, osteosarcoma occurred with almost 100% penetrance. Further analysis revealed that osteosarcoma development is likely to be initiated by the loss of p53 and potentiated by the loss of pRb.

Cancer Stem Cell Hypothesis
Heterogeneity is a defining feature of solid tumors. Several factors contribute to this heterogeneity, including genetic mutations, epigenetic changes, interactions with the microenvironment, cellular morphology, and proliferation and differentiation capacity. The cancer stem cell (CSC) hypothesis proposes that a heterogeneous tumor contains a hierarchal organization of cells in which only a small subset called CSCs are responsible for sustaining tumor growth. The first evidence of CSCs came from studies in acute myeloid leukemia (AML). In 1994, Lapidot et al. demonstrated that only a small percentage of AML cells were capable of generating leukemia when transplanted.
Since then, CSCs or CSC-like cells have been identified in several types of cancers, including breast, brain, colon, prostate, and bone.

CSCs are generally defined as tumor cells with stem-like characteristics that are responsible for sustaining tumor growth. Similar to normal stem cells, CSCs have self-renewal potential and differentiation capacity. The CSC division process is also similar to that of normal stem cells. CSCs can divide through either symmetric or asymmetric division, although primarily asymmetric division. During asymmetric division, CSCs divide to produce two daughter cells: an identical CSC with self-renewal capacity and a differentiated progenitor cell responsible for the majority of cell division (Figure 2). The exact origin of CSCs is uncertain. CSCs may arise from either normal stem cells or more differentiated cells that have acquired stem cell-like properties during malignant transformation.

In addition, evidence suggests that CSCs are resistant to cancer therapies such as chemotherapy and radiation. CSCs have several properties that make them resistant to traditional cancer therapies, including enhanced DNA repair ability, quiescence, increased expression of drug efflux transporters, and increased resistance to apoptosis. Traditional cancer therapies, therefore, may reduce the majority of the primary tumor but actually miss the small subset of CSCs. It is possible that CSCs are drug-resistant and consequently responsible for tumor recurrence and metastasis formation. Thus, the development of CSC-targeted therapies is important to prevent primary tumor recurrence and metastasis.

Cancer Stem Cells in Osteosarcoma

Recent studies have identified the existence of CSC-like cells in osteosarcoma. Gibbs et al. were the first to isolate a CSC subpopulation from nine biopsies of untreated osteosarcoma and the MG-63 osteosarcoma cell line using a sphere formation assay. The cells grew in spherical colonies, also called sarcospheres, when cultured with epidermal growth factor and basic fibroblast growth factor under serum starvation and anchorage-independent conditions. The sarcosphere-derived cells had increased expression of the stem cell markers Oct4 and Nanog compared with adherent cells. These sarcospheres were also shown to have the ability to self-renew through the formation of secondary spheres. Several other groups have since confirmed the capability of isolating CSCs expressing Oct4 and Nanog from osteosarcoma using sphere culture. In addition to Oct4 and Nanog, the stem cell transcription factor Sox2 has also been shown to be required for osteosarcoma self-renewal. Using the MG-63 osteosarcoma cell line model, it has been shown that MG-63 spheres also have a higher resistance to chemotherapy drugs and a greater
expression of DNA mismatch repair enzymes than adherent MG-63 cells. To date, sphere culture is the most widely used method for isolating osteosarcoma CSC-like cells. Sphere formation, however, can also occur within non-stem cell populations. Therefore, a more detailed analysis is needed to better characterize and identify osteosarcoma CSCs.

CSC-like cells from osteosarcoma have also been isolated by fluorescent and magnetic cell sorting for CD133+ (prominin), CD117+ (c-kit), and Stro-1+. Tirino et al. identified a small population of CD133+ cells in several human osteosarcoma cell lines with stem-like characteristics including a high proliferation rate and the ability to form spheres in culture. CD117+ Stro-1+ cells have been shown to have increased tumorigenicity when injected subcutaneously into mice, increased metastasis after orthotopic injections, and drug-resistant properties. Recently, Ying et al. used an inverse-lineage tracking strategy coupled with serial human-to-mouse xenotransplantation to identify osteosarcoma cells with CSC-like properties. They found that CD49f− CD133+ cells had CSC-like properties including self-renewal and strong tumorigenicity that correlated with diminished osteogenic fate, while CD49f+ had limited tumorigenicity and more differentiated osteogenic features. High aldehyde dehydrogenase (ALDH) activity has also been used to identify CSC-like cells in osteosarcoma.

In addition to osteosarcoma, CSC-like cells have also been characterized in other sarcomas, including Ewing sarcoma and rhabdomyosarcoma, using sphere formation and marker analysis of CD133 and ALDH. Ewing sarcoma is the second most common malignant bone tumor and, similar to osteosarcoma, is associated with poor prognosis and low survival rates. Suva et al. isolated a subpopulation of CD133+ tumor cells from primary Ewing sarcoma tumors. They showed that these cells were able to initiate and sustain tumor growth through serial transplantation in immunodeficient mice. The CD133+ cells also expressed higher levels of stem cell markers Oct4 and Nanog than the CD133− cells.

One major challenge in the osteosarcoma CSC field is to identify reliable and consensus CSC markers. One reason for the variability among different studies is that the markers expressed by CSC may differ among patients. Thus, putative osteosarcoma CSC markers need to be tested in a significant number of patients to determine how to assign those markers based on the type, subtype, or stage of cancer, as well as how to distinguish tumorigenic cells from non-tumorigenic cells in different tumors. It will also be important to perform lineage tracing studies in order to determine the origin and characteristics of the CSCs that contribute to tumor growth and disease progression.

Yang et al. recently reported what may be the first CSCs discovered in bone in a mouse model. Metachondromatosis is a benign cartilage-tumor syndrome caused by uncontrolled chondrocyte proliferation in humans, resulting from loss-of-function mutations in PTPN11. The authors deleted Ptpn11 in mice and, using lineage tracing studies, identified a population of progenitor cells in the perichondrium tissue layer that surrounds cartilage in long bones. These cells, similar to mesenchymal stem cells, can differentiate into several cell types including osteoblasts, chondrocytes, and adipocytes, in vitro. They have shown that Ptpn11 acts as a tumor suppressor in these CSC-like cells; therefore, the deletion of Ptpn11 initiates the formation of cartilage tumors.
The transcriptional cofactor JAB1 is highly expressed in many different types of cancers, and has emerged as a novel player in tumorigenesis through its effects on cell proliferation, differentiation, survival, and cell cycle progression.38 Our laboratory is studying the potential role of JAB1 in the pathogenesis of osteosarcoma. We have confirmed that JAB1 is highly expressed in biopsy samples of osteosarcoma patients. In addition, JAB1 knockdown in the metastatic 143B osteosarcoma cell-line exhibits significantly reduced cell proliferation, colony formation, and cell-line exhibits significantly reduced cell proliferation, colony formation, and motility, suggesting that down-regulating JAB1 expression in osteosarcoma reduces tumorigenesis. The underlying mechanisms of JAB1 involvement in tumor development, however, remain poorly understood. We have previously shown that Jab1 plays critical roles in the successive steps of skeletogenesis in vivo.39 Further elucidation of the crucial roles of Jab1 in osteoprogenitor cells during skeletal development may provide insights into the effect of JAB1 on key CSC properties, such as stem cell maintenance and renewal, and may eventually lead to the development of JAB1-targeted cancer therapies.

Conclusion
The poor prognosis of osteosarcoma patients is related to drug resistance, and osteosarcoma cancer stem cells are proposed to be at least partly responsible for this drug resistance. The development of CSC-targeted therapy, therefore, can potentially prevent tumor recurrence and increase survival rates of osteosarcoma patients. However, CSC research is still in its infancy, especially for osteosarcoma and other bone cancers, and many challenges still remain. Future research is needed to determine an optimal method for osteosarcoma stem cell identification and isolation, and to further understand the mechanisms of CSC self-renewal, metastasis, and drug resistance.

Acknowledgements
We thank Valerie Schmedlen for editorial assistance.

References


STEREOPHOTOGRAMMETRIC MEASUREMENT OF SMALL WOUNDS

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Abstract
We investigated the hypothesis that three-dimensional stereophotogrammetry (SPG) imaging shows suitable inter-observer reliability and can evaluate the healing pathway of small wounds. 6mm diameter control and ischemic wounds were created in a standardized model employing six month old male Fischer 344 rats. Electrical stimulation (ES) was applied to ischemic wounds using the ISSD, an untethered, independently-powered, integrated surface stimulation device. A secondary occlusive dressing was applied to cover the ISSD and control wound regions. ES was applied for up to 14 days in 75 rats. Eight rats had ISSD devices applied but no stimulation was applied. Wound healing status was assessed using the 3D Lifeviz Micro SPG auto-focusing camera on post-operative day (POD) 1, 7 and 12 or 14. Control and treated ischemic wounds healed over the study timeframe leading to 180 control wound images and 222 ischemic wound images for analysis. Images were analyzed using DermaPix software by two independent raters who reliably determined longitudinal changes in over 75% of control wound images and nearly 80% of ischemic wound images. Intra-rater reliability using Pearson product-moment correlation coefficients for the majority of wound variables were high (r>0.7). Wound volume greater than zero was not well correlated for control or ischemic wounds, and wound perimeter was only moderately correlated for ischemic wounds.

Normalized longitudinal changes were compared between control, ES treated ischemic and untreated ischemic wounds. Ischemic wounds were slower to heal than control wounds. ES treated ischemic wounds showed greater reductions in wound surface area and perimeter than untreated ischemic wounds. ES may promote healing in the same manner as control wounds in the rat; preferentially by lateral contraction.

SPG imaging can track small feature changes, including accurate monitoring of the wound healing pathway. The LifeViz 3D Micro and DermaPix system can minimize inter-rater difference in small wound outcomes measurements and reduce the need for specialized training.

Our current findings support the value of using SPG imaging to quantify small features in pre-clinical models.

Introduction
Preclinical studies are necessary to evaluate novel interventions in wound therapy; however in-vitro studies inadequately represent the clinical wound. It is therefore necessary to utilize appropriate animal models for in-vivo research. In many other fields, small animal models are used to study human disease and disorders.

Chronic wounds are a complex and highly prevalent clinical problem with many confounding factors and causes. If a wound fails to heal within 30 days, the Centers for Medicare and Medicaid Services consider the wound chronic.1 In clinical practice, a wound is considered chronic if it fails to heal within three months.2 Chronic wounds burden both the affected individual and the healthcare providers. Clinical management seeks to restore normal healing pathways which have been disrupted by factors such as tissue ischemia. Rodent models have historically been challenging to implement in pre-clinical studies of chronic wounds, because rodents do not heal in the same way as humans. Our group has employed a modification of the rat ischemic wound model initially developed by Gould et al. to study the effects of electrical stimulation on ischemic wound healing.3,4 This model employs wounds that are initially 6mm in diameter.

In order to monitor the progression of wound healing over time in these small wounds, reliable non-destructive assessment techniques are essential. Quantitative and accurate measurement of wound size is a critical component of comprehensive wound assessment. In addition to being small, these wounds may become irregularly shaped as they heal. A planar digital image with appropriate analytical software may provide information on wound surface area, but cannot inform the clinician about wound depth or texture.

Three-dimensional stereophotogrammetry (SPG) provides the capacity to obtain more comprehensive quantitative...
measurements of wound geometry. The underlying principle of SPG imaging is based on binocular human vision. A stereoscopic camera has two lenses and captures two images of the same object simultaneously at slightly different angles. In the same way as the human brain reconstructs the image from each eye into three-dimensional vision, SPG data analysis reconstructs a 3D region of interest from two SPG images. Use of digital imaging technology provides detailed feature measurements—a significant quantitative advantage over human vision.

Stereophotogrammetry systems have become more cost-effective with recent technological advances in both hardware and software. SPG imaging is gaining popularity in clinical use for the assessment of chronic and acute wounds.5,6,7 Recently, 3D wound measurement using the LifeViz camera with DermaPix software (Quantificare, San Mateo, CA) to analyze wound geometry has been shown to be useful in a clinical setting.8 Davis et al. found that this system could be used with high reliability by multiple observers of varying skill levels. The DermaPix software application was shown to be effective in analyzing the characteristics of large wounds in a clinical setting.

The LifeViz SPG system is also available as the 3D LifeViz Micro, designed specifically for capturing high-resolution SPG images of small features, such as wrinkles, acne lesions, small burns and wounds.8 These capabilities indicate that the 3D LifeViz Micro camera and DermaPix analysis system may be a useful tool for assessing fine features in small animal pre-clinical models.

The goal of the current study was to investigate the hypothesis that stereophotogrammetric imaging shows suitable inter-observer reliability for examining the healing of small wounds in a rat ischemic wound model.

**Methods**

**Intervention and Assessment**

Six month old male Fischer 344 rats weighing 400-450 grams were acclimatized and housed under standard conditions, using procedures and experimental protocols approved by the Case Western Reserve Institutional Animal Care and Use Committee (Cleveland, OH). Normal and chronic, ischemic wounds were created surgically using our modification of the Gould rat ischemic wound model. Using aseptic surgical technique, a bipedicle flap (26x100mm) was created over the dorsum of the rat centered over the spine. The flap dimensions were drawn using a sterile surgical pen. Four 6 mm wounds were then created symmetrically about the midline, 5.0 cm from the base of the scapula using a punch biopsy. Wounds were placed in a line perpendicular to the rat’s spine. The inner two wounds were centered about the spine over the flap region. The outer two wounds were centered 1 cm lateral to the bipedicle flap. The full thickness punch wounds included the skin and panniculus carnosus, but did not include the muscle fascia. Biopsied tissue was resected between the planes of the panniculus carnosus and the muscle fascia. A dorsal, bipedicle flap was then raised deep to the panniculus carnosus and precut, non-reinforced, sterilized medical grade silicone sheeting, 10 mm thickness (Sil-Tec, Technical Products Inc, Decatur, GA) inserted underneath. The skin flap edges and the silicone sheet were sutured to the adjacent skin using interrupted, non-resorbable sutures.5 Electrical stimulation (ES) was applied to the ischemic wounds using the ISSD, an untethered, independently-powered, integrated surface stimulation device developed by our group.10 A secondary occlusive dressing (Tegaderm, 3M Health Care, St Paul, MN) was applied to cover the ISSD and control wound regions. ES was applied constantly for up to 14 days in 75 rats. Eight rats also had ISSD devices applied but no stimulation was applied (negative control).

