Penn Medicine

PENN ORTHOPAEDICS

EXCELLENCE *IN MOTION* 2017

INNOVATORS
IN ORTHOPAEDIC CARE

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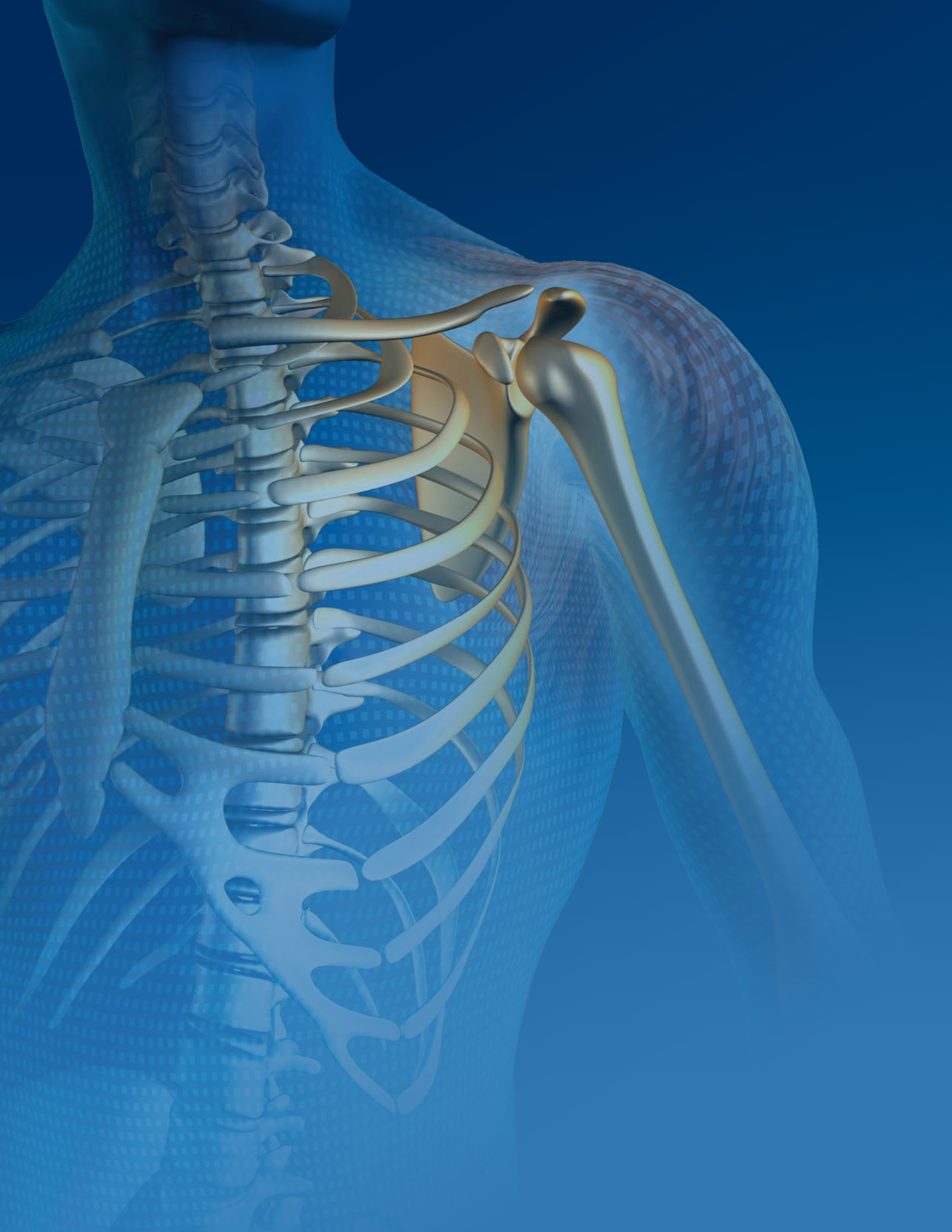


Source: Sabina Louise Pierce

To My Colleagues,

It is with great pride that I present the latest edition of Excellence in Motion, the newsletter of Penn Orthopaedics.

In the past year, Penn Orthopaedics has significantly expanded implementation of disease teams and defined clinical pathways. The basis of this approach is thinking about care from a patient perspective—facilitating collaboration and optimized outcomes with specialists across all the disciplines involved in the treatment plan of a patient throughout the continuum of care.

Recent advancements in 3D printing, advanced materials, biologics, and other advancements have revolutionized the way we are able to turn research into results. At Penn Orthopaedics' Biedermann Lab for Orthopaedic Research—made possible through a generous gift from the Biedermann family—researchers and surgeons have collaborated to test new options for treating patients using state-of-the-art technology. Here we share some of their innovative results.