Wound healing status was assessed

<table>
<thead>
<tr>
<th>Variable</th>
<th>Wound type</th>
<th>r</th>
<th>R²</th>
<th>Standard Error of the Estimate</th>
<th>95% CI</th>
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<tr>
<td><strong>Surface Area</strong></td>
<td>Control</td>
<td>0.95</td>
<td>0.91</td>
<td>6.54</td>
<td>1.06 to 1.18</td>
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<tr>
<td></td>
<td>Ischemic</td>
<td>0.73</td>
<td>0.53</td>
<td>10.41</td>
<td>0.94 to 1.23</td>
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<tr>
<td><strong>Perimeter</strong></td>
<td>Control</td>
<td>0.85</td>
<td>0.72</td>
<td>3.10</td>
<td>0.89 to 1.09</td>
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<tr>
<td></td>
<td>Ischemic</td>
<td>0.63</td>
<td>0.39</td>
<td>3.56</td>
<td>0.92 to 1.32</td>
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<tr>
<td><strong>Average Depth</strong></td>
<td>Control</td>
<td>0.93</td>
<td>0.85</td>
<td>0.12</td>
<td>0.90 to 0.95</td>
</tr>
<tr>
<td></td>
<td>Ischemic</td>
<td>0.85</td>
<td>0.72</td>
<td>0.12</td>
<td>0.80 to 0.88</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>Control</td>
<td>0.95</td>
<td>0.89</td>
<td>6.46</td>
<td>0.99 to 0.96</td>
</tr>
<tr>
<td></td>
<td>Ischemic</td>
<td>0.85</td>
<td>0.73</td>
<td>5.75</td>
<td>0.82 to 0.89</td>
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<tr>
<td><strong>Volume &lt;0</strong></td>
<td>Control</td>
<td>0.96</td>
<td>0.91</td>
<td>5.90</td>
<td>0.94 to 0.97</td>
</tr>
<tr>
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<td>Ischemic</td>
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<td>0.74</td>
<td>5.72</td>
<td>0.82 to 0.89</td>
</tr>
<tr>
<td><strong>Volume &gt;0</strong></td>
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<td>0.10</td>
<td>0.41</td>
<td>0.16 to 0.46</td>
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<tr>
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<td>0.37</td>
<td>0.02 to 0.17</td>
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<td><strong>Rugosity</strong></td>
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<td>0.91</td>
<td>0.09</td>
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<tr>
<td></td>
<td>Ischemic</td>
<td>0.88</td>
<td>0.78</td>
<td>0.09</td>
<td>0.85 to 0.91</td>
</tr>
</tbody>
</table>

Table 1: Inter-rater correlation coefficients for small wound measurement.
using SPG imaging with the 3D LifeViz Micro auto-focusing camera. SPG images of each of the rat’s four wounds were recorded on post-operative day (POD) 1, 7 and 12 or 14. Images were recorded with the wound in the center of the frame, in a landscape orientation with the anterior side at the top of the frame. The 3D LifeViz Micro camera features orientation and distance control using two lasers, one under each lens of the camera. When held at the correct distance from the wound, normal to the wound bed, the lasers project two overlapping circles onto the wound, allowing the user to standardize distance and orientation. All images were uploaded to the DermaPix software for further analysis.

**Wound Image Analysis**

Wound image analysis used the DermaPix imaging software which is a

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**Figure 1:** Relative change in wound surface area.

**Figure 2:** Relative change in wound perimeter.

**Figure 3:** Relative change in wound average depth.

**Figure 4:** Relative change in wound total volume.

**Figure 5:** Relative change in wound volume <0.

**Figure 6:** Relative change in wound rugosity.
component of the LifeViz SPG system. Each unprocessed LifeViz SPG image comprises two 2D images. The right-side image is used to define a region of interest (ROI) around the wound from which DermaPix generates a single 3D reconstruction.

In order to determine wound geometry, the wound margin was traced, allowing DermaPix to calculate several wound variables of interest: perimeter, surface area, total volume, volume above the contour, volume below the contour, maximum depth and rugosity. Surface area is calculated based on the 3D surface curvature of the region surrounding the wound margin. DermaPix software calculates both volume and depth relative to the reconstructed skin surface (where the surface would be if the wound was not present); thus, a wound has a negative volume and depth. A healed wound or scar would have a minimal or positive volume and depth. Measurement outputs for each wound were saved for further analysis.

**Evaluation**

In order to test the repeatability (accuracy) of DermaPix wound image analysis, two independent raters measured all wounds. Both raters had no prior training or experience in wound assessment or digital image processing. They independently received a short training session and then attempted to carry out measurements on all wounds at all time points.

**Data Analysis**

DermaPix output variables were analyzed to determine the intra-rater reliability of the 3D wound measurements obtained. Correlation coefficients were determined for valid data using the Pearson product-moment correlation coefficient.

Longitudinal changes were compared between control wounds, ES treated ischemic wounds and untreated ischemic wounds. Changes in wound variables for each wound were normalized relative to values obtained at POD1 and pooled for each group at each timepoint.

**Results**

Wound images were collected from a population of 83 Fisher 344 male rats. All rats had two control, non-ischemic wounds, 75 rats had two ischemic wounds treated with ES and 8 rats had two ischemic wounds that did not receive treatment. Wound images were obtained at POD1, 7 and 12 or 14. Both control and treated ischemic wounds healed over the study timeframe leading to 180 control wound images and 222 ischemic wound images for analysis.

Rater #1 found 100% of control wound images and 97% of ischemic wound images to be readable. Rater #2 found 78% of control wound images and 90% of ischemic wound images to be readable. On closer review it was found that rater #1 analyzed several control wounds that showed only a scar. In these wounds, volume and depth are very low or zero but surface area and perimeter may still be moderate. Rater #2 had opted not to analyze these healed wounds. Overall, there was good concordance of readable images between the two raters; 78% of control wounds and 87% of ischemic wounds could be directly compared. High correlation coefficients (r>0.7) were found for the majority of wound variables (Table 1). Wound volume greater than zero was not well correlated for control or ischemic wounds, and wound perimeter was only moderately correlated for ischemic wounds.

Longitudinal changes in wound volume greater than zero were not examined due to the poor inter-rater correlation. Data for all other wound variables were pooled and are shown in Figures 1-6. As noted above, the majority of control wounds were healed or very nearly closed by POD12/14. This resulted in 100% decrease in 3D wound variables, specifically wound volume and average depth, although wound surface area and perimeter were less than 100% decreased due to the presence of a measurable scar.

Overall, ischemic wounds were slower to heal than control wounds in the current model. Ischemic wounds treated with ES showed greater reductions in wound surface area and perimeter than untreated ischemic wounds, although changes in wound volume and average depth at POD12/14 were similar. This finding implies that ES treated wounds may heal preferentially by lateral contraction rather than filling from the wound bed. This is similar to the healing geometry of control wounds in the rat.

**Conclusion**

Pre-clinical testing in a small animal model is an important stage in many types of research, before a new drug, treatment, or device can be used in a clinical trial for humans. Experimental treatments designed around the healing of wounds must go through several trials in both small and large animal models before reaching clinical trials in humans. Accurate, reliable measurements of an intervention’s impact on wound healing is essential for pre-clinical trials. Stereophotogrammetry analysis using the DermaPix software gives several advantages over 2D image processing. 3D geometrical analysis reveals the depth or height of a surface feature, feature volume, and 3D true curvature surface area, which may be dramatically different from planar 2D area. Accurate and reliable software can provide important information for wound healing assessment for both clinical and research settings.

In the current study, DermaPix was used to analyze small wounds in a rat ischemic wound model, with an initial wound diameter of 6mm. In pre-clinical settings, reliable wound assessment presents a requirement for greater accuracy because...
absolute changes in wound size can be an order of magnitude smaller than in a clinical wound. Two independent raters reliably determined longitudinal changes in over 75% of all control wound images and nearly 80% of ischemic wound images. Both raters demonstrated similar rates of image usability for calculations. It was found that ischemic wound perimeter measurement had only moderate inter-rater correlation (r=0.63), which may be indicative of the irregular wound shapes observed in these wounds.

The current findings support the hypothesis that the LifeViz 3D Micro and DermaPix software can minimize differences between raters in small wound outcomes measurements and reduce the need for specialized training. DermaPix has already been shown to be a useful tool in the clinic. Our current findings support the value of using SPG imaging in quantifying small features in pre-clinical models.

Limitations
As noted above, wound images were not 100% readable for both raters. In some cases one rater assessed a healed wound that exhibited a small scar. However, in a small number of cases, wound images were unreadable due to the wound being filled with fluid, causing a shiny surface which DermaPix may interpret as a peak.

As found in our clinical study the combination of wound shape and camera orientation can affect the measurements obtained. However, the LifeViz 3D Micro system is designed to minimize the effect of wound orientation by the use of laser beams that must be properly oriented and focused in the center of the wound. In the current study less than 10% of images were invalid or unreadable.

Acknowledgements
The authors would like to acknowledge Chris Chung for image data analysis.

References
BIPOLAR SEALER DEVICES USED IN POSTERIOR SPINAL FUSION FOR SCOLIOSIS REDUCE BLOOD LOSS AND TRANSFUSION REQUIREMENTS: SUMMARY OF A 2 YEAR EXPERIENCE

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Department of Orthopaedic Surgery, Division of Pediatric Orthopaedic Surgery, Case Western Reserve University


Abstract
Reducing perioperative blood loss and the need for transfusions in patients undergoing spinal surgery is important to orthopedic surgeons. Since 2001, at our institution, all pediatric patients undergoing posterior spinal fusion for idiopathic and neuromuscular scoliosis have received epsilon aminocaproic acid (Amicar) during surgery, which we have shown in previous studies significantly reduces perioperative blood utilization. As an effort to further reduce blood loss and transfusions, we began using a bipolar sealer device (Aquamantys®, Salient Surgical Technologies) as an adjunct to traditional monopolar electrocautery. A retrospective review of our first 2 years of experience with this device was performed using a control group of the immediately preceding patients in whom the device was not used. We used a standardized requirement for transfusion in all groups (Hgb <7.0). In posterior spinal fusion for both idiopathic and neuromuscular scoliosis, we found there was a significant reduction in the transfusion requirements in patients where the bipolar sealer device was used (p=0.024 and p=0.001 for idiopathic and neuromuscular scoliosis, respectively).

Introduction
Perioperative blood loss and blood transfusions remain a concern to orthopaedic surgeons involved in caring for patients undergoing spine surgery for scoliosis. Many factors have been associated with the severity of blood loss, including the surgical techniques used, surgical duration, number of levels fused, the use of autograft from other sites (e.g. iliac crest), mean arterial pressure during surgery, and patient positioning.1-6 Past measures aimed at reducing perioperative blood loss and transfusions have been targeted at reducing abdominal compression and vena caval pressure, the use of preoperative autologous blood donation, hypotensive anesthesia, and the use of anti-fibrinolytics.1-8 These measures have had varying degrees of success.

Prior studies at our institution have shown the efficacy of Amicar (epsilon-aminoacproic acid) in reducing blood loss and transfusions in pediatric patients undergoing spine surgery for idiopathic and neuromuscular scoliosis.6,9-11 Currently these patients receive a preoperative bolus along with a continuous infusion of Amicar for the duration of the procedure. This has led to a decrease in the perioperative blood loss as well as the rate of intraoperative and postoperative blood utilization, and therefore less risk of morbidity to the patients and a lower cost to the hospital.6,9,10,12-13

Patients with neuromuscular scoliosis present a particularly difficult situation. Multiple studies have shown an increased risk for large volumes of blood loss and increasing transfusion requirements in this subgroup of patients.14-16 Attempts to optimize these patients with erythropoietin preoperatively have failed to make any difference.17 Therefore, it becomes even more important to effectively control intraoperative blood loss during posterior spinal fusion for neuromuscular scoliosis.

We have continued to investigate new techniques for further reducing perioperative blood loss and transfusions for scoliosis surgery. One such technique is using a bipolar sealer device in addition to standard electrocautery to aid in dissection during posterior spinal fusion. In February 2009, we began using a bipolar sealer device (Aquamantys®, Salient Surgical Technologies) as an additional tool to obtain hemostasis in all cases of posterior spinal surgery. This device uses radiofrequency energy in combination with...
saline irrigation to cause coagulation and sealing of soft tissue and bone at a much lower temperature (<100°C) than standard electrocautery.\textsuperscript{18,19} The use of this device has been reported in the literature for many clinical applications, including orthopaedic oncology\textsuperscript{20}, hip and knee arthroplasty\textsuperscript{18,19,21,22}, liver resection\textsuperscript{23,24}, pulmonary resection\textsuperscript{25}, and spine surgery\textsuperscript{26}. One previous study has shown decreased blood loss and transfusion requirements in patients undergoing fusion for adolescent idiopathic scoliosis\textsuperscript{27}, and other investigators have presented similar results with this type of device at surgical conferences.\textsuperscript{28-30} To our knowledge no peer-reviewed data exists on the device’s effects during fusion for neuromuscular scoliosis.

We conducted a review of our 2 year experience with this device in both neuromuscular and idiopathic scoliosis patients. We postulated that use of this device has decreased perioperative blood loss and transfusion requirements.

**Materials and Methods**

We conducted a retrospective review of our first twenty-five months of use of the Aquamantys\textsuperscript{®} bipolar sealer. Appropriate Institutional Review Board approval was obtained. All patients with a diagnosis of adolescent idiopathic scoliosis or neuromuscular scoliosis who were undergoing a posterior spinal fusion as treatment were included. Patients with early onset scoliosis (age <10 years old), patients requiring an anterior procedure (either staged or same day), and patients with preoperative coagulation abnormalities were excluded from the study group. We identified 49 patients who underwent posterior-only spinal fusion for adolescent idiopathic scoliosis during this time period. One patient was excluded due to a preoperative coagulation abnormality, leaving a total of 48 patients in the investigational group. A control group consisting of the previous 49 patients immediately prior to instating the use of the bipolar sealer device, and who also met the same inclusion criteria, was used for comparison. There were also 51 neuromuscular scoliosis patients identified, and they were compared to the previous 51 patients who underwent fusion without the use of this device.

In both groups, we analyzed age, gender, preoperative height and weight, the Cobb angle of the major curve, the number of vertebrae fused, the type of construct utilized (all pedicle screws versus hybrid screw and hook construct), operative time, and hospital length of stay. Operative time was recorded from the anesthesia log. The intraoperative estimated blood loss was combined with the recorded postoperative drain output to determine the total perioperative blood loss. Estimated intraoperative blood loss was determined by measuring the suction drainage, subtracting any irrigation fluid, and weighing the tapes and sponges. Drain outputs were measured and recorded by the hospital nursing staff on the inpatient unit. The number of autologous and blood bank units transfused either intraoperatively or postoperatively was recorded for all patients. Cell saver suction was used in all cases, and the total volume transfused in the perioperative period was also recorded. The total blood volume transfused was calculated as the total cell saver volume transfused plus the total volume of any autologous or blood bank units transfused.

**Intraoperative Procedure:**

The patients in both groups underwent the same intraoperative technique and postoperative protocol with the exception of the use of the bipolar sealer device in the investigational group. Each patient underwent general anesthesia and endotracheal intubation. Following induction of anesthesia, all patients received Amicar (epsilon-aminocaproic acid) via pump infusion during the procedure. The infusion was discontinued at the time of wound closure.

Patients were positioned prone on the Jackson table. A midline incision was used covering the preplanned levels of instrumentation. The subcutaneous tissues were infiltrated with 1500,000 epinephrine-normal saline solution. The spinous processes were identified and their cartilaginous tips divided with electrocautery. The paraspinal muscles in this area were then infiltrated with the same epinephrine-normal saline solution. The spinous processes, laminae, and transverse processes were thoroughly exposed. Hemostasis was maintained through monopolar electrocautery, and use of the bipolar sealer device as needed in the study group.

Pedicle screw and hook sites were prepared in a standard manner, and all faceted joints were excised. Segmental spine instrumentation techniques were utilized. Rods were secured together with cross-links. Intraoperative spinal monitoring using somatosensory and motor-evoked potential techniques was performed on all patients. Once instrumentation was complete, the exposed areas of the spine were decorticated and morselized bone graft was packed throughout the instrumented area. All patients received cancellous crouten allograft. None of the patients in the study had iliac crest bone graft harvested. The fascia was closed with absorbable sutures and a suction drain was laid on top of the fascia. Skin closure was then completed.

The patients in the study received intraoperative transfusion based on the amount of blood loss and their intraoperative hemoglobin levels as determined by the anesthesiologist. Any blood scavenged and returned to the patient was not subtracted from estimated intraoperative blood loss. The cell saver volume was included in the total blood volume transfused.
**Postoperative Protocol:**
Patients in both groups were managed after surgery in the same manner using our institutional “carepath.” The suction drain was removed the morning of the second day or when the drainage was less than 25mL per eight hour nursing shift. Patients are typically discharged on the fifth postoperative day. Postoperative transfusion was based on hemoglobin levels. If the hemoglobin was less than 7.0 g/dL, then transfusion was performed.

**Statistical Analysis:**
Multiple parameters were compared between the groups using the Mann-Whitney nonparametric test for independent samples. Data analysis was performed with the use of SPSS version 17.0 (SPSS Inc., Chicago, IL).