Keith L. Wapner, MD, Chief of Foot and Ankle Orthopaedic Surgery, provides the fascinating history of ankle replacement and compares ankle replacement to ankle fusion as the optimal treatment for patients with severe ankle pain. This article dives into the comparison of the procedures, their results, and ultimately reveals the future of ankle replacement vs fusion.

As part of the Penn Spine Center, the renowned Penn Adult Spine Deformity program, led by Vincent Arlet, MD, Chief of Orthopaedic Spine Surgery, takes on challenging cases. Penn uses a host of minimally-invasive options coupled with advanced 3D imaging of the whole body, enable Penn to provide better outcomes and less pain to even the most complex patients. Here we highlight their incredible work.

Hands-on learning and practice for many advanced surgeries and new approaches are immensely valuable, though these opportunities can be limited. The Penn Human Tissue Lab provides this opportunity for medical students, residents, and visiting and attending physicians to develop their surgical skills and practice new techniques on fresh, cadaveric specimens. Learn more about the exciting work made possible through the practice facilitated by this advanced cadaver laboratory—such as Vascularized Composite Allotransplantation.

Having now performed three bilateral Vascularized Composite Allotransplantation procedures, we update you onthe remarkable progress our patients have made. From competing in Crossfit competitions to throwing out the first pitch for the Baltimore Orioles, our patients are living fuller, richer lives as a result of this life-changing surgery.

Penn Orthopaedics continues to act as a catalyst for advanced clinical care across the spectrum of orthopaedic medicine and surgery, increasingly engaging the frontiers of known science and exceeding the common expectations of our field. I hope you find this issue enlightening and I look forward to sharing more highlights with you in the future.

L. Scott Levin, MD, FACS

Paul B. Magnuson Professor of Bone and Joint Surgery
Chair, Department of Orthopaedic Surgery
Professor of Surgery, Division of Plastic Surgery
Medical Director, Penn Musculoskeletal Center

Innovative Approach:

MANAGING MUSCULOSKELETAL CARE
Along the *Patient Pathway*

The goals of improving quality, increasing access and decreasing costs are not new objectives in healthcare delivery. Penn's Musculoskeletal and Rheumatology (MSKR) Service Line is leading the way in managing these competing priorities. The disease team approach—organizing care by multidisciplinary groups focusing on specific patient populations and episodes of care—breaks down barriers and puts the patient first.

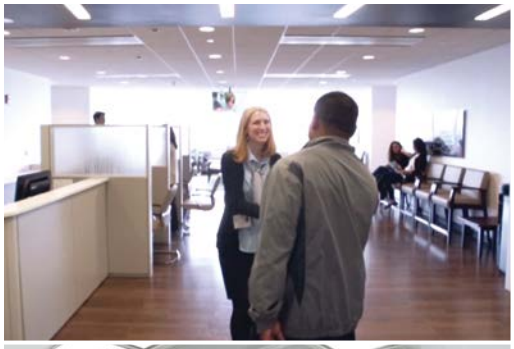
Rachel Kleinman PhD

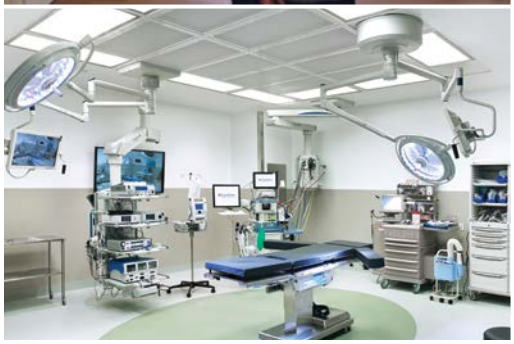
A New Way to Think About Patient Care

The MSKR Service Line launched its first disease teams in 2015, including degenerative arthritis, trauma and fracture, and inflammatory arthritis. "We moved to this model because the traditional way that hospitals and physician practices are organized doesn't provide clinicians and staff the opportunity to think about the full continuum of care," said Rachel Kleinman, Penn MSKR Director of Service Line and Network Integration. "This approach manages a disease state or injury in an integrated way, mirroring the way a patient approaches their own medical care."

Building the Process

To capture the full progression of a disease or injury, teams map out patient pathways. This process involves the careful, patient-focused evaluation of all aspects of the existing treatment plan within the health system, across all departments who will be providing care for a condition or disease from initial presentation through recovery. A multidisciplinary group of physicians, nurses, therapists, social workers, and administrators meet to review individual patients and identify challenges. Opportunities for improvement are highlighted, often resulting in new or refined protocols. The disease team then meets regularly to review individual patients and progress on defined metrics, continually optimizing and improving patient care.





Measurable Impact

The results are there, and they're powerful. Each of the patient pathways implemented at Penn have produced significant benefits for patients and physicians alike.

"The average time to OR for a geriatric hip fracture patient is about 15 hours, well below the geriatric hip fracture pathway team's goal of 24 hours," Kleinman said. Additionally, hospital length of stay for these patients is averaging below five days. Now, the geriatric hip fracture team is focusing on post-acute pathways for patients, partnering closely with local skilled nursing facilities (SNFs). Together, they are creating pathways that delineate therapy milestones, nursing and medical management guidelines, and even patient expectation for participation in rehabilitation.

The Shoulder Arthroplasty Enhanced Recovery Protocol (ShARP) team has reduced length of stay from three days to one day, mainly through the use of an ambulatory pain pump that goes home with the patient. This new protocol was identified as an opportunity and implemented using the pathway process. "Leaving the hospital before noon post-op day one is a huge patient satisfier," said Kleinman.

Even as length of stay for major lower joint replacement has been steadily declining, the degenerative arthritis team has created a sub-group to work on developing a patient pathway for outpatient joint replacements. To date, the team is focusing on making patient education more interactive, and thus, more effective; instituting pre-surgical therapy guidelines; and hardwiring all staff communication and hand-offs down to the minute.

Finally, the sports performance and injury team, formed in 2016, is currently focusing on ACL injuries, recently analyzing the variation in OR costs across surgeons. From implants to sutures, unit costs are analyzed, identifying savings and reducing waste.

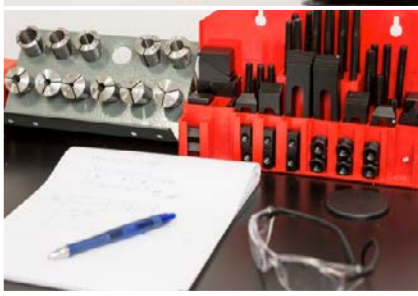
Patient Pathways for the Future

"This approach manages a disease state or injury in an integrated way, mirroring the way a patient approaches their own medical care...it is the primary lens through which we think about quality, process improvement, and ultimately program development from this point forward"

—**RACHEL KLEINMAN,** PENN MSKR DIRECTOR OF SERVICE LINE AND NETWORK INTEGRATION

"We've been working on this for almost two years and we've accomplished a lot—but we still have more work to do," said Kleinman. "Every pathway has projects waiting to be started." Moreover, the service line plans to launch two more disease teams covering systemic rheumatic diseases and bone disease.

As the health system continues to grow, disease teams and pathways provide a forum for integrating care across disease team populations, circulating best clinical and operational practices among all of the Penn Medicine hospitals. "It is the primary lens through which we think about quality, process improvement, and ultimately program development from this point forward," Kleinman said.



Biedermann Lab Turns Biomechanical Research INTO INNOVATIVE RESULTS

At a time when 3D printing, advanced materials, biologics, and other factors are revolutionizing orthopaedics, the Biedermann Lab for Orthopaedic Research at Penn Medicine brings together scientists, engineers, and surgeons with the goal of quickly turning research into results for patients. Engaged in a robust range of biomechanical research projects, the Lab is focused on the clinical applications of research. Penn researchers are collaborating with surgeons to test new ways to treat a range of musculoskeletal conditions and injuries. Scientists in the new laboratory draw on input from orthopaedic experts and use the latest technology to find real-world solutions.

Michael W. Hast, PhD

"Our research ideas are developed from problems that are affecting the daily clinical practices of our surgeons. The goal of every investigation is to improve patients' mobility and quality of life."

—MICHAEL W. HAST, PHD, DIRECTOR OF THE BIEDERMANN LAB

Building the Lab

With a degree in mechanical engineering and his specialization in biomechanical research, Michael W. Hast, PhD, Director of the Biedermann Lab, is uniquely qualified to lead this collaborative team. His experience and expertise has shaped both the research in the lab and the design of the lab itself.

Located within the new, state-of-the-art Penn Medicine University City building, which also houses the Penn Musculoskeletal Center location two floors below, the Biedermann Lab was designed to operate in synergy with orthopaedic clinical activities—becoming operational in 2015. The lab's more than 3,200 square foot facility provides ample space for studies to be conducted concurrently and includes a dissection/prep room, implant room, machine shop, main testing lab, and offices. The lab is well appointed with a selection of leading-edge equipment specifically chosen by Dr. Hast to enable the lab to quickly and precisely test potential treatment solutions presented by Penn surgeons. Imaging is performed with a stereomicroscope and mobile C-arm, a 3D motion tracking system captures movement during dynamic tests, and fabrication and testing are supported by a 3D printer, vertical mill, and two universal testing frames.

Commitment to Continued Innovation: Penn and the Biedermanns

The Biedermann family has a distinguished history in facilitating collaborative efforts between engineers and physicians. That commitment to improving patient lives through orthopaedic research has continued for over 100 years through four generations of the Biedermann family. In 1916, Max Biedermann started his prosthetics work in Germany with research noted for collaborations between physicians and engineers.