**Results**

**Adolescent Idiopathic Scoliosis:**
Baseline characteristics between the two groups were similar (Table 1). The bipolar-sealer group had, on average, almost 1 full fusion level greater than the control group. There was no significant difference in operative time between the two groups, however there was a significant decrease in the intraoperative and total perioperative blood loss in the bipolar-sealer group (Table 2). Interestingly, the postoperative blood loss was measured to be greater (by way of hemovac drain output) in the bipolar-sealer group. This finding remained consistent when a subgroup analysis of hybrid constructs (using hooks and screws) and all pedicle screw constructs was performed. Additionally, significantly decreased intraoperative blood loss was seen when the bipolar-sealer was used in both the hybrid constructs (541mL vs. 987mL, p<0.001) and all pedicle screw constructs (691mL vs. 1253mL, p=0.0003).

The transfusion requirements in the idiopathic scoliosis group were decreased significantly by the use of the bipolar-sealer device (Table 3). All patients had their cell saver volume returned to them, and in the bipolar-sealer group this was a significantly lower volume. Total transfusion requirement in terms of autologous and allogenic transfusions (number of units of blood per patient) was 50% lower in the bipolar-sealer group. This difference was statistically significant (p=0.024). Again, subgroup analyses were performed between hybrid and all pedicle screw constructs, the difference in total transfusion requirements remained lower in the bipolar sealer group for hybrid constructs (0.23 units/patient vs. 0.55 units/patient, p=0.04). The difference did not reach statistical significance in the all pedicle screw group (0.32 units/patient vs. 0.61 units/patient, p=0.34).

**Neuromuscular Scoliosis:**
Baseline characteristics between the two groups were similar (Table 4). There was a higher percentage of all pedicle screw constructs in the bipolar-sealer group compared to the control group. No difference in operative time was found, but there was a significant decrease in the intraoperative blood loss when the bipolar sealer device was used (Table 5). Again, we noted significantly higher postoperative blood loss in the bipolar-sealer group compared to the control group. Transfusion requirements in the neuromuscular subset were again found to be 50% lower in the bipolar sealer group.
This difference was significantly different ($p=0.001$). Additionally, when the total number of patients requiring autogenous or allogenic transfusions during or after surgery were compared, the bipolar-sealer group significantly and consistently demonstrated fewer patients needing transfusions (Table 6).

**Discussion**

Minimizing perioperative blood loss and blood transfusions in patients undergoing posterior spinal fusion for scoliosis is an important concept. Since 2001, we have been using Amicar routinely in all spinal fusion procedures for scoliosis to reduce blood loss and transfusion rates. This study demonstrates that even with the drop in transfusions we have previously reported with the use of Amicar, we have continued to decrease our perioperative blood loss and transfusion rate with the addition of a bipolar sealer device during posterior spinal fusion for idiopathic and neuromuscular scoliosis.

Patients who undergo surgery for spinal deformity are subjected to long operations with extensive surgical dissection. Estimated blood loss for spinal deformity procedures in the pediatric population has been reported to be as low as several hundred milliliters to upwards of four liters. Aiming to reduce blood loss in spinal deformity surgery is not a trivial undertaking, as blood transfusions are not without their own complications. Studies have shown that blood transfusions in the perioperative period have been associated with postoperative infections, longer stays in intensive care units, and even a higher mortality rate. Additional complications of transfusions include simple febrile reactions, allergic reactions, acute or delayed immune hemolytic reactions, iron overload, and graft-versus-host disease. Any measure that can effectively reduce the incidence of perioperative transfusions, and subsequently reduce exposing the patient to potential complications, is of value to the individual as well as the hospital and health care system.

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increased drain output postoperatively, those who had the bipolar sealer used during surgery still had a significantly lower total perioperative blood loss and a lower overall rate of allogenic transfusion.

There were several weaknesses of this current study. One would be its retrospective nature. However, due to the large number of these procedures performed at our institution, and the consistency among each surgeon with which they are performed, it would be unlikely that other variables besides the use of the bipolar sealer were a factor. Another potential weakness is the relatively small numbers of patients in the idiopathic scoliosis subgroup analyses. Hybrid constructs, as opposed to all pedicle screw constructs, have become more common at our institution. Even though the total perioperative blood loss and total transfused volume was significantly lower in the bipolar sealer group for all pedicle screw constructs, the difference in transfusion rate did not reach statistical significance in this group. All of these relationships, including the total transfusion rate, were significantly lower in the bipolar sealer group when the hybrid constructs were compared to each other. Finally, there was not a well-defined protocol for use of the bipolar sealer during the procedure. It was opened and set up at the beginning of the procedure, but its use was as an adjunct to monopolar electrocautery and was at the surgeon's discretion during the case.

In conclusion, the use of a bipolar sealer device during posterior spinal fusion for idiopathic and neuromuscular scoliosis significantly lowers total perioperative blood loss and cuts the transfusion rate in half when compared to using conventional monopolar electrocautery alone. Further studies investigating the use of this device in other types of spinal surgery warrant consideration. Ideally, these studies would be prospective and randomized, and would also involve a standardized protocol for use of the device during the procedure. After reviewing our data from the first two years of our experience, we have continued to use this device on all posterior spinal fusion procedures for adolescent idiopathic scoliosis and neuromuscular scoliosis.

References

**Table 5:** Neuromuscular scoliosis operative time and blood loss.

<table>
<thead>
<tr>
<th></th>
<th>Bipolar Sealer (N=51)</th>
<th>Control (n=51)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative Time (min)</td>
<td>360</td>
<td>385</td>
<td>0.091</td>
</tr>
<tr>
<td>Intraop EBL (mL)</td>
<td>741</td>
<td>1052</td>
<td>0.003</td>
</tr>
<tr>
<td>Postop (hemovac) output (mL)</td>
<td>935</td>
<td>642</td>
<td>0.001</td>
</tr>
<tr>
<td>Total EBL (mL)</td>
<td>1676</td>
<td>1713</td>
<td>0.843</td>
</tr>
</tbody>
</table>

**Table 6:** Neuromuscular scoliosis blood utilization.

<table>
<thead>
<tr>
<th></th>
<th>Bipolar Sealer (N=51)</th>
<th>Control (n=51)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop Hgb (g/dL)</td>
<td>13.8</td>
<td>13.7</td>
<td>0.676</td>
</tr>
<tr>
<td>Cell Saver given (mL)</td>
<td>167</td>
<td>158</td>
<td>0.773</td>
</tr>
<tr>
<td>Auto units intraop</td>
<td>0.00</td>
<td>0.04</td>
<td>0.155</td>
</tr>
<tr>
<td>Auto units postop</td>
<td>0.02</td>
<td>0.00</td>
<td>0.317</td>
</tr>
<tr>
<td>Number receiving auto units</td>
<td>1</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>Bank units intraop</td>
<td>0.51</td>
<td>0.96</td>
<td>0.005</td>
</tr>
<tr>
<td>Bank units postop</td>
<td>0.24</td>
<td>0.53</td>
<td>0.01</td>
</tr>
<tr>
<td>Number receiving bank units</td>
<td>26</td>
<td>39</td>
<td>0.013</td>
</tr>
<tr>
<td>Total Transfused Volume (mL)</td>
<td>415</td>
<td>656</td>
<td>0.004</td>
</tr>
<tr>
<td>Total transfusion requirement (units/patient)</td>
<td>0.76</td>
<td>1.53</td>
<td>0.001</td>
</tr>
</tbody>
</table>


PERIPROSTHETIC JOINT INFECTION IN PATIENTS WITH INFLAMMATORY JOINT DISEASE: PERIOPERATIVE MEDICATION MANAGEMENT, DIAGNOSIS, AND THERAPY

Todd A. Morrison, MD1, Mark Figgie, MD2, Andy O. Miller, MD3,4, Susan M. Goodman, MD4

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2 Department of Orthopedic Surgery, Hospital for Special Surgery, New York, NY
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Abstract

Background: Prevention, early identification and effective management of periprosthetic joint infection (PJI) in patients with inflammatory joint disease (IJD) present unique challenges for physicians. Discontinuing disease-modifying anti-rheumatoid drugs (DMARDs) perioperatively may reduce immunosuppression and infection risk at the expense of increasing disease flares. Interpreting traditional diagnostic markers of PJI can be difficult due to disease-related inflammation.

Purpose: This review is designed to answer how to (1) manage immunosuppressive/DMARD therapy perioperatively; (2) diagnose PJI in patients with IJD; (3) treat PJI in this population.

Methods: The PubMed database was searched for relevant articles with subsequent review by independent authors.

Results: While there is evidence to support the use of methotrexate perioperatively in RA patients, it remains unclear whether using anti-TNF medications perioperatively increases the risk of surgical site infections. Serum ESR and CRP can be useful for diagnosis of PJI in this population, but only as part of comprehensive workup that ultimately relies upon sampling of joint fluid. Management of PJI depends on several clinical factors including duration of infection and the likelihood of biofilm presence, the infecting organism, sensitivity to antibiotic therapy and host immune status. The evidence suggests that two-stage revision or resection arthroplasty is more likely to eradicate infection, particularly when MRSA is the pathogen.

Conclusion: Immunosuppression and baseline inflammatory changes in the IJD population can complicate the prevention, diagnosis and treatment of PJI. Understanding the increase in risk associated with IJD and its treatment is essential for proper management when patients undergo lower extremity arthroplasty.

Introduction

Periprosthetic joint infection (PJI) is a serious complication of total joint arthroplasty (TJA). The incidence of PJI is increasing along with the rise in the incidence and prevalence of total joint arthroplasties. According to an analysis of Nationwide Inpatient Sample data from 2001-2010, the incidence of infection following total knee (TKA) and total hip (THA) arthroplasty was 2.4% and 2.0%, respectively. During this time, the annual cost of revisions for infection increased from $320 million to $566 million and is projected to exceed $1.62 billion by 2020.

Of particular concern is a subgroup of patients with inflammatory joint disease (IJD). This group includes patients with rheumatoid arthritis (RA), juvenile inflammatory arthritis (JIA), and spondylarthritis such as ankylosing spondylitis (AS) and psoriatic arthritis (PsA). It has been shown that patients with rheumatoid arthritis (RA) are at a 1.6 times greater risk of revision TKA for PJI with a five-year survivorship rate of 98.9% versus 99.3% for patients with osteoarthritis (OA). Sources for PJI in all patients include hematogenous seeding and contiguous (usually primary surgical site) infection. Contiguous infection is likely due to skin flora and typically occurs within...
three months after arthroplasty, whereas hematogenous seeding can be from a variety of pathogens, often from an abnormal mucosal (oral, GI) or cutaneous site. While *Staphylococcus epidermis* is the leading pathogen in all PJI, a report of 200 PJI cases in RA patients identified *Staphylococcus aureus* (*S. aureus*) as the most common pathogen. A recent comparison of PJI cases caused by either contiguous or hematogenous *S. aureus* infection found that PJI in patients with RA were equally likely to occur via either route. Early case series of patients with PsA reported deep infection rates of 5.5–16.6%. High levels of bacteria reside in psoriatic plaques, including streptococcal and staphylococcal species, which may be the source of the increase in PJI infection.

Once within the joint space, bacteria attach to implants via adherins and multiply to reach a quorum, or predetermined concentration at which they can develop a polysaccharide matrix. This biofilm matrix creates a sophisticated microenvironment that allows bacteria to interact with one another via nanowires and shields them from antibiotics. Biofilms can increase minimal bactericidal concentrations of antibiotics by factors of more than a thousand, to concentrations that are not clinically safe or achievable. Biofilms require variable amounts of time (days to weeks) to grow and become fully established, and it is therefore unsurprising that early diagnosis and treatment of PJI has been associated with improved success of hardware-retention strategies.

Inflammatory joint disease has been identified as an independent risk factor for PJI. Bongartz et al found an overall infection rate of 3.7% in RA patients, with 5.9% of revision arthroplasties complicated by PJI and 30.4% of all infections occurring in joints that had been previously affected by PJI. Both revision arthroplasty and prior PJI were identified as risk factors for PJI. Risk of PJI was only 3.5% if revision arthroplasty surgery was performed in a joint with no prior PJI. Active RA is also a risk factor for infection, and patients with more swollen and tender joints are at higher risk for infection, adding to the conflict between holding and continuing disease-modifying anti-rheumatoid drugs (DMARDs) perioperatively.

Given the need for immunosuppression and baseline inflammatory characteristics of patients with IJD, preventing, diagnosing and treating PJI presents several challenges. The objective of this literature review is to synthesize data in order to optimize the management of perioperative DMARD therapy, the diagnosis of PJI and treatment of PJI in this challenging population.

**Methods**

To answer the questions proposed in this review, the PubMed database was searched for English language publications through September 2012 using the terms “inflammatory arthritis”, “arthroplasty” and “infection”. The initial search returned a total of 1,477 publications of which 1178 were full text articles. These articles were then searched for the keywords “DMARD”, “diagnosis” and “treatment”. The titles and abstracts of the resulting articles were then screened for relevance. Relevant articles included randomized control trials as well as prospective cohort and retrospective studies. A total of 33 relevant articles were identified and were reviewed by the authors.

**Results**

The relevant literature on how perioperative immunosuppressive DMARD therapy should be managed is limited to the RA population. Grennan et al examined the perioperative use of methotrexate in RA patients and found no difference in early or late infection rates between those patients who continued or discontinued drug therapy four weeks prior to surgery. Their initial study demonstrated an increase in disease flares in those patients who stopped methotrexate, leading to the recommendation that this DMARD be continued perioperatively. A 2006 literature review on perioperative DMARDs noted this finding, but was unable to make definitive recommendations on the perioperative use of corticosteroids or other non-biologic DMARDs due to insufficient prospective data. There is also a paucity of high-quality data regarding the perioperative use of biologic DMARDs including anti-tumor necrosis factor (anti-TNF) drugs and interleukin-6 antagonists. A recent retrospective review demonstrated an acute surgical site infection rate of 0.7% in RA patients and identified the use of anti-TNF DMARDs like infliximab or etanercept and longer RA duration as significant risk factors for infection overall. However, anti-TNF therapy was not an associated risk factor for deep surgical site infections. There was no information regarding the interruption of anti-TNF therapy as it relates to rheumatoid flares. The perioperative use of anti-TNF medications in RA patients undergoing lower extremity TJA has been examined in three observational studies which all demonstrated conflicting results. A previous review determined that only one contained high quality data, albeit with low statistical power.

Several diagnostic tests for PJI in patients with IJD have been examined. C-reactive protein (CRP)>1mg/dL and erythrocyte sedimentation rate (ESR)>30mm/hr at a minimum of three weeks postoperatively were found to have inconsistent sensitivities and specificities for the diagnosis of hip and knee PJI in several...
PERIPROSTHETIC JOINT INFECTION IN PATIENTS WITH INFLAMMATORY JOINT DISEASE

studies (Table 1). While patients with connective tissue disorders were included in these studies, they were not analyzed independently from osteoarthritis. One retrospective review of 228 suspected PJI’s found that CRP was more sensitive than ESR when infection was defined by a minimum of one positive intraoperative culture for virulent organisms such as Streptococci species or Gram-negative bacterium or three positive intraoperative cultures for less virulent organisms like coagulase negative staphylococci or propionibacterium species.16 Although other studies17-19 have determined optimal cutoff values for serum ESR and CRP diagnostic for infection, patients with inflammatory arthritis were excluded from the analysis. Despite this, these studies demonstrated the strong sensitivity and specificity of serum ESR and CRP in the detection of PJI. To date, only one study has specifically examined inflammatory markers for PJI in patients with IJD. Cipriano et al recently compared the optimal diagnostic threshold of ESR and CRP values for 61 patients with inflammatory arthritis and 810 patients with non-inflammatory arthritis with suspected chronic PJI and found similar cut off values for each group. Furthermore, serum ESR and CRP had comparable sensitivities, specificities, negative predictive values and positive predictive values for PJI in both inflammatory and non-inflammatory arthritis.20 As expected, they did observe a significantly higher incidence of PJI in patients with IJD. Several synovial fluid markers have also been investigated. Cipriano et al observed that optimal cutoff values for WBC count and polymorphic neutrophil percentage (PMN%) do not differ in patients with underlying inflammatory conditions and that synovial fluid WBC count and differential had the highest sensitivity and specificity for differentiating septic from aseptic failure in patients with inflammatory and noninflammatory arthritis (Table 2).20 However, inflammatory synovitis may similarly elevate these parameters. Given this overlap in values further evaluation for infection in patients with inflammatory arthritis and elevated WBC count and PMN% in the appropriate clinical setting is recommended.

There is limited data regarding the optimal treatment of PJI in patients with IJD. A recent retrospective review of revision TKA in patients with RA describes the outcomes of 1B cases of subacute and chronic PJI.21 Of the twelve patients who received a two-stage revision, five of them subsequently died within six months, while three went on to have failures secondary to reinfection at a mean of 39.6 months. Despite these failures, the mean postoperative Knee Society Score, function score and range of motion significantly improved postoperatively for all patients who had revision for infection. The authors could not report implant survival probability for revision secondary to infection due to relatively few cases; however, implant survival for both mechanical failure and infection was 76.8% at 59 months. It is difficult to make any conclusions about revision TKA for PJI in IJD patients based

<table>
<thead>
<tr>
<th>Article</th>
<th>Joint</th>
<th>ESR Threshold (mm/hr)</th>
<th>CRP Threshold (mg/L)</th>
<th>Management of IJD Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spangehl et al. (1999)</td>
<td>Hip</td>
<td>30 (SN = 82%, SP = 85%)</td>
<td>10 (SN = 96%, SP = 92%)</td>
<td>23 patients with IJD were excluded from analysis</td>
</tr>
<tr>
<td>Baré et al. (2006)</td>
<td>Knee</td>
<td>30 (SN = 63%, SP = 55%)</td>
<td>10 (SN = 60%, SP = 63%)</td>
<td>No mention of how IJD patients were managed during analysis</td>
</tr>
<tr>
<td>Bernard et al. (2004)</td>
<td>Hip &amp; Knee</td>
<td>30 (SN = 87%, SP = 47%)</td>
<td>10 (SN = 97%, SP = 81%)</td>
<td>Included in analysis</td>
</tr>
<tr>
<td>Della Valle et al. (2007)</td>
<td>Knee</td>
<td>30 (SN = 90.2%, SP = 66%)</td>
<td>10 (SN = 95.1%, SP = 75.5%)</td>
<td>Excluded</td>
</tr>
<tr>
<td>Greidanus et al. (2007)</td>
<td>Knee</td>
<td>22.5 (SN = 93%, SP = 83%)</td>
<td>13.5 (SN = 91%, SP = 86%)</td>
<td>Excluded</td>
</tr>
<tr>
<td>Schinsky et al. (2008)</td>
<td>Hip</td>
<td>30 (SN = 97%, SP = 39%)</td>
<td>10 (SN = 94%, SP = 71%)</td>
<td>Excluded</td>
</tr>
<tr>
<td>Cipriano et al. (2012)</td>
<td>Hip &amp; Knee</td>
<td>30 in IJD (SN = 94.4%, SP = 59.9%)</td>
<td>17 in IJD (SN = 93.8%, SP = 70.3%)</td>
<td>Separate and comparative analyses of 61 IJD patients and 810 OA patients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 in OA (SN = 87.2%, SP = 67.1%)</td>
<td>15 in OA (SN = 85.8%, SP = 83.4%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Summary of previous studies examining erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) for the diagnosis of periprosthetic joint infection. IJD = inflammatory joint disease, OA = osteoarthritis, SN = sensitivity, SP = specificity.
on this data alone. A larger case series of 200 RA patients with PJI found rates of five-year survival, defined as time free of treatment failure, for patients with debridement and retention of components, two-stage revision, and resection arthroplasty to be 32%, 79%, and 62% respectively.\(^3\) Patients with younger prosthesis age and shorter duration of symptoms were more likely to be treated with debridement and retention of components while older patients with *S. aureus* infection were more likely to be treated with resection arthroplasty without implantation. Debridement and retention of components had 5.9 times increased risk of treatment failure when compared to two-stage revision. The success of two-stage revision and resection arthroplasty in this case series may be the result of prosthesis removal whereas debridement and retention may provide a continued source of reinfection due to biofilm formation.

### Conclusion

Prevention, early identification and effective management of PJI in the IJD population present unique challenges for physicians. Discontinuing DMARDs perioperatively may reduce immunosuppression at the expense of increasing disease flares. Interpreting traditional diagnostic markers of PJI can be complicated by baseline disease-related inflammation. Eradicating infection can be difficult. The purpose of this review was to answer the following clinical questions; what is the optimal perioperative management of immunosuppressive DMARD therapy, how is PJI diagnosed in this population, and how should PJI be treated in this population?

One of the major limitations of this review is that patients with IJD undergoing lower extremity TJA are inconsistently categorized clearly by diagnosis. For instance, several of the articles classified multiple types of arthritis under a single category of "inflammatory arthritis", while other articles were specific in regard to diagnosis such as RA or PsA, making it difficult to compare and contrast the findings of multiple studies. Despite this, it was possible to enumerate and discuss the major questions of this review using the available literature.

While there is evidence to support the use of methotrexate perioperatively, it remains unclear whether patients with RA using anti-TNF medications perioperatively are at increased risk of surgical site infections compared to patients on synthetic DMARDs or corticosteroids. However, given the devastating consequences of PJI, the

### Table 2: Summary of Previous Studies Examining Synovial White Blood Cell Count and Differential (PMN%) for the Diagnosis of Periprosthetic Joint Infection

<table>
<thead>
<tr>
<th>Article</th>
<th>Joint</th>
<th>Synovial WBC Count Threshold (WBC/μL)</th>
<th>PMN% Threshold</th>
<th>Management of IJD Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spangehl et al. (1999)</td>
<td>Hip</td>
<td>1100 (SN = 20%, SP = 96%)</td>
<td>75% (SN = 24%, SP = 89%)</td>
<td>23 patients with IJD were excluded from analysis</td>
</tr>
<tr>
<td>Kersey et al. (2000)</td>
<td>Knee</td>
<td>2000</td>
<td>50%</td>
<td>&gt;50% PMN seen only in four patients with RA with high rate of false positive</td>
</tr>
<tr>
<td>Manson et al. (2003)</td>
<td>Knee</td>
<td>2500 (SN = 69%, SP = 98%)</td>
<td>60% (SN = 76%, SP = 89%)</td>
<td>Analysis included four patients with IJD, however no conclusions were made</td>
</tr>
<tr>
<td>Tampuz et al. (2004)</td>
<td>Knee</td>
<td>1700 (SN = 94%, SP = 88%)</td>
<td>65% (SN = 97%, SP = 98%)</td>
<td>Excluded</td>
</tr>
<tr>
<td>Della Valle et al. (2007)</td>
<td>Knee</td>
<td>3000 (SN = 100%, SP = 98.1%)</td>
<td>65% (SN = 97.6%, SP = 84.9%)</td>
<td>Excluded</td>
</tr>
<tr>
<td>Schinsky et al. (2008)</td>
<td>Hip</td>
<td>4200 (SN = 84%, SP = 93%)</td>
<td>80% (SN = 84%, SP = 82%)</td>
<td>Excluded</td>
</tr>
<tr>
<td>Cipriano et al. (2012)</td>
<td>Hip &amp; Knee</td>
<td>3444 in IJD (SN = 88.2%, SP = 80.0%)</td>
<td>75% in IJD (SN = 100%, SP = 81.8%)</td>
<td>Separate and comparative analyses of 61 IJD patients and 810 OA patients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3450 in OA (SN = 91.0%, SP = 93.0%)</td>
<td>78% in OA (SN = 95.5%, SP = 87.3%)</td>
<td></td>
</tr>
</tbody>
</table>

*IJD = inflammatory joint disease, OA = osteoarthritis, RA = rheumatoid arthritis, SN = sensitivity, SP = specificity.*
American College of Rheumatology recommends that biologic DMARDs should not be used at least one week prior to surgery, with the possibility of an earlier preoperative cessation as determined by pharmacokinetic half-life, and restarted two weeks postoperatively, once the incision is healed. Use of biologic agents in the perioperative period may have additional consequences caused by masking the normal inflammatory febrile response. Patients on tocilizumab, a humanized anti-IL-6 receptor antibody, may not mount an appropriate inflammatory response to stress or infection, and fail to mount the normal rise in CRP and fever. This may impact wound healing, and may make recognition of acute perioperative events more difficult. In fact, the increase in revisions for infections in RA patients during the first postoperative year may be due to the difficulty in differentiating between RA disease flare and PIJ.

Serum ESR and CRP can be useful for diagnosis of PIJ in this population, but only as part of comprehensive workup that ultimately relies upon sampling of joint fluid. Neither serum ESR or CRP alone is adequate to diagnose or exclude infection, as they vary with disease activity in patients with inflammatory arthritis. C-reactive protein has been shown to have the highest correlation with disease activity in patients with rheumatoid arthritis and ankylosing spondylitis. Additional variability in ESR and CRP levels is seen in early versus late onset RA, although these differences disappear after age-adjustment. Therefore, it is important to keep in mind the natural variability of these parameters. Inflammatory synovitis may similarly elevate these markers and should be considered in cases where no evidence of infection is apparent on culture or histological examination of periprosthetic tissue. While joint aspirate and intraoperative culture have traditionally served as

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**Figure 1:** The American Academy of Orthopaedic Surgeons (AAOS) algorithm for diagnosing periprosthetic knee infection in a high-risk population that includes immunosuppressed patients. The following states are considered indicative of immunosuppression: suppressive medication such as prednisone, infliximab, adalimumab, methotrexate and etanercept, autoimmune diseases (lupus, rheumatoid arthritis, ankylosing spondylitis, Reiter’s syndrome, psoriatic arthropathy), and inflammatory arthritis. Adapted with permission. ESR= erythrocyte sedimentation rate, CRP= C-reactive protein.
the gold standard for diagnosis of PJI, a multicenter study found a relatively high percentage of both false-negative and false-positive cases, regardless of whether or not perioperative antibiotics were received. The study did not assess the utility of microbial culture results in optimizing the antibiotic treatment of PJI. Furthermore, this study excluded patients with inflammatory arthritis and underscores the importance of synovial fluid culture in the IJD population due to the variability in values like ESR and CRP and synovial fluid cell counts for patients with IJD. Therefore, the value of synovial culture may outweigh the risks of false positives. Interpreting the sometimes-conflicting results of multiple diagnostic tests presents a challenge for establishing a definitive diagnosis, regardless of whether a patient has IJD. The Musculoskeletal Infection Society states that an infection exists if any of the following are present: (1) sinus tract communicates with prosthesis or (2) a pathogen is isolated by cultures from two separate tissue samples, or (3) four of six criteria are met including elevated serum ESR and CRP, elevated synovial WBC count, elevated synovial PMN%, purulence in the affected joint, pathogen isolated by culture from single tissue sample, or the presence of greater than five neutrophils per high-powered field at 400 times magnification in periprosthetic tissue. This consensus does not differentiate criteria for patients with IJD. However the AAOS has suggested guidelines for the diagnosis of periprosthetic knee infection in a high-risk population that includes immunosuppressed patients (Figure 1).

Management of PJI depends on several clinical factors including the likelihood of biofilm presence, the infecting organism, sensitivity to antibiotic therapy and host immune status. The evidence suggests that two-stage revision or resection arthroplasty is more likely to eradicate infection, particularly when MRSA is the pathogen. PJI has been divided into four categories based on clinical presentation of infection and its temporal relationship to the index surgery. This treatment algorithm was evaluated in 114 periprosthetic knee infections, and an overall infection control rate of 100% at a minimum of two years was seen with 82% of the first line treatments being successful. Although this study did not include patients with IJD, conservative management with a two-stage revision showed a higher cure rate than any other technique in osteoarthritis patients. In certain clinical situations such as in early/acute infections, or when patients have major comorbidities making them poor operative candidates, retention of hardware can be selected. However it has a lower rate of cure and patients usually require continued infection control and suppression via prolonged oral antibiotics.

Immunosuppression and baseline inflammation in the IJD population can complicate the prevention, diagnosis and treatment of PJI. Understanding the current literature regarding this topic is essential for proper management of patients undergoing lower extremity arthroplasty.

References
joint infection after total hip or knee arthroplasty in rheumatoid arthritis patients treated with nonbiologic and biologic disease-modifying antirheumatic drugs. Mod Rheumatol. 2011;21(5):469-75.


A NEW TOOL FOR ANALYZING THE BIOLOGY
OF THE SKELETON: Prx1CreER-GFP AND
Col1a1CreER-DsRed TRANSGENIC MICE
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Abstract
We recently generated Prx1CreER-GFP and Col1a1CreER-DsRed transgenic mice that allow us to visualize osteochondro-progenitor cells and committed osteoblasts—in vivo. These mice, which express fluorescent proteins in distinct cell populations in the bone, will be useful for analyzing bone cell differentiation under various orthopaedic conditions such as fracture healing. In this review, we will summarize our recent analyses of these transgenic mouse lines.

Introduction
Transgenic mice that express fluorescent proteins under cell-type-specific promoters allow the identification of specific cell populations within the bone. Such mouse models will greatly facilitate the biological analysis of orthopaedic conditions. We recently generated two lines of transgenic mice that express green fluorescent protein (GFP), a fluorescent protein with green fluorescence, and DsRed, a fluorescent protein with red fluorescence, in specific cell populations in the bone. We used a 2.4 kb Prx1 promoter to drive the expression of GFP and CreER under the control of a 2.4 kb Prx1 promoter. CreER is a fusion protein of Cre recombinase and estrogen receptor that allows tamoxifen-inducible gene recombination at theloxP site, a specific DNA sequence recognized by Cre recombinase. The Prx1 promoter was originally reported to direct transgene expression in undifferentiated mesenchymal cells in the developing limb bud. Consistent with the report, our macroscopic observation using the GFP fluorescence demonstrated that the Prx1CreER-GFP transgene is expressed in the developing limb bud during embryonic development. In addition, our histological analysis indicated that the Prx1CreER-GFP transgene is expressed in the developing limb bud during embryonic development. In contrast, both transgenes are expressed in the inner cambium layer of the periosteum after bone formation and in the cranial suture mesenchyme interposing the developing cranial bones. We also isolated GFP-expressing cells and CreER under the control of a 3.2 kb Col1a1 promoter. The 3.2 kb Col1a1 promoter is known to direct transgene expression in immature osteoblasts. We found that the Col1a1CreER-DsRed transgenic mice show DsRed fluorescence in the skeleton elements corresponding to the localization of osteoblasts. Histological analysis indicated that the transgene is expressed in osteoblasts lining the cortical bone and trabecular bone as well as in some of the osteocytes.

Prx1CreER-GFP and Col1a1CreER-DsRed Transgenes Mark Distinct Cell Populations
To further characterize Prx1CreER-GFP- and Col1a1CreER-DsRed-expressing cells, we crossed Prx1CreER-GFP transgenic mice and Col1a1CreER-DsRed transgenic mice and generated Prx1CreER-GFP, Col1a1CreER-DsRed double transgenic mice. Our histological analysis of the double transgenic mice indicated that Prx1CreER-GFP-expressing cells and Col1a1CreER-DsRed-expressing cells are distinct cell populations in the bone. While both transgenes are expressed in the inner cambium layer of the periosteum, the Col1a1CreER-DsRed transgene is expressed in the innermost layer lining the cortical bone. In contrast, Prx1CreER-GFP-expressing cells are localized at a greater distance from the cortical bone surface compared with the Col1a1CreER-DsRed-expressing cells. We also isolated GFP-expressing cells and CreER under the control of a 3.2 kb Col1a1 promoter. The 3.2 kb Col1a1 promoter is known to direct transgene expression in immature osteoblasts. We found that the Col1a1CreER-DsRed transgenic mice show DsRed fluorescence in the skeleton elements corresponding to the localization of osteoblasts. Histological analysis indicated that the transgene is expressed in osteoblasts lining the cortical bone and trabecular bone as well as in some of the osteocytes.
and DsRed-expressing cells from the bone of double transgenic mice by enzymatic digestion followed by flow cytometry. Flow cytometric analysis confirmed the non-overlapping expression of the Prx1CreER-GFP and Col1a1CreER-DsRed transgenes.