The innovative research conducted at the Biedermann lab for Orthopaedic Research is made possible through a generous gift to Penn by Max's grandson and great-grandchildren who founded it in his honor and to show their support for an institution with both excellent biomechanical research and exceptional surgeons—such as the lab's clinical advisor Samir

Mehta, MD, Chief of Orthopaedic Trauma and Fracture at Penn. "This new lab gives Penn's renowned biomechanical experts an ideal venue to explore clinically relevant research. We are very grateful to the Biedermann family for making this progress possible" said L. Scott Levin, MD, FACS, Chair of the Department of Orthopaedic Surgery.

Samir Mehta, MD

Research and Results: Sharing All Outcomes

Studies now in progress relate to the biomechanics of upper extremity trauma in osteoporotic bone, pediatric spine applications, and tendon conditions. Although much of its research uses cadaveric specimens, the lab often works with subjects in Penn's Human Motion Laboratory as well.

"Using both approaches lets us develop and validate computational models that can predict things that cannot be estimated with either just a human motion analysis or a simple cadaver experiment," Dr. Hast explains. For example, when studying contact forces within joints, the researchers can use cadaveric specimens to look at forces created during a simple movement, but computational models afford the opportunity to analyze more complex motions, such as activities of daily living.

The lab's research philosophy is to learn from all investigations and share results, whether successful or not. "Even if we are wrong, we are going to tell the world about it," Dr. Hast said. "It's a tenet here and it drives good research."

Among recent successful experiments was a study to examine implant designs for repairing upper arm fractures in the elderly. Because this population often has weakened bones, physicians are concerned about the stresses involving bone screws that interdigitate into plates. The lab tested several different implant designs and determined that bone screws secured to plates with locking caps provide superior support. That research project has been accepted for publication in the Journal of Orthopaedic Trauma.

Another study, looking at a different screw construct for implants to repair elbow fracture, did not show benefit for implant longevity although it had been hypothesized that it would. Researchers concluded that the novel screw placement did not improve overall fatigue mechanics despite making the implant more stable. These findings are also being submitted for publication.

"We don't want to test things and brush them under the carpet if we don't like what we see," Dr. Hast said. "Sharing also reduces duplicating research unnecessarily. We are trying to break that mold so we can accelerate the pace of improvement of orthopaedic care."

(A) Flouroscope (B) 3D printer (C) Universal testing frame (D) 3D motion tracking camera (E) Universal testing frame (close up)

"This lab is a great way to celebrate our first 100 years being members of the orthopaedic community. We are looking forward to seeing the lab perform meaningful research to advance musculoskeletal treatment concepts."

— MARKKU BIEDERMANN

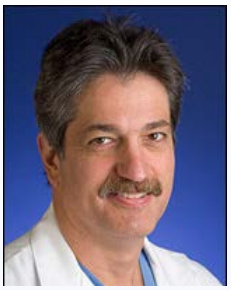
SUBMIT Your Research Idea

The lab encourages potential collaborators from Penn and elsewhere to submit research ideas through a questionnaire on the lab's website. Collaborators must agree that information will be shared even if an idea doesn't work out.

To submit research ideas for consideration, visit www.med.upenn.edu/biedermann and *click* COLLABORATE at the top of the page.

SEVERE ANKLE PAIN:
ARTHROPLASTY OR ARTHRODESIS?

For many years, ankle arthrodesis (ankle fusion) had been the gold standard for treatment of pain arising from ankle arthritis when bracing proved inadequate or impractical for long-term use. However, while arthrodesis can effectively relieve pain, it also significantly restricts function and can cause other issues.



Keith L. Wapner, MD

Over time, the restricted movement caused by fusion increases stress on adjacent joints and can lead to secondary arthritis in those joints. "Because of the potential outcomes from arthrodesis, physicians in the 1970's began exploring the possibility of using ankle arthroplasty (total ankle replacement) to obtain better results," said Keith L. Wapner, MD, Chief of Foot and Ankle Orthopaedic Surgery at Penn Medicine.

Total ankle replacement was first developed with approaches similar to what was in use for hip and knee replacements. Yet the technology of early ankle arthroplasties did not work well in the ankle's less stable environment, so arthrodesis continued to be the recommended treatment for another twenty years.

As technology improved in the 1990's, total ankle replacement design underwent significant biomechanical change. One implant, a mobile-bearing, three-component ankle prosthesis, was developed in Europe and tested in the U.S., beginning in 1998, to compare it to arthrodesis. This implant, STAR, received FDA approval in 2009 after showing comparable pain relief and significantly better function improvement.