**Prx1CreER-GFP and Col1a1CreER-DsRed-expressing Cells Show Distinct Gene Expression Profiles**

We further extracted RNA from each cell population and performed microarray analysis. We identified 497 genes that are differentially expressed between the two cell populations. Our analysis identified a number of osteoblast-related genes that are expressed at higher levels in Col1a1CreER-DsRed-expressing cells. We also found that Prx1CreER-GFP-expressing cells express genes associated with chondrocytes, periosteal cells, and mesenchymal stem cells at higher levels. Real-time PCR analysis further confirmed that Col1a1CreER-DsRed-expressing cells show higher expression of osteoblast markers Runx2, Osterix, Satb2, Col1a1, Spp1, and Ibcp, while Prx1CreER-GFP-expressing cells show higher expression of chondrocyte markers Sox9, Sulf-1, Aggrecan, Hapln1, 4Cyt1-1, and Col2a1, of periosteal markers Asporin, Periostin, and Thrombospondin 2, and of markers associated with mesenchymal stem cells, Cxcl12 (SDF-1), Ly6a (Sca-1), Thy1 (CD90), and Alcam (CD166). Based on the gene expression profile, Prx1CreER-GFP-expressing cells may best be described as undifferentiated mesenchymal cells with the molecular characteristics of periosteal and mesenchymal stem cells, while Col1a1CreER-DsRed-expressing cells can be described as differentiated osteoblasts.

**Chondrogenic and Osteogenic Potential of GFP- and DsRed-expressing Cells**

We examined the chondrogenic and osteogenic potential of Prx1CreER-GFP- and Col1a1CreER-DsRed-expressing cells. For chondrogenic differentiation, each cell population was plated in micromass and treated with BMP2. In Prx1CreER-GFP-expressing cells, BMP2 treatment for 7 days caused a 20-fold and 4-fold increase in Aggrecan and Col2a1 expression, respectively, while the same BMP2 treatment did not induce Aggrecan and Col2a1 expression in Col1a1CreER-DsRed-expressing cells. These results indicate the chondrogenic potential of Prx1CreER-GFP-expressing cells and the lack of chondrogenic potential in Col1a1CreER-DsRed-expressing cells. For osteogenic differentiation, Prx1CreER-GFP-expressing cells were plated in culture and treated with beta-glycerophosphate and ascorbic acid after reaching confluence. After 3 weeks of osteogenic induction, these cells formed mineralized bone nodules as indicated by calcine blue fluorescence and alizarin red staining. The cells in the mineralized nodules showed DsRed fluorescence, indicating that Prx1CreER-GFP-expressing cells differentiated into osteoblasts expressing the Col1a1CreER-DsRed transgene (Figure 3). These results support the notion that Prx1CreER-GFP-expressing cells are precursor cells for Col1a1CreER-DsRed-expressing cells.

**Prx1CreER-GFP-expressing Cells Give Rise To Chondrocytes and Osteoblasts in vivo**

Since Prx1CreER-GFP-expressing cells displayed osteogenic and chondrogenic differentiation in culture, we further examined whether Prx1CreER-GFP-expressing cells differentiate into...
osteoblasts and chondrocytes \textit{in vivo} by inducing Cre-\textit{loxP}-mediated recombination in \textit{Rosa26 LacZ} reporter mice.\textsuperscript{1,2} In this system, X-gal staining allows the identification of cells that are derived from Prx1CreER-GFP-expressing cells. We first crossed Prx1CreER-GFP transgenic mice with \textit{Rosa26 LacZ} reporter mice and induced Cre recombinase activity by tamoxifen injection into the pregnant mother. X-gal staining of the long bones and calvariae showed intense staining in chondrocytes and osteoblasts, indicating that Prx1CreER-GFP-expressing cells differentiate into chondrocytes and osteoblasts \textit{in vivo}.

**Prx1CreER-GFP-expressing Cells Give Rise To Chondrocytes and Osteoblasts in Fracture Callus**

We also examined whether Prx1CreER-GFP-expressing cells give rise to chondrocytes and osteoblasts in the fracture callus.\textsuperscript{1} Tamoxifen was injected into \textit{Rosa26 LacZ}; Prx1CreER-GFP mice and diaphyseal fractures were created in the ulna or femur. X-gal staining of the fracture callus indicated positive staining in some of the chondrocytes in the cartilaginous callus and in osteoblasts lining the bone trabeculae in the newly formed subperiosteal bone. These observations indicate that Prx1CreER-GFP expressing cells differentiate into chondrocytes and osteoblasts in the fracture callus and participate in fracture healing.

**Conclusion**

We recently established two transgenic mouse lines that express GFP and DsRed in distinct cell populations within the bone. In \textit{Col1a1CreER-DsRed} transgenic mice, DsRed is expressed in committed osteoblasts. These cells do not show chondrogenic differentiation even under permissive conditions. In contrast, in Prx1CreER-GFP transgenic mice, GFP is expressed in osteochondro-progenitor cells in the periosteum. Prx1CreER-GFP-expressing cells are capable of differentiating into chondrocytes and osteoblasts \textit{in vivo} and \textit{in vitro}. These cells also participate in fracture healing and give rise to chondrocytes and osteoblasts in fracture callus. Since these transgenic mice can be crossed with any mouse models, the transgenes will be useful for the isolation and visualization of each cell population under various skeletal conditions. Furthermore, the concomitant expression of CreER in these transgenic mouse lines also allows Cre-\textit{loxP} mediated gene recombination in each cell population. These transgenic mouse lines will offer novel approaches for analyzing the biology of the skeleton.

**Acknowledgements**

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**References**


**Figure 3:** Prx1CreER-GFP-expressing cells differentiate into DsRed-expressing osteoblasts. Prx1CreER-GFP-expressing cells were isolated from the calvariae of newborn Prx1CreER-GFP; \textit{Col1a1CreER-DsRed} double transgenic mice by enzymatic digestion followed by flow cytometry. After 25 days of osteogenic induction with ascorbic acid and beta-glycerophosphate, Prx1CreER-GFP-expressing cells formed bone nodules containing DsRed-expressing osteoblasts (right panel).
ATTRITIONAL RUPTURE OF FLEXOR TENDONS DUE TO PISOTIQUETRAL OSTEOARTHRITIS IN A PATIENT WITH PRIOR TRANSVERSE CARPAL LIGAMENT RELEASE: A CASE REPORT

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Introduction
Possible etiologies of attritional flexor tendon rupture of the hand encompass several different causes, including focal as well as systemic pathology, leading to frictional force on the tendon itself. This case report is regarding flexor digitorum profundus tendon rupture of the ring and small fingers due to pisotriquetral osteoarthritis (PTOA); it also proposes a possible correlation of PTOA with prior transverse carpal release.

Case Report
A 77-year-old woman presented to the office with pain and loss of full flexion in her right hand ring and small finger. Four months previously, she had received an intra-operative corticosteroid shot for suspected trigger finger during a right total shoulder arthroplasty. However, she subsequently lost active flexion of her ring and small fingers. She had a history of systemic lupus erythematosus (well controlled on Plaquenil), osteoarthritis, and a non-contributory occupational history. She had had a previous carpal tunnel release in the same hand more than 10 years previously. Physical exam was notable for absent right-hand ring and small finger active proximal interphalangeal and distal interphalangeal joint flexion. Normal passive range of motion was preserved. There was a fusiform area of soft tissue swelling on the ulnar aspect of the volar forearm proximal to the wrist flexion crease that appeared to move with attempted active and passive finger flexion. There was no evidence of a neurologic etiology to her clinical findings. X-Ray of the right hand and wrist demonstrated advanced degenerative changes involving the wrist and thumb with abnormal positioning of the pisiform relative to the triquetrum (Figure 1). Assessment was attritional rupture of the ring and small finger flexor tendons. Surgery revealed rupture of the ring and small finger flexor digitorum profundus (FDP) tendons in the carpal tunnel at the pisotriquetral joint level. There was considerable degenerative change in the pisotriquetral joint with a capsular tear. The pisiform was pronated approximately 90° resulting in exposure of the irregular articular surface to the contents of the carpal tunnel through the capsular defect. The flexor digitorum superficialis (FDS) tendons were intact and encased in proliferative tenosynovium, but had no excursion through this inflammatory mass. Excision of the pisiform and repair of the capsule was followed by the successful transfer of the ruptured ring and small finger FDP tendons to the middle finger FDP tendon.

Discussion
When considering the causes of ulnar FDP tendon rupture in this patient, it is important to relate her history to previously documented causes. Her FDP rupture occurred in Zone IV, the carpal region. Most likely, the nidus of FDP rupture was pisotriquetral osteoarthritis (PTOA). Osteoarthritis of the pisotriquetral joint is well-documented.¹ PTOA presents clinically as point tenderness over the joint as well as crepitus caused by ulnar deviation.² Bony irregularity in this process can cause significant pain even without function loss; excision of the pisiform often yields resolution of symptoms.³,⁴ The FDP tendons are most at risk for injury following development of PTOA due to their close proximity to the pisotriquetral joint.⁵ Lutz et al, Takami et al, Saitoh et al, and Grant et al have all documented the clinical, radiographic, and physical concordance of PTOA and rupture of the ulnar-most FDP tendons, always of the fifth digit and usually of the fourth as well.⁵,⁶,⁷,⁸ These authors do not attempt to propose an etiology of PTOA. A paper by Stahl et al implicates the transverse carpal ligament (TCL) in the development of PTOA. Anatomically the TCL is a carpal arch stabilizer, which attaches to the pisohamate and pisometacarpal ligaments; incision of the TCL may cause...
instability in the pisiform, which is functionally a sesamoid bone without strong connection to the rest of the wrist joint. This patient had had previous carpal tunnel surgery, which may have caused or predisposed her to PTOA and lead to attritional rupture of her FDP tendons. It should be noted that a cadaveric study by Rayan et al analyzed the pisotriquetral joint and determined that the primary joint stabilizers were the pisohamate, pisometacarpal, and ulnar pisotriquetral ligaments; this study asserted that the TCL is a secondary stabilizer and has only minor influence on the joint. However, it is still not clear if release of the TCL leads to degenerative stress on the primary stabilizers. This prior procedure may have allowed the pisiform to pronate and could have contributed to this patient’s pathology. It is important for the clinician to document the development of PTOA in patients with wrist pain following TCL release. In the future, enough evidence may surface to warrant osteoarthritic pisiform excision as prophylaxis against attritional tendon rupture.

References

Figure 1 - AP X-Ray of the right wrist showing misalignment of the pisiform (P) in relation to the triquetrum (T) and osteoarthritic change in the pisotriquetral joint (white arrow).
LONG-TERM RESULTS AFTER LATERAL RETINACULAR RELEASE

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Abstract

Purpose: To determine long-term patient satisfaction and self-rated functional outcomes after isolated arthroscopic lateral retinacular release (LRR) in patients with patellofemoral pain related to lateral patellar compression syndrome with and without patellofemoral degenerative changes.

Methods: Twenty-nine patients (33 knees) were retrospectively reviewed at an average of 9.5 years after an arthroscopic LRR for lateral patellar compression syndrome. Patients were grouped according to the severity of articular cartilage injury in the patellofemoral joint: Group 1 - Grade 0-II chondrosis; Group 2 - Grade III-IV chondrosis. Patient-rated pre-operative function, current function, satisfaction with the surgery outcome, and IKDC scores were evaluated.

Results: Patient satisfaction was excellent or good in 90% of the knees in Group 1 and in 93% of the knees in Group 2. Function improved significantly in both groups (p < 0.001). IKDC scores were significantly higher in Group 1 than in Group 2 (p < 0.03). Functional outcome worsened with time in Group 2 but not Group 1 (p < 0.003). Age did not correlate with IKDC scores or functional improvement.

Conclusions: Arthroscopic LRR for patients with lateral patellar compression syndrome can provide a high satisfaction rate and long-term functional improvement.

Introduction

Anterior knee pain is a common reason for patients to seek treatment from an orthopaedic surgeon. It can result from mal-alignment, patellofemoral instability, post-traumatic arthritis and degeneration of the cartilage in the patellofemoral joint, or it can develop from no identifiable cause.1 Fortunately, regardless of the source, physical therapy focusing on quadriceps strengthening, bracing, orthotics, weight loss, and cortisone injection is successful in 80% of patients.2 Surgical release of the lateral retinaculum, whether open or arthroscopic, may provide relief of symptoms for those that have failed conservative treatment.3 However, the indications for performing a lateral retinacular release (LRR) are still debated.

Clinical results after an LRR are inconsistent and largely depend upon the etiology of pain and dysfunction. In general, an LRR is discouraged as an isolated procedure to treat patellar instability because of poor results, especially over time.4,5 Currently, an accepted indication to perform an isolated LRR is the presence of anterior knee pain unresponsive to at least 3 months of physical therapy in a patient with excessive lateral patellar compression due to a tight lateral retinaculum. A tight lateral retinaculum manifests as negative patellar tilt not reducible to neutral tilt and less than 50% medial patellar glide. It is still not clear how an isolated LRR affects long term patient satisfaction and functional improvement in patients with lateral patellar compression syndrome. It is also not clear what factors influence outcomes in these patients.

The purpose of this study was to determine the long term (greater than 5 years) patient satisfaction and self-rated functional outcomes after isolated arthroscopic LRR for patients with patellofemoral pain related to lateral patellar compression syndrome. In addition, our goal was to clarify what factors correlate to a lower patient-rated satisfaction and poorer functional improvement after an LRR. We focused our interest specifically on the severity of articular cartilage degeneration and how it affected patient reported outcome. Our hypothesis is that more advanced cartilage degeneration predicts less patient-reported satisfaction with the procedure and poorer functional outcome.

Methods

We retrospectively identified ninety-eight patients (108 knees) who had undergone an arthroscopic LRR, either as a single procedure or as part of a proximal/distal realignment, by a single surgeon (BNV) between 1995 and 2003. After initial screening, we identified patients who had an LRR as a single procedure for symptoms consistent with lateral patellar


compression syndrome. Lateral patellar compression syndrome was defined as the presence of negative patellar tilt that was not reducible to neutral or positive tilt with direct manipulation with the knee in extension and less than 50% of medial patellar translation. We excluded patients who had a concomitant proximal or distal re-alignment procedure, medial patellofemoral ligament reconstruction, or patellofemoral microfracture or abrasion chondroplasty. We excluded patients with a history of patellar dislocation, physical exam findings suggestive of patellar instability, generalized ligamentous laxity, and greater than 50% of medial or lateral patellar translation. We also excluded patients who had advanced cartilage degeneration (Outerbridge Grade III or IV) in the medial or lateral compartments identified at the time of arthroscopy to reduce skewed results caused by associated degenerative changes in the tibial-femoral articulation. Lastly, we excluded patients with ligamentous injury or associated meniscal pathology. Prior to surgery, all patients who were included in the analysis had patellofemoral pain treated with rest, anti-inflammatories, and physical therapy for a minimum 3 months and exam findings consistent with lateral patellar compression syndrome. Institutional review board (IRB) approval was obtained to conduct this research.

We identified 46 patients (51 knees) from the chart review who fit our inclusion criteria. Of these 46 patients, 15 had no available contact information and 2 declined participation in the study. This left 29 patients (33 knees) who were available for analysis with an average follow-up of 9.5 years (range 6 to 14 years). The knees of the patients who were available for follow-up were divided into two groups based on the severity of cartilage degeneration of the patella or femoral trochlea seen at the time of surgery. The articular cartilage was classified according to the Outerbridge classification. Patients were assigned to Group 1 if they had no chondrosis or mild chondrosis (Outerbridge grade 0-II) on any part of the patella or femoral trochlea. Patients were assigned to Group 2 if they had moderate to severe chondrosis (Outerbridge grade III-IV) on any part of the patella or femoral trochlea. There were 17 patients (20 knees) assigned to Group 1 and 12 patients (13 knees) assigned to Group 2. The average follow-up in Group 1 was 9.8 years and the average follow-up in Group 2 was 9.1 years.

The patients in both groups were asked to rate their overall satisfaction with the outcome of their surgery for each knee (if applicable). They were also asked to rate their pre-operative and current function on a scale from 0-10 with 0 indicating an inability to perform daily activities and 10 representing no limitations in daily activities. Lastly, they were asked to complete an International Knee Documentation Committee (IKDC) subjective knee survey. The functional outcome scale is included in the IKDC subjective knee survey. The results in Group 1 and Group 2 were evaluated for differences in patient-rated satisfaction, functional outcome, and IKDC scores. Additionally, body mass index (BMI) was calculated for each patient. The effect of BMI, age, and time since surgery were analyzed to see if these variables had any influence on functional outcome and IKDC scores.

**Surgical technique**

Standard anterolateral, anteromedial, and superolateral portals were created. A diagnostic arthroscopy was performed through the anterolateral portal in order to document the presence and severity of chondrosis in the patellofemoral articulation, the medial and lateral compartments, and any associated meniscal or ligament injury. Then, the patellofemoral articulation was evaluated through the superolateral portal with a 70-degree arthroscope. While viewing through the superolateral portal, all patients demonstrated lateral patellar tracking under direct visualization with failure of the patella to centralize by 60 degrees of knee flexion. The arthroscopic LRR was performed with an ArthroCare radiofrequency hook (Austin, Texas) placed in the anterolateral portal. The lateral retinaculum was released starting at the level of the superior pole of the patella and extended distally to the lateral portal. If the patella did not centralize by 30 degrees of knee flexion, the release was extended further distally to the level of the tibial tubercle. Supplementary procedures such as proximal and/or distal realignment procedures were done if the patella failed to centralize by 30 degrees of knee flexion after the extended release. Those needing supplementary procedures were not included in this study. The criteria indicating that an adequate release had been performed included 60 degrees of positive lateral patellar tilt, 50% medial patellar translation, and a centralized patella by 30 degrees of knee flexion.

**Post Operative Protocol**

During the first week, patients wore a knee immobilizer and were permitted full weight-bearing as tolerated. At one week post operatively, all patients were referred to physical therapy with a standard protocol. The immobilizer was discontinued as soon as protective quadriceps function returned. Therapy was initiated with active progression of motion as tolerated, quadriceps isometrics, and passive patella mobilization. By four weeks post-operatively, all patients were progressed to stationary bicycling as tolerated and closed kinetic chain quadriceps strengthening. Therapy goals were full motion, prevention of atrophy, normal gait, and maintenance of a positive passive lateral patellar tilt.

**Statistics**

Statistical analysis was performed by a Ph.D. statistician. A post-hoc power analysis was performed based on the functional
improvement variable to account for potential beta error. To obtain 80% power, 37 patients both in Groups 1 and 2 were needed to detect a 2 point change in functional improvement with a significance level set at 0.05. Wilcoxon signed ranks test was used to compare the change in functional outcomes in patients within Groups 1 and 2. The Mann-Whitney U-test was used to compare differences in functional improvement between Groups 1 and 2. A Student t-test was used to compare body mass index (BMI), age, and IKDC scores between Groups 1 and 2. A linear regression analysis was used to determine whether BMI, age, and time since surgery influenced IKDC scores or functional improvement.

Results
All patients in this series demonstrated degenerative changes in the central or lateral patella or trochlea. None of the patients had medial patellar or trochlear chondromalacia. The average age at the time of surgery in Group 1 was 24.6 years, and the average age in Group 2 was 40.6 years. There was a significant difference in age between Group 1 and Group 2 (p < 0.001). The average BMI was 25.7 in Group 1, and 31.8 in Group 2. There was a significant difference in BMI between Group 1 and Group 2 (p < 0.02).

Patient Satisfaction
Overall, patients rated their satisfaction with the outcome of their lateral retinacular release as “very satisfied” (58%) or “satisfied” (33%) in 30 of 33 knees (91%), “somewhat dissatisfied” in 1 of 33 knees (3%), and “very dissatisfied” in 2 of 33 knees (6%) (Figure 1A). In Group 1, patients rated their satisfaction with the outcome of their lateral retinacular release as “very satisfied” (55%) or “satisfied” (35%) in 18 of 20 knees (90%), “somewhat dissatisfied” in 1 of 20 knees (5%), and “very dissatisfied” in 1 of 20 knees (5%) (Figure 1B). In Group 2, patients rated their satisfaction with the outcome of their lateral retinacular release as “very satisfied” (62%) or “satisfied” (31%) in 12 of 13 knees (93%) and “very dissatisfied” in 1 of 13 knees (7%) (Figure 1C). Four patients in Group 2 eventually had total knee replacement an average of 11.7 years (range 10-14 years) after their lateral retinacular release. Of those four patients, two were “very satisfied,” one was “satisfied”, and one was “very dissatisfied” with the outcome of their lateral retinacular release.

Self-rated Functional Improvement
Patients rated their pre-operative function and their current function. In Group 1, the average pre-operative rating of function was 3.9 (range 0-10). The average current function was 8.9 (range 5-10) (Figure 2). There was a significant difference in pre-operative and current function self-rating (p < 0.001). In Group 2, the average pre-operative rating of function was 2 (range 0-5). The average current function was 7.5 (range 5-10). There was a significant difference in pre-operative and current function (p < 0.001) (Figure 2). The average current function results do not include the patients who underwent a total knee replacement. The distribution of functional improvement in Group 1 was more varied between patients than in Group 2 (Figure 3A and 3B). There was no significant difference in functional improvement between Group 1 and Group 2 (p > 0.5) (Figure 4). There were no complications in either treatment group.
The average current IKDC score was 77 (range 46-100) in Group 1 and 60 (range 26-96) in Group 2. The average current IKDC scores in Group 2 did not include patients who had undergone a total knee replacement. There was a significant difference in the average current IKDC scores between Group 1 and Group 2 (p< 0.03) (Figure 5).

**Is BMI associated with IKDC scores and functional improvement?**

A linear regression analysis was performed to assess if there was any association between BMI and worse IKDC scores or functional improvement rating. There was no significant association between BMI and IKDC scores in Group 1 (p< 0.2) or in Group 2 (p> 0.5). There was a significant association between BMI and poor functional improvement rating in Group 1 (p<0.003) but not in Group 2 (p<0.2).

**Is age associated with IKDC scores and functional improvement?**

A linear regression analysis was performed to assess if there was any association between age and worse IKDC scores or functional improvement rating. There was no significant association between age and IKDC scores in Group 1 (p> 0.5) or in Group 2 (p> 0.5). There was no significant association between age and functional improvement rating in Group 1 (p<0.3) or in Group 2 (p<0.2).

**Is time since surgery associated with IKDC scores and functional improvement?**

A linear regression analysis was performed to assess if there was any association between time since surgery and worse IKDC scores or functional improvement rating. There was no significant association between time since surgery and IKDC scores in Group 1 (p> 0.5) or in Group 2 (p> 0.5). There was a significant association between time since surgery and poor functional improvement rating in Group 2 (p<0.02) but not in Group 1 (p > 0.5).

**Discussion**

Anterior knee pain related to lateral patellar compression syndrome is a common and challenging problem to treat, particularly in patients who have persistent pain despite non-operative treatment. Our results demonstrate
LONG-TERM RESULTS AFTER LATERAL RETINACULAR RELEASE

that an LRR in the carefully selected patient has potential to provide sustained improvement in overall function of the affected knee and result in a high level patient satisfaction. Not unexpectedly, patients with advanced chondrosis in the patellofemoral joint reported lower overall knee function and lower IKDC scores than those with only mild chondrosis. However, patients with advanced chondrosis still reported high satisfaction with the outcome of their surgery and reported very consistent improvement in overall function of their knee after surgery. Furthermore, three of the four patients who eventually had a total knee replacement rated their satisfaction with the surgery as “satisfied” or “very satisfied” suggesting that the procedure provided enough pain relief to postpone the need for knee replacement. As expected in patients with more advanced degenerative joint disease, the length of time since surgery correlated with a worse functional outcome.

The results from previous studies looking at the results after an LRR have been difficult to compare due to differences in patient selection, methods of evaluation, and length of follow-up. Some studies have included patients with both patellofemoral pain and patellar instability. Osborne and Fulford reported outcomes after an open lateral release in 75 military servicemen and women with patellofemoral pain. They reported a good result if the patient was able to return to service or athletics and a poor result if there was no relief of symptoms. They reported 60% good results at three years for those with Grade I or II chondromalacia and poor results in all 5 patients with Grade III or IV chondromalacia. They did not report etiology of the pain. Aglietti et al also suggested patients with grade-II or less chondromalacia benefited from an LRR. Their patient population however was heterogeneous and included those with patellar instability, anterior parapatellar pain, and patellofemoral arthritis. Gerbino et al reported that 78% of adolescents undergoing a lateral release for maltracking and patellar instability did not need any further operations with greater than 5 year follow-up.

Clinical results in more focused patient populations also vary. Grana et al reported the results of LRR in 43 knees with patellar mal-alignment and no evidence of instability. All patients in this series reported that their activities were limited by anterior pain had unsatisfactory pre-operative function. At an average 2.5 years after surgery follow-up 39 of 43 had satisfactory return of function. There was a limited discussion of results related to the degree of patellofemoral degeneration and the follow-up period was short. Ogilvie-Harris and Jackson followed 319 patients for 5 years after an LRR. Of the 319 patients, 56 patients had an LRR for maltracking. A good result was defined as no symptoms and return to unrestricted activity. A bad result was defined as the presence of any symptoms that led to a decrease in activity. They showed that the results were related to the degree of chondromalacia (Grade I - with 85% good results, Grade III 20% good results). Korkala et al reported that patients with arthroscopically-diagnosed grade II to grade IV chondromalacia improved with LRR at 35 months, although their results did not reach statistical significance. Panni et al reported satisfactory outcomes in 70% of patients with lateral patellar compression syndrome reported after 5-12 years. Lastly, Adirinto and Cobb reported on 50 patients who had an LRR for patellofemoral arthritis. This study excluded patients with a tight lateral retinaculum pre-operatively, mal-alignment and instability. At an average follow-up of 2.5 years, 85% had improvement in pain and only 56% were “very satisfied” or “satisfied” with the outcome of their surgery. These results may be skewed by the inclusion of patients who also had degenerative joint disease in the medial and lateral compartments. These studies suggest that greater degrees of chondromalacia predict a poorer outcome but they used stringent criteria for a good result that may not apply to all patients and activity levels.

Our study differs from many others in that we only included...
patients with specific symptoms and physical exam findings consistent with excessive lateral patellar compression and excluded patients with degenerative changes in the medial and lateral compartments. In addition, we assessed outcomes using patient satisfaction rating and a continuous variable functional rating scale so that improvements could be detected even if patients did not return to full activities. We chose to assess functional improvement as our outcome variable rather than pain since we expected that more significant pain would influence changes in functional improvement. This study is unique in that it evaluates the outcomes after LRR in patients with isolated patellofemoral disease which minimizes the confounding factors of medial and lateral compartment osteoarthritis on outcomes. It also is unique in that it shows that an LRR has good long term patient satisfaction regardless of the severity of osteoarthritis and the need for arthroplasty. It also shows that although not perfect, activity level or function can be improved in many patients after this surgery.

Patients with no chondrosis or only mild chondrosis also reported good satisfaction with the outcome of their surgery. They had higher pre-operative and current functional outcomes and higher IKDC scores than those with more advanced degenerative changes. However, there was more variability in their rating of functional improvement compared to those with more advanced chondrosis. This is, in part, explained by the fact that several patients started with pre-operative functional ratings of 8-10 and they could not improve more than one or two points. This highlights a potential ceiling effect of this rating scale. In addition, patients with a higher BMI had worse functional outcomes in this group. The fact that BMI influenced the results from Group 1 but not Group 2 could result from the fact that we were under-powered to detect a difference, given the small number of patients in the Group 2 cohort.

The limitations of this study are inherent to a retrospective review. First, the study population is small in number and 17 knees (35%) were lost to follow-up. The results in these patients, if known, may have influenced the results. Also, because of the small number of patients in this series, it is possible that findings not reaching statistical significant are suffering from beta error. Therefore, we have focused our discussion on those findings that were found to be significant. Second, there is no pre-operative objective (IKDC scores) or subjective data (functional rating) to compare with current outcome measures. The post-operative assessment of pre-operative function is subject to recall bias that may not accurately reflect true patient function prior to surgery. Also, there is no information regarding the function of those who went on to total knee arthroplasty. This may skew the results towards a more favorable outcome in group 2. However, it is clear that most of the patients recall severe limitations in their activities related to their knee that improved significantly after surgery and greater than 90% of patients in both groups were satisfied with their outcome after surgery.

In conclusion, our findings indicate that arthroscopic LRR for patients with lateral patellar compression syndrome, with and without advanced chondrosis isolated to the patellofemoral joint, can provide a high satisfaction rating and long-term functional improvement if the release can provide 60 degrees of positive lateral patellar tilt, 50% medial patellar translation, and a centralized patella by 30 degrees of knee flexion.

References
RETENTION VERSUS REMOVAL OF A UNICORTICAL PLATE USED AS A REDUCTION AIDE FOR INTRAMEDULLARY NAILING OF PROXIMAL EXTRA-ARTICULAR TIBIA FRACTURES

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Abstract

Introduction: Intramedullary devices have become a common method of fixation for extra-articular proximal tibial shaft fractures. Several techniques have been published to help prevent malreduction when intramedullary nails are used including the use of a unicortical plate at the fracture site. However, no series to date has examined whether or not this plate should be removed at the end of the case. The main aim of this study was to determine if retention versus removal of the unicortical plate at the end of the case would affect the rate of nonunion. We hypothesized that there would be an increased rate of nonunion in those cases in which the plate was retained.

Methods: A retrospective review was carried out of all extra-articular proximal tibial shaft fractures that were treated at our Level I Trauma Center between January 1, 2002 and December 31, 2010 with an intramedullary nail. The operative reports of all patients were reviewed to determine if a unicortical plate had been utilized as a reduction aide. The medical record and imaging for each eligible patient was reviewed to record demographic data as well as to determine time to union, the primary outcome measure in this study. Statistical analysis was done with a Fisher’s Exact Test with significance set at p<0.05.

Results: There were 225 fractures treated with an intramedullary nail. In 37 of these cases, a unicortical plate was utilized to obtain the reduction. In 11 instances, the plate was retained and in 26 cases the plate was removed at the conclusion of surgery. All injuries were sustained from a high energy mechanism of injury. Seventy eight percent of these fractures were open injuries, 93% of which were classified as Gustilo-Anderson type IIIA or IIIB. There was no significant difference in the rate of nonunion between the retained and the removed group (p=0.454). There was only one malunion in the retained group; the fracture healed in valgus and procurvatum.

Conclusion: There was no significant difference in the rate of nonunion between retention and removal of a unicortical placed used for reduction in a series of high energy extra-articular proximal tibia fractures treated with an intramedullary nail. This is limited by the fact that the sample size represented here is small. It is interesting to note that the only malunion occurred in the retained group. A larger multi-center series would be necessary to determine if retention of the unicortical plate truly has a significant effect on the rate of malunion.

Introduction

Extra-articular proximal tibial shaft fractures comprise approximately 5-11% of all tibial shaft fractures. Unlike mid-shaft tibia fractures, they are more difficult to treat because of their short, intact proximal fragment as well as their meta-diaphyseal nature. They are also associated with a higher incidence of fracture-related complications including soft tissue compromise, arterial injury and compartment syndrome. Numerous different treatment options are available to treat these fractures including closed treatment, external fixation, intramedullary nailing and plating. Intramedullary nailing has several advantages including load sharing rather than load bearing, limited exposure near the fracture site, preventing further compromise to the soft tissue envelope, sparing of the extraosseous blood supply, and familiarity to the surgeon as it is commonly used to treat diaphyseal fractures.