At Penn Medicine, this prosthesis is the primary ankle implant used. "My comfort in using this particular implant is because it's the one with the most literature to support success," said Dr. Wapner. "I participated in the clinical trial and I am very familiar with its benefits." Constructed with upgraded polyethylene, it has more precise surgical instrumentation than its original European design and other implants, and is the only ankle prosthesis FDA-approved for use without cement. Because it does not use cement, large bone cuts are not needed. This preserves more of the ankle's load-bearing capacity and enables better bone growth onto the prosthesis.

Replacement vs Fusion

Ankle replacement and ankle fusion differ significantly both in procedure and patient benefits.

Comparing Procedures

During ankle arthroplasty or ankle replacement surgery, an incision is made down the front of the ankle, the ankle capsule is opened and any bone spurs are removed. An alignment guide is attached to the tibia and placed over the ankle. Then, using x-ray guidance, the surgeon removes the arthritic portion from the bottom of the tibia bone, places the talus in the proper position and makes a second cut on the top of the talus, parallel

Ankle x-ray following arthroplasty

to the tibia cut. This creates proper spacing between the bones. Small additional cuts may be used to shape the bone. The tibia component of the implant is put in first and then the talar component. The third component adds an appropriate size of polyethylene for stability. The surgeon then adjusts muscle and ligament balancing. This is especially important for correcting ankle and foot position at the same time to avoid putting abnormal force on the ankle and to optimize mobility.

In ankle arthrodesis or fusion surgery, incisions are made to the outside or front of the ankle. The joint surfaces are prepared by removing the arthritic bone and the joint is properly aligned. The tibia and talar bones are fused into one structure, held together by screws, screws and plates, or nails. During the surgery, x-rays guide hardware placement and check joint alignment. After fusion, the ankle loses mobility, which changes how the person walks. Surrounding joints also receive added stress and may develop arthritis.

Comparing Results

Research comparing the two approaches showed, after 24 months, 70.6 percent efficacy for replacement and 14.9 percent for fusion. Follow-up more than 9 years after arthroplasty found that patients' American Orthopaedic Foot and Ankle Society (AOFAS) scores for pain and function were significantly improved with replacement using this device. Pre-operative scores of 7.1 for pain and 26.7 for function improved to postoperative scores of 32.9 and 41.3, respectively. In addition, 92 percent of patients were satisfied with the surgery or would recommend it to someone else. Five-year survivorship was 96 percent; 10-year survivorship was 90 percent.

An additional benefit of arthroplasty at Penn is that the procedure with this implant requires much less bone to be removed than for other implants, making it a good first-time option for appropriate patients. This is particularly good for younger patients who may require a secondary replacement down the road. Other implants require much more bone removal which makes a secondary replacement significantly more difficult or not possible in some cases. It also has a complication rate of only six percent, compared to as much as 56 percent for fusion.

"Penn Orthopaedics has been performing ankle replacements since 2004...this experience is especially helpful for complex corrections"

–KEITH L. WAPNER, MD, CHIEF OF FOOT AND ANKLE ORTHOPAEDIC SURGERY AT PENN MEDICINE

Who Benefits From Replacement?

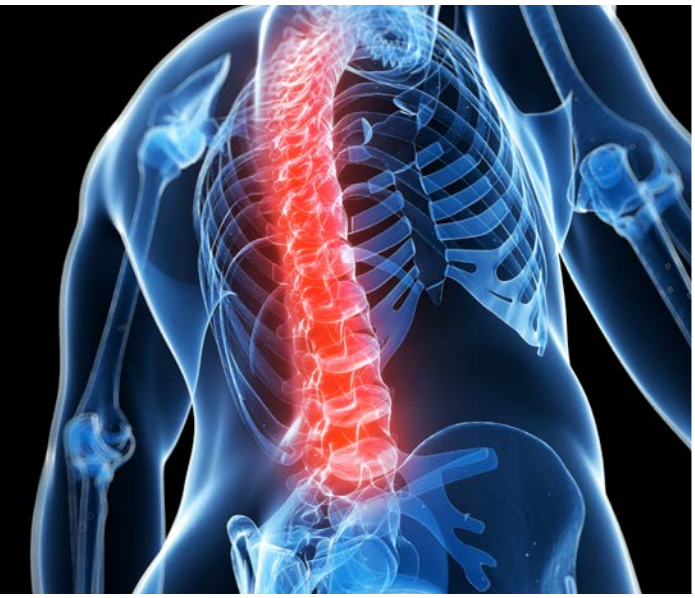
Many patients with advanced osteoarthritis of the ankle can benefit from total ankle replacement. Its use is indicated for those who are older than 50, non-obese, and have degenerative, post-traumatic or inflammatory arthritis of the ankle, ankle arthritis involvement of adjacent joints or arthrodesis in the opposite ankle. The most favorable results occur in patients with congruent joints with no coronal plane deformities. Incongruent joints present greater challenges, but can be addressed with various techniques of ligament and muscle balancing or bony realignment procedures.