However, use of an intramedullary device for these proximal fractures can be difficult and may ultimately lead to malunion in the form of valgus angulation, apex anterior deformity and residual displacement at the fracture site. This is secondary to the deforming forces at the fracture site. The apex anterior deformity is caused by the pull of the patellar tendon on the proximal...
piece into extension and the pull of the hamstrings and gastrocnemius on the distal piece into flexion. This deformity is amplified when the knee is flexed for standard intramedullary nailing. Valgus deformity occurs secondary to the deforming forces caused by the pes anserinus tendons and the anterior compartment musculature of the leg. Reports in the literature have noted malalignment rates in proximal meta-diaphyseal tibia fractures to be as high as 44%-84% as compared to 7%-8% for mid-diaphyseal and distal tibial shaft fractures. As a result of the high incidence of malalignment using standard intramedullary nailing for these fractures, several techniques have been published to help with reduction. These include using a proximal and lateral starting point, use of a semi-extended position for insertion of the nail, insertion of blocking screws, use of an external fixator to facilitate reduction, and provisional fixation with a unicortical plate.

The main focus of this study was the use of a unicortical plate for provisional fixation when using an intramedullary nail. When this technique is employed, a short small fragment plate is placed anteriorly, anteromedially or posteromedially and secured to the proximal and distal fragments with at least two unicortical screws. This secures a provisional reduction and offsets the tendency for apex anterior and valgus malalignment. Although it has been demonstrated in the literature to be an effective and reliable tool in assisting in the prevention of malalignment, it does come at the expense of further disruption of the soft tissue envelope.

One thing that remains unclear in the literature is whether this plate should be removed at the conclusion of surgery or left in place. Furthermore, it has yet to be determined what effect, if any, this decision has on outcome, specifically on fracture union. The concern with retention of the plate is that it will create too stiff of a construct at the fracture site, ultimately impeding secondary bone healing usually achieved with the relative stability provided by the intramedullary device. The goal of this study was to determine if there was a significant difference in the rate of nonunion in those proximal tibial shaft fractures that were treated with an intramedullary nail and a unicortical plate in which the plate was retained versus removed at the conclusion of surgery. Our hypothesis was that those patients who retained the plate would have a higher rate of nonunion.

### Materials and Methods

This study was a retrospective review utilizing consecutive patients from the trauma database at a Level I Trauma Center who were treated between January 1, 2002 and December 31, 2010. The initial search criteria for the database included patients over the age of 18 years old who had sustained fractures classified by the AO-OTA classification as 41-A2, 41-A3, 42-A, 42-B or 42-C that were treated with an intramedullary nail. The available operative reports, injury films and operating room imaging of all identified patients were reviewed for inclusion in the final study population. Patients were included only if a unicortical plate had been utilized as a reduction aide. Exclusion criteria included use of other reduction aides or nailing techniques, ipsilateral intra-articular proximal or distal tibia fractures, and open physes on imaging. After the eligible patients were identified, the medical record for each patient was reviewed further to obtain information on the mechanism of injury, Gustilo-Anderson type for open fractures, additional injuries that were sustained at the time of the initial trauma, medical comorbidities, smoking status and post-operative complications. All available follow up imaging was reviewed to establish time to union and degree of malunion if present.

The main outcome measure for this study was time to union as defined as the time in months postoperatively at which bridging bone was visible across the fracture site.

<table>
<thead>
<tr>
<th>Table 1: Demographic data. (MVC – motor vehicle collision, MCC – motorcycle collision, ATV – all-terrain vehicle)</th>
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<tbody>
<tr>
<td><strong>Retention</strong></td>
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*Other: gunshot wound, crush injury, assault
three of four cortices at the fracture site. Statistical analysis was done with a Fisher’s Exact Test with significance set at p<0.05. This study was approved by the MetroHealth Medical Center Institutional Review Board.

Results

The search of the trauma database identified 225 proximal extra-articular tibia fractures that were treated with an intramedullary nail. Of these 225 patients, 37 patients met our inclusion criteria and had a unicortical plate placed to aid in reduction of the fracture. In 11 cases, the plate was retained and in 26 cases the plate was removed before the conclusion of the operation. Demographic data for each group is listed in Table 1 including gender, mechanism of injury, fracture classification and number of open fractures with corresponding Gustilo-Anderson type. All cases in which the plate was retained were classified as 41A-2 or 41A-3 fractures and in the majority of cases in which the plate was removed, the fractures were classified as 42A, B or C (57%). All injuries were sustained from a high energy mechanism of injury, the large majority of which occurred from motor vehicle, motorcycle and all-terrain-vehicle accidents, falls from height and pedestrians struck. Seventy-eight percent of these fractures were open injuries, 93% of which were classified as Gustilo-Anderson type IIIA or IIIB. Almost all of the injuries in the plate removal group were open fractures (88.5%), whereas only 54.6% of the fractures in the retention group were open.

Five patients were lost to long term follow up (4 patients in the retention group and 1 in the removal group) and one patient expired shortly after surgery from an unrelated cause (removal group). Two nonunions occurred in the retention group and seven occurred in the removed group. There was no significant difference in the rate of nonunion between the retained and the removed group (p=0.454). There was only one malunion in the retained group; the fracture healed in valgus and procurvatum and required a subsequent osteotomy. Two delayed unions occurred, both in the group in which the plate was removed.

Discussion

We found no difference in the rate of nonunion in retention versus removal of a unicortical plate that was utilized as a reduction aide in the intramedullary nailing of extra-articular proximal tibia fractures. The concern with retention of a unicortical plate when utilizing an intramedullary device for fracture fixation is the potential to create an overly stiff construct that may impede the secondary bone healing usually present with the relative stability provided by the intramedullary device. Both devices used in concert may cause confusion of the osteocytes at the fracture site ultimately leading to nonunion. Archdeacon et al, in a review article on provisional plate fixation for fractures, note that they prefer to leave the plate in place at the conclusion of the case for “further reduction of fracture motion.”12 The current study showed no difference in nonunion rate between the two groups, nor did it show an unreasonably high percentage of nonunions in the retention group overall (18.2%), suggesting that while motion at the fracture site was further reduced with the unicortical plate, there was still some flexibility at the fracture site allowing for secondary bone healing to occur. In a recent review article by Liporace et al looking at techniques for intramedullary fixation of proximal tibial shaft fractures, the authors also raise the concern of creating an overly stiff construct with unicortical plate fixation. They suggest with retention of the plate that “very flexible” fixation be employed utilizing limited unicortical screw fixation. If bicortical screw fixation is initially needed for reduction, this should be exchanged for unicortical screw fixation at the end of the case to create an environment which they refer to as “controlled instability.”6 Interestingly, all fractures in the group in which the plate was retained were classified as 41A-2 and 41A-3, whereas the majority of the cases in which the plate was removed where classified as 42A, B or C. It is possible that there was a bias towards retention of the plates in those fractures that were in fact more proximal in the tibial shaft to help assist in the stability of the reduction and further prevent valgus and apex anterior deformity as the fracture healed. An intramedullary nail offers the least purchase for reduction in the meta-diaphyseal region where the canal is the widest and retention of the plate may add an increased level of stability.6 This increased level of stability proximally has also been shown to be achieved in biomechanical studies with the placement of multiple proximal interlocking bolts into the nail as well as placement of these bolts in multiple planes.13,14 In those cases in which the plate was utilized more distally, the surgeon may have felt more at ease removing the plate as the fracture was more diaphyseal in nature where the intramedullary nail has more purchase and thus is more resistant to malangulation after surgery. It is also important to note that 88.5% of the fractures in the removal group were open fractures whereas only 54.6% of the fractures in the retention group were open. The benefit of using an intramedullary device in an open fracture is a decreased risk of exposed hardware in the open wound. Perhaps the soft tissue envelope in those cases in which the plate was retained was better than in the cases in which it was removed.

There are three small published series that discuss the outcomes of utilizing provisional plate fixation when using
an intramedullary nail to fix tibial shaft fractures. Dunbar et al indicate in their series that all plates were removed at the conclusion of surgery, however all of the fractures in their series were classified as 42A, B, or C. They documented a 16.7% nonunion rate, but all fractures in their series were Gustilo-Anderson type III open fractures which may have contributed to the higher rate of nonunion, similar to the cohort in this study. In another small series looking at only proximal quarter tibial shaft fractures, Nork et al reported retention of 10 of the 13 plates utilized as reduction aids. The decision to leave the plate was left to the discretion of the surgeon. In their study they had a 100% union rate at the proximal fracture site, however, only 35.1% of the fractures in their cohort were open. In a 2007 publication, Kim et al describe a percutaneous technique for provisional unicortical plating in 9 patients. They removed all of their plates at the end of the procedure and had a 100% union rate at 6 months postoperatively. One of the patients in their study who had sustained a segmental tibia fracture had what they referred to as a mild valgus malunion that was secondary to eccentric reaming secondary to placement of the unicortical plate. Although they discuss the benefits of percutaneous plate fixation in their study for the soft tissues, they do not explicitly state the soft tissue injuries present in their cohort. In our series, two of the nine nonunions occurred in closed fractures. This may warrant further investigation into the use of percutaneous application of the provisional plate in the setting of a closed fracture to prevent periosteal stripping.

There are several limitations to this study, first and foremost being the relatively small sample size. Further investigation of this problem may be served better by a multi-center study. In conjunction with the small sample size, there was a high rate of patients who were lost to follow up in the retention group. Again, this could be negated by a larger sample size. Overall, there was a high rate of open fractures in this study (93%), all from high energy mechanisms of injury. This may have led to an overall larger amount of soft tissue stripping predisposing our cohort to delayed union and nonunion. This increased incidence of high energy fractures in our group may represent a confounding variable that could have also contributed to the rate of nonunion.

In conclusion, we found no difference in the rate of nonunion whether we retained or removed a unicortical plate for provisional reduction of proximal tibial shaft fractures. There was one malunion that occurred in a patient in which the plate was retained. When utilizing a unicortical plate for provisional reduction of an extra-articular proximal tibia fracture that is to be treated with an intramedullary nail, we recommend minimizing further soft tissue stripping during placement, especially in the case of a closed fracture. It is unclear whether this plate should be removed or retained at the conclusion of the case. Consideration should be made for overall stiffness of the fixation construct, bone quality of the patient, soft tissue envelope, location of the fracture in the tibial shaft, and ability to maintain the reduction with an intramedullary device alone throughout the post-operative period.

References

Abstract

Background: A poor understanding of cost among health care providers may contribute to high health care expenditures. Currently there exists no study which has examined surgeons’ knowledge of implantable medical device (IMD) cost.

Questions/purposes: (1) Determine the level of comfort with orthopaedic IMD costs among orthopaedic residents and attending surgeons; (2) quantify how accurately surgeons understand the costs of orthopaedic IMDs, (3) identify which constructs yield the most accurate cost-estimations among residents and attending surgeons.

Methods: A questionnaire was presented to 60 residents and 37 attending orthopaedic surgeons from two large academic medical centers. Respondents estimated the cost of thirteen commonly used orthopaedic devices. Fifty-one surgeons participated (36 residents, 15 attending surgeons). The overall response rate was 53%. Cost-estimates were compared against the actual material costs, and we recorded the percentage error for each estimation.

Results: More than half of respondents rated their knowledge of IMD cost as poor. The mean percentage error in estimation for all respondents was 69% +/- 42%. Overall, 67% of responses were underestimations and 33% were overestimations. Residents demonstrated a mean percentage error of 73% +/- 50% (range, 29%–289%), versus a mean percentage error of 59% +/- 9% (range, 49%–79%) for attending surgeons (p=0.10). Residents and attending surgeons demonstrated differences in accuracy within groups and between groups based on the IMD being estimated.

Conclusions: Knowledge of orthopaedic IMD costs among the orthopaedic residents and attending surgeons surveyed was poor. Further investigation of how physicians conceptualize material costs will be important to healthcare cost control.

Introduction

The rapid and unsustainable increase in American healthcare spending is an important public policy issue that has attracted a great deal of attention in the press and in orthopaedic literature. Implantable medical device (IMD) costs were estimated to have reached $80 billion in 2007, and orthopaedic implant costs alone were expected to grow at a rate of 9.8% annually, reaching $23 billion by 2012. A recent study of 31 hospitals by the U.S. Government Accountability Office (GAO) found that expenditures for procedures involving the use of IMDs increased from $16.1 billion to $19.8 billion over a 5-year period from 2004 to 2009, and orthopaedic devices accounted for the largest portion of this increase. Total hip and knee replacements already constitute the largest hospital expenditure category for Medicare. Robinson et al. found that the cost of total hip and knee implants represented a large percentage of the overall cost of these procedures, ranging from 13% to 87% in a study of 61 hospitals in 2008.

The manufacturers of orthopaedic IMDs are in a highly competitive industry, and pricing contracts between hospitals and manufacturers are usually confidential. Orthopaedic surgeons’ lack of knowledge of implant pricing may have real implications for healthcare cost control: as outlined in a recent editorial, when neither the patient nor the surgeon directly pays for the costs of orthopaedic implants, both parties often believe that “newer is better,” which can lead to out-of-control costs. The average price of hip and knee implants has increased by over 100% in the past decade, making it difficult to control costs. Educating surgeons about the cost of orthopaedic IMDs has
not traditionally been considered the responsibility of training programs. However, accurate knowledge of cost and the benefits of treatments utilizing these IMDs will become increasingly important to orthopaedic surgeons in the future, as new devices are introduced, and the healthcare landscape changes dramatically. It is intuitive that surgeons can only participate in cost-containment if they know the cost of the materials used. The degree of knowledge of IMD costs among orthopaedic residents in training and their attending surgeons is unclear.

We therefore (1) determined the level of comfort with orthopaedic IMD costs among residents and attending surgeons; (2) quantified how accurately surgeons understand the costs of orthopaedic IMDs, and (3) identified which constructs yielded the most accurate cost-estimations among residents and attending surgeons.

Materials and Methods
We administered a 17-item, anonymous questionnaire to 60 orthopaedic residents and 37 attending surgeons at two high-volume academic medical centers. The questionnaire was sent via email at one institution and was administered at grand rounds at the second institution. Approval was granted from the institutional review board at one institution prior to beginning this study. Consent to participate was implied by a participant’s completion of the questionnaire. Neither the residents nor attending surgeons had prior knowledge that the questionnaire would be administered.

The questionnaire was completed by a total of fifty-one surgeons, of whom thirty-six were residents and fifteen were attending surgeons. The overall response rate was 53% (60% among residents, and 41% among attending surgeons). Twenty-nine responses (20 residents and 9 attending surgeons) were obtained from one institution, and twenty-two responses were obtained from the other institution (16 residents and 6 attending surgeons). Responses were obtained from residents at all training levels and from surgeons with experience ranging from < 5 years to > 25 years in practice.

Respondents were asked to list their years in training or, in the case of attending surgeons, the number of years in practice, and to rate their perceived knowledge of implant costs prior to completing the questionnaire. Respondents were then asked to estimate the hospital costs of thirteen different orthopaedic IMDs that are commonly used in the operating room. The error in each estimation, when compared against actual hospital costs provided by our institution, was then calculated and compared between the groups.

Figure 1: An electronic survey was emailed to orthopaedic residents and attending surgeons at two academic medical centers. Each respondent was asked to estimate the cost of 13 orthopaedic IMDs that are commonly used in the operating room. The error in each estimation, when compared against actual hospital costs provided by our institution, was then calculated and compared between the groups.
construct, or an exact quantity of bone cement (Figure 1).

After the questionnaires had been collected, respondents were divided into groups based on whether they identified themselves as residents or attending surgeons. These groups were then further subdivided based upon the years of training or, in the case of attending surgeons, years in practice. The accuracy of cost-estimation was accomplished by comparing our questionnaire responses with actual hospital cost calculations that were provided by one institution, due to the need for confidentiality between the two institutions. We verified with IMD personnel that costs were not different by more than 5% between the institutions. Retail costs of orthopaedic IMDs are more easily obtained but do not represent the true costs paid by hospitals. The absolute difference between each respondent’s estimated cost and the actual hospital cost was then determined, and this value was then divided by the true hospital cost to calculate the percentage error contained in each response. In order to maintain the confidentiality of the hospital’s contract with the manufacturers, only the percentage errors were used for the final analysis.