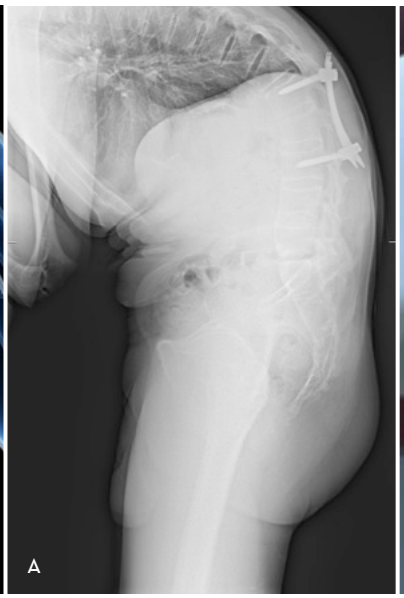
Arthroplasty preserves function but does not enable patients to regain lost motion, so it may not be a solution for patients who want to participate in sports or be very active. It is not recommended for those who are younger than 40, obese, smoke, or do manual labor. Relative contraindications include previous arthrodesis, malalignment or deformity of ankle structures. Absolute contraindications are active or prior joint or bone infection, history of osteomyelitis severe neuromuscular disorder, poor soft tissue envelope, and avascular necrosis.

Ankle Replacement Moving Forward

"Penn Orthopaedics has been performing ankle replacements since 2004, so our surgeons' experiences with muscle and ligament balancing during arthroplasty gives them greater skill in making higher degree corrections," Dr. Wapner says. "This experience is especially helpful for complex corrections needed due to trauma."

The technology for total ankle replacement continues to improve. With each new generation of prostheses, surgeons are learning more about how to fine-tune placement and use of the implants. "The results going forward are just going to be better and better," Dr. Wapner said.





Penn Adult Spine Deformity Program *heals with*

EXPERTISE & ADVANCED CARE

Patients who once were told that nothing could be done for their severe scoliosis now can gain significant improvement in function and quality of life at the Penn Adult Spine Deformity Program. As the only adult hospital in Pennsylvania using advanced technology for imaging the whole spine, and with experts who are skilled in the latest minimally-invasive approaches, the program produces exceptional results.

Vincent Arlet, MD

Treatment at Penn

"We take on challenging cases that lots of other places would not take on," said Vincent Arlet, MD, Chief of Orthopaedic Spine Surgery.

The first treatments for spine deformity are conservative, such as bracing, cortisone injections, physical therapy or pain medication. If those treatments are not effective, surgery may be recommended.

Scoliosis surgery at Penn is distinguished from many other centers in that Penn surgeons use a minimally-invasive front or side approach when possible. This avoids problems and complications that may be caused by cutting muscles and nerves when doing surgery from the back and results in patients having shorter hospital stays, smaller incisions, reduced blood loss, and less need for post-operative medications.

Of these minimally-invasive options, Anterior Lumbar Interbody Fusion (ALIF) surgery, Direct Lateral Interbody Fusion (DLIF), and Oblique Lumbar Interbody Fusion (OLIF) surgery are often used at Penn and result in better outcomes and less pain for patients compared to other approaches. All procedures use muscle sparing technologies.

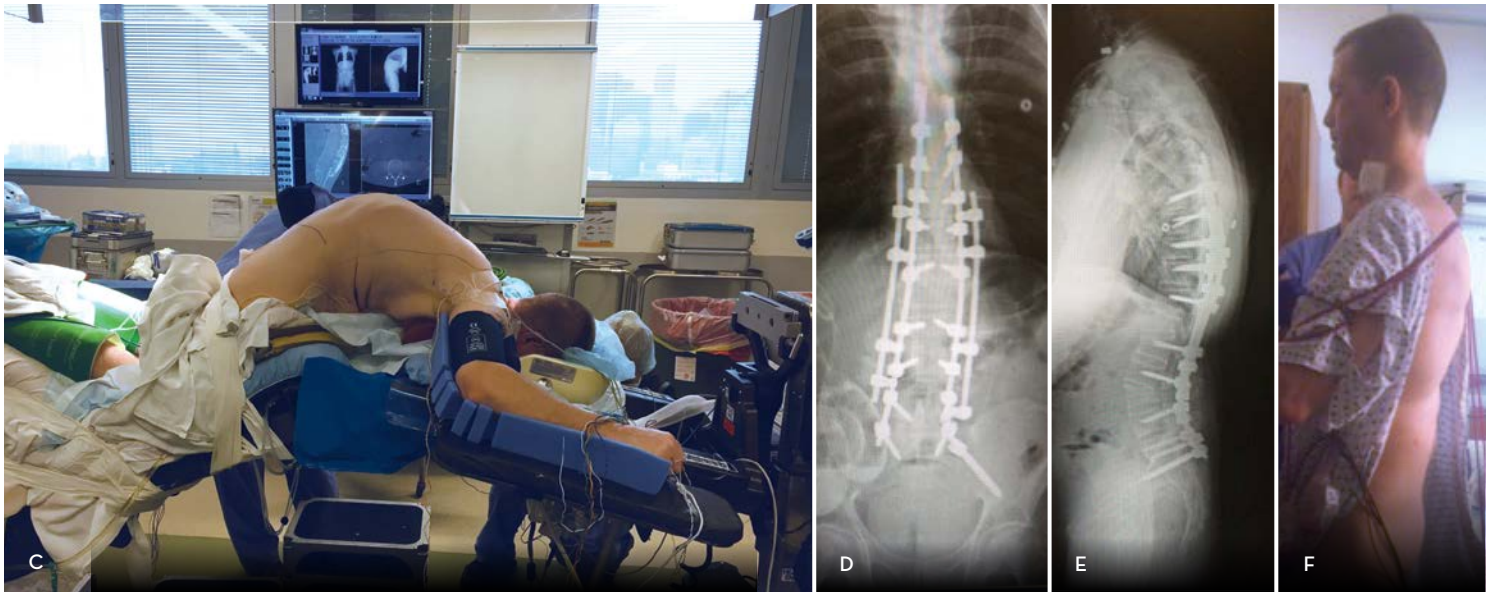
ALIF approaches the spine from the front of the body, while DLIF accesses it through a small incision in the patient's side and OLIF from the flank of the patient. In either approach, disc material is removed from between two lumbar vertebrae, creating a space. A bone graft or implant is inserted into the space, supported by rods and screws.