The percentage error in each estimation was calculated by subtracting the hospital cost of the implant from the respondent’s estimated cost, and then dividing that result by the hospital cost of the implant (\(\text{Percentage Error} = \frac{\text{Hospital Cost} - \text{Estimated Cost}}{\text{Hospital Cost}}\)). The mean percentage error and standard deviation of the mean were calculated for the residents as a group and for the attending surgeons as a group. The absolute value of each percentage error was then used to calculate the mean percentage error for the group.

### Results

Two respondents conceptualized their knowledge of orthopaedic implant cost as being good. Twelve respondents felt that their knowledge was fair, and thirty-two felt that their knowledge was poor. Five respondents rated their knowledge of orthopaedic implant costs as “none.”

The overall mean percentage error in cost-estimation for the study population was 69% +/- 42% (range, 29%-289%). Taking all responses into account, 67% were underestimations, and the proportion of underestimations was nearly identical between residents and attending surgeons. The mean underestimation was 52% (n = 455), and the mean overestimation was 104% (n = 208). Residents demonstrated a mean percentage error of 73% +/- 50% (range, 29%-289%), versus a mean percentage error of 59% +/- 9% (range, 49%-79%) for attending surgeons. This difference showed a trend toward significance (p=0.10) (Table 1).

Residents were most accurate when estimating the cost of a distal radius locking plate and a clavicle locking plate; however, the mean errors for these constructs were 50% and 57%, respectively, meaning that, at their best, the residents’ responses were wrong.

<table>
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<th>Group</th>
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<th>Percentage Error</th>
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<tr>
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<td>69</td>
<td>43</td>
</tr>
<tr>
<td>Attending Surgeons</td>
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<tr>
<td>PGY-5</td>
<td>5</td>
<td>55</td>
<td>23</td>
</tr>
</tbody>
</table>

**Table 1**: Percentage errors for all participants. PGY = Post Graduate Year

<table>
<thead>
<tr>
<th>Device</th>
<th>Attending Surgeons</th>
<th>Residents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal radius locking plate</td>
<td>43</td>
<td>50</td>
</tr>
<tr>
<td>Radius Dynamic Compression Plate</td>
<td>122</td>
<td>111</td>
</tr>
<tr>
<td>Clavicle locking plate</td>
<td>76</td>
<td>57</td>
</tr>
<tr>
<td>Sliding Hip Screw</td>
<td>39</td>
<td>58</td>
</tr>
<tr>
<td>Cephalomedullary Nail</td>
<td>49</td>
<td>60</td>
</tr>
<tr>
<td>TKA w/ Cemented Tibia</td>
<td>36</td>
<td>58</td>
</tr>
<tr>
<td>TKA w/ All-Poly Tibia</td>
<td>44</td>
<td>61</td>
</tr>
<tr>
<td>Anterior Cervical Fusion</td>
<td>96</td>
<td>103</td>
</tr>
<tr>
<td>Construct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior Cervical Fusion</td>
<td>53</td>
<td>62</td>
</tr>
<tr>
<td>Construct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone Morphogenetic Protein</td>
<td>80</td>
<td>61</td>
</tr>
<tr>
<td>Demineralized Bone Matrix</td>
<td>51</td>
<td>89</td>
</tr>
<tr>
<td>Bone Cement</td>
<td>57</td>
<td>60</td>
</tr>
<tr>
<td>Antibiotic-Impregnated Bone</td>
<td>75</td>
<td>78</td>
</tr>
<tr>
<td>Cement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2**: Percentage error for each device measured for all respondents. TKA = total knee arthroplasty
by approximately half the cost of the implant. Residents were least accurate in estimating the cost of a dynamic compression plate for the distal radius (111% error) and an anterior cervical fusion construct (103% error). Attending surgeons were most accurate when estimating the cost of a cemented total knee construct (36% error) and a sliding hip screw construct (39% error), and they were least accurate when estimating the cost of a dynamic compression plate for the distal radius (122% error) and an anterior cervical fusion construct (96% error) (Table 2).

Discussion
Orthopaedic surgeons’ knowledge of surgical materials costs is important to the success of cost-control measures which are becoming more important in modern healthcare. Due to variations in price and competition within the industry, it is sometimes difficult for surgeons to determine the costs of the materials they use. We have conducted a study in order to (1) determine the level of comfort with orthopaedic IMD costs among orthopaedic residents and attending surgeons; (2) quantify how accurately surgeons understand the costs of orthopaedic IMDs, and (3) identify which constructs yield the most accurate cost-estimations among residents and attending surgeons.

This study had limitations due to the nature of our investigation. All of the surgeons practiced or trained primarily at large, high-volume academic institutions, and thus, we could not examine for any differences in the community practice settings. Further investigation of the differences in price conceptualization between the academic and community practice settings may help to identify the reasons for any differences in understanding, if these exist. However, we feel that our study provides a good starting point for any discussion of such a difference. We based our true hospital costs on the figures presented to us by one of our institutions. This was done out of necessity, however, because confidentiality agreements prohibit the sharing of cost data between our institutions. We were, however, able to verify that costs did not differ by more than 5% between our two medical centers, and this difference is small in relation to the levels of error demonstrated by our survey respondents. It should be noted that the retail costs of these items were not used in our investigation because these do not accurately portray the true costs to our institutions, nor to most institutions in the country. Most hospitals receive significant discounts on IMDs, making hospital cost significantly lower than retail cost. Because most responses represented underestimation of cost, the use of retail costs would likely have resulted in even greater errors in estimation by our study participants. Finally, our questionnaire response rate was relatively low, and this is possibly important, as it may reflect the lack of interest in the cost of IMDs among physicians. Rather than a limitation, we feel that this low response rate is an important finding, as it could be the case that those surgeons who participated in the study are the ones having the greatest interest in the pricing of implants, which only emphasizes the lack of accurate knowledge regarding IMD costs among surgeons.

It is interesting to note that, at the outset of this study, most respondents acknowledged that their familiarity with orthopaedic IMD costs was poor. No previous study has examined physicians’ attitudes about medical device costs or the accurate conceptualization of these costs, but the issue is an important one: the costs of IMDs have been found to account for a high percentage of hospital costs, and in some cases the payments hospitals make to manufacturers for IMDs used in surgical procedures are higher than the payments made to surgeons for performing those procedures. The United States Government Accountability Office (GAO) has been investigating these costs, specifically as they are billed directly to patients, and in 2013 will begin incorporating them into the bundled payments provided to institutions through Medicare’s Prospective Payment System (PPS). The GAO investigation noted substantial variation in the prices paid by hospitals for the same device – specifically 78%-83% variation in hospital cost for the same THA (total hip arthroplasty) and TKA (total knee arthroplasty) implants – and cited relationships between physicians and manufacturers as being instrumental in this difference. A recent study of hospitals in California by Robinson et al. reached this same conclusion, finding that TKA implants varied from $1797 to $12093 and THA implants varied between $2392 and $12651 between medical centers. It should not be surprising that the surgeons who participated in this study did not have an accurate knowledge of IMD costs, as confidentiality agreements between hospitals and manufacturers make disclosure of price information difficult, and, in fact, the GAO report includes a discussion of the difficulty their organization had in obtaining this information for the report.

The overall accuracy of cost estimation demonstrated by our study was poor. Taking all estimations into account, twenty-two residents and ten attending surgeons demonstrated overall mean errors in their knowledge of orthopaedic IMD costs to be between 50% and 100%, while five residents had overall mean errors greater than 100%. Even though these two large academic
medical centers received considerable discounts on orthopaedic IMDs, most responses were underestimations. It is unclear how surgeons should best be educated regarding these costs. Although institutions could list the prices of operating room materials directly on the packaging, neither of our institutions currently employs this practice, and it may be the case that current contractual confidentiality agreements would prevent this from occurring. Some hospitals, unable to disclose cost to their own physicians due to confidentiality agreements with manufacturers, choose to use colored stickers on IMDs to indicate high, medium, or low cost.8,9 Direct collaboration between manufacturers and surgeons for the purpose of education, especially of residents during their training, would be beneficial, but would be highly scrutinized due to the 2005-2007 Department of Justice investigation and eventual prosecution of orthopaedic device manufacturers for improper relationships with surgeons.10 The relationships between surgeons and industry continue to be cited as factors which complicate the effective negotiation of prices between hospitals and device companies.8,9

The accuracy of cost estimation in our study differed based upon the implant being studied. It appears that knowledge of cost is influenced by familiarity with a material or device. For instance, the anterior cervical fusion construct—a highly specialized device used by a relatively small number of practicing surgeons—showed consistently poor accuracy in estimation across groups. The greatest accuracy was observed when attending surgeons estimated the costs of a cemented TKA and a sliding hip screw, which are two implants that many have used often in the course of their training and/or practice. The residents also demonstrated a similar pattern, which possibly exists because of recent publications, regarding cost comparisons between some of these implants.11,12 Newer products were associated with a greater percentage error in our study, and, because these products are also more expensive than older IMDs, these errors are magnified in terms of actual device expenditures. These findings regarding familiarity with a device and its cost demonstrate that surgeons can learn and retain pricing information if it is presented to them, whether through direct discussions with other surgeons or reading the orthopaedic literature. At present, given the confidentiality agreements between hospitals and industry propensity toward non-transparency in pricing, these discussions and the academic work of other surgeons are the only practical means of obtaining cost information for most orthopaedic surgeons. Based on the results of our study, this learning model is in need of significant change.

In conclusion, we found orthopaedic surgeons have poor knowledge of orthopaedic IMD costs. In order for surgeons to actively participate in cost-containment in a healthcare environment in which spending will be intensely scrutinized, they must have a thorough understanding of IMD pricing. As the current level of expenditures is not sustainable, new strategies for the education of surgeons regarding costs of IMDs and an evidence-based rationale for their use should be utilized.

Acknowledgements

The authors thank the orthopaedic surgery departments at University Hospitals Case Medical Center (Cleveland, OH) and the University of Michigan Medical Center (Ann Arbor, MI) for their participation in this study. We also recognize the assistance of representatives from Biomet, Inc. (Warsaw, IN), DePuy Orthopaedics, Inc. (Warsaw, IN), Stryker Orthopaedics (Kalamaizoo, MI), Synthes, Inc. (West Chester, PA), and Zimmer, Inc. (Warsaw, IN).

References

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Nemours/Alfred I. duPont Hospital for Children
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University of Michigan School of Medicine  
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**Donald R. Resnick**
Chief, Musculoskeletal Imaging
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Dr. Mark Robbin, Division Chief of Musculoskeletal Radiology at University Hospitals, with Dr. Resnick and Dr. Marcus.

Dr. Resnick gives Grand Rounds.

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Thanks to a generous donation from Dr. & Mrs. Victor Goldberg and donations from his colleagues, friends and former patients, University Hospitals Case Medical Center has established an endowed annual lectureship in the Department of Orthopaedic Surgery. This lectureship will honor the tremendous contributions and leadership of Dr. Goldberg. The inaugural Victor M. Goldberg, MD Visiting Professor will be held in the Fall of 2014.

Dr. Victor and Mrs. Harriet Goldberg.
OBITUARY

DR MARCOS ENRIQUE AMONGERO

Marcos Enrique Amongero, MD age 52, passed away on August 19, 2013 at the Hospice of Dayton. He graduated from Wyoming High School in Cincinnati in 1978, Emory University in Atlanta, GA with a BS in 1982, Universidad de Monterrey in Monterrey, Mexico in 1986, George Washington University Medical School in Washington, DC with an MD in 1989, Case Western Reserve University Orthopaedic Residency in Cleveland, OH in 1994, and UC Davis Spine Fellowship in Sacramento, CA in 1995. Marcos practiced as an Orthopaedic Spine Surgeon with the Orthopaedic Institute of Dayton (OID). He retired after eighteen years of practice in 2013. Marcos was an active member and racer with the Porsche Club of America and the Sports Car Club of America. He enjoyed memberships at the Motorsports Country Club of Cincinnati and the Dayton Country Club. Marcos was a key physician contributor to the development and construction of the Orthopaedic spine unit at Miami Valley Hospital. He served on many boards including; the Community Blood Center/Community Tissue Services and OID. He was a past chair of the Department of Orthopaedics and the medical director of Orthopaedic Spine at MVH. He also supported Doctor’s Without Borders, the Dayton Art institute, the Boonshoft Museum, and the DVAC. Marcos was a dedicated family man and surgeon who achieved a balance between home and his profession. Love of life and his competitive spirit could be seen in his pursuit of travel, skiing, car racing and support of the arts. He included his family in all his exploring and activities. He was a genuinely caring, generous person, who had boundless dreams that kept his wife, children and peers wanting to live life to its fullest. He served the community passionately and with humility, using his great surgical abilities and being bilingual, to help people whenever he could. Marcos is survived by his wife and high school sweetheart of 35 years, Martha (Dunlop); children, Lauren, Sonja, Nicolas, Anthony and Josh, parents; Flavio and Noemi, brothers; Christian, Kevin and his wife Tori along with their children Emerson and Sophia, as well as many other loving relatives, residing in the US and Argentina.

OBITUARY

DR GEORGE EDWARD SPENCER, JR.

George Edward Spencer, Jr., MD of Mount Dora, FL entered into eternal life on May 23, 2013. A native of Cleveland, OH, George was born to Jesse Fairbank and George Edward Spencer, Sr. George is survived by his loving and devoted wife of 68 years, Jean (nee Toth), his son, Geoffrey Thomas Spencer (Poppy). George is the loving father of his late son, George Edward Spencer, III (Catherine), and further survived by grandchildren, Ted Spencer (Jennifer), Lisa Spencer Carlton (Calvin), Jonathon Spencer, and five great-grandchildren, and many loving and adoring friends. In 1945, George received his medical degree and graduated Cum Laude from University of Michigan Medical School. He immediately interned at Charity Hospital of Louisiana in New Orleans. In 1946, as a naval physician, he was a Lieutenant JG and assigned to the Veterans Hospital in Jackson, MS. In 1948, George returned to Cleveland and completed his Orthopaedic training at the University Hospital in Cleveland, OH, where he eventually became professor of Orthopaedic Surgery and joined the staff at University Hospital. In 1975, he became Chief of Orthopaedic Surgery at St. Lukes Hospital in Cleveland, OH. In 1989, George retired, and he and Jean moved to Mount Dora, Florida. George was a member and past president of the Cleveland Orthopaedic Club. He was President of the Clinical Orthopaedic Society, as well as a member of the American Medical Association, American Academy of Orthopaedic Surgeons, and American Orthopaedic Association. George was a devoted husband and father; he and his wife Jean enjoyed many travels around the world. One of George’s greatest passions was racing his beloved Flying Scot sailboat, Misty, which he enjoyed with his two sons. George raced and sailed Misty on Lake Erie, Crystal Lake, Michigan, Chautauqua Lake, New York and Lake Dora in Mount Dora, FL. George and Jean both shared many happy times with their good friends from the Mount Dora community and Mount Dora Yacht Club, where George was proud to be the Regatta Chair for 6 consecutive years.
Congratulations to the five graduating chiefs of the class of 2013. All five will be completing a fellowship in the 2013-2014 academic year.

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University of Pittsburgh Medical Center
Pittsburgh, PA

Ethan Lea, MD
Trauma
University of California – Davis
Sacramento, CA

James Learned, MD
Trauma
Harborview Medical Center, University of
Washington
Seattle, WA

Troy Mounts, MD
Spine
The Rothman Institute at Jefferson
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      ii. Methods - Describe the study design in detail using standard methodologic terms. All study designs should include information how the sample was identified (inclusions and exclusions). The statistical section should be described in detail, with particular emphasis on the statistical strategy.
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      iii. Results – Provide a detailed report on the data obtained during the study.
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