At Penn these procedures are performed with a surgeon trained in anterior approach to the spine and both the spine team and the approach team have an experience of more than 1,000 cases

Imaging the Whole Spine

Understanding the benefits of optimal imaging, Penn's Adult Spine Deformity Program also stands out for its use of new technologies to support careful diagnosis and complex treatments. The EOS imaging system allows for the whole body, from head to toe, to be x-rayed in 3D. This complete view enables Penn surgeons to precisely tailor spine surgery, correct the deformity, and restore each patient's original anatomy.

Penn Medicine is the only adult Pennsylvania center with this type of detailed imaging system, which uses five times less radiation than a conventional radiography. In addition,



(A/B) fifty five year old man with Ankylosing Spondylitis and severe back pain as well as inability to stand up straight and down going gaze. Patient had undergone previous surgery for fracture of the spine years before. (C) Positioning of the patient with the special OSI table that is matched to his deformity. (D) Close up x-ray view of surgical field after two pedicule subtraction osteotomies. (E/F) Post operative result: Patient being extremely satisfied.

Penn has an MRI machine that is safe for patients who have pacemakers and other implants that ordinarily prohibit MRI imaging. Such technology produces better imaging for preoperative planning, fewer complications and improved surgical outcomes.

Focusing precisely on every aspect of treating adult spine deformity is of greatest importance to the program, Dr. Arlet noted. "We want to get the most perfect result we possibly can, so we are careful in every single detail."

Multidisciplinary Penn Spine Center

Penn Spine Center specialists from many disciplines work with the spine deformity program to plan the best treatment for each patient. These experts include specialists from Orthopaedics, Neurosurgery, Physical Medicine and Rehabilitation, Physical Therapy, Cardiovascular Medicine and Pain Medicine.

"We offer patients safety and expertise in all of these domains. This collaboration between spine specialists from all of these disciplines is what makes the Penn Spine Center one of the most sophisticated and comprehensive programs in the nation."

–VINCENT ARLET, MD, CHIEF OF ORTHOPAEDIC SPINE SURGERY

The Best Treatments for Each Patient

Penn's comprehensive Adult Spine Deformity Program treats spine deformities in adult patients, ranging from older teenagers to seniors. The program's experienced specialists excel at evaluating all spine conditions with the latest imaging technology to provide the most advanced, effective treatments.

For teenagers with scoliosis, Penn Spine Center physicians understand when bracing is appropriate or if surgery is needed. They also have solutions for young adults with adolescent idiopathic scoliosis that cannot be treated any longer in the pediatric setting. Because scoliosis worsens and causes more problems with age, patients in their 40s and 50s may have pain from spine deformity. The program provides treatment to relieve pain and slow further progression of the condition.

Penn's multidisciplinary spine specialists successfully treat many patients in their 60s and older who have severe scoliosis with increased back and nerve pain, or leg pain from spinal stenosis. Experts in the Adult Spine Deformity Program assess which patients may need conservative treatment such as physical therapy, cortisone injections, or geriatric rehabilitation, and which could best benefit from surgery. As the only adult center in Pennsylvania with imaging equipment to see the complete spine, surgery at Penn is able to correct the spine deformity to the patient's precise anatomy.

"In other words, the spine deformity surgery is customized to each patient" says Dr. Arlet. "It is no longer acceptable to perform one type of surgery that would meet every patient need. For each patient we have to review and discuss with our patient the different surgical options and choose accordingly the best one with best outcomes. At Penn, the correction of the scoliosis, kyphosis, flat back or spondylolisthesis is tailored to each patient's specific anatomy and needs. This approach allows a safer surgery in many instances maximizing results."

PRACTICE MAKES PERFECT

IN THE PENN HUMAN TISSUE LAB

When patients go to the operating room for a surgical procedure, they rely on their physicians' training and experience with the surgery. Yet, for many surgeries and new approaches, hands-on learning opportunities may be limited.

In the Penn Human Tissue Laboratory, medical students, residents, and visiting and attending physicians develop their surgical skills and practice new techniques on fresh, cadaveric specimens. The lab, which is equipped with leading-edge technology and 16 large workstations, is one of only a few human tissue labs of its kind in the nation.

The Benefits of Practice

Having such a facility at Penn enables surgeons, physicians, trainees, and others to study anatomy and advance clinical care safely. "We make mistakes on fresh cadavers rather than on live patients," said **L. Scott Levin, MD, FACS**, Chair of the Department of Orthopaedic Surgery and Professor of Surgery (Division of Plastic Surgery). "We would rather learn from a simulated environment than in the operating room." The tissue lab also is a vital resource for supporting research and education.

The lab features ample, well-lit work spaces, sophisticated technical equipment, the latest instrumentation, a gowning area, and classroom. It has access to nearby lecture halls and dining, and offers flexible hours. High-quality donated cadaveric body parts used in the tissue lab are obtained through the morgue at the Perelman School of Medicine. With these valuable specimens, the lab makes it possible to simulate working on a live patient in a normal operating room.

Penn faculty use the tissue lab to test new implantable devices or practice procedures, such as advanced arthroscopy and joint replacement. The lab is particularly valuable when preparing for complex cases. For example, hand transplant surgery conducted through the Penn Transplant Institute was extensively rehearsed in the lab. These testing and practice sessions enable team physicians to develop and improve complex surgeries and result in safer, shorter operations with better outcomes.

Education in the Lab

The lab holds regularly scheduled surgical approach and regional anatomy workshops to add to other related learning in the Penn curriculum. "Our residents fully integrate the lab into their education in orthopaedic surgery, as do other Penn residencies in the health system," Dr. Levin said. Team-based sessions for arthroplasty, sports medicine, upper extremities, and shoulder and elbow are also held there.

Since its opening in 2011, the tissue lab has expanded and increased its capacity for training Penn physicians and researchers, as well as others in the field. It has become a center for CME seminars, Grand Rounds programs by visiting professors, and symposia, courses, workshops, and meetings conducted by groups such as the International Congress for Joint Reconstruction (ICJR), Foundation for Orthopaedic Trauma, and the American Society for Reconstructive Transplantation (ASRT).

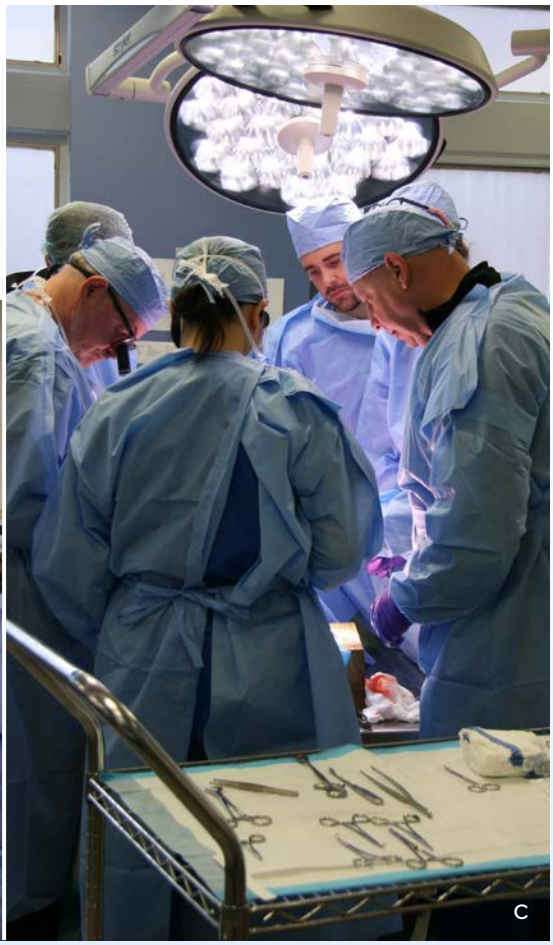
Lab manager Lorianne Kish-Burdsall directs the tissue lab and manages the selection and storage of specimens. She coordinates simulations and educational activities, including a recent training workshop for hand fellows interested in learning more about microsurgery.

"The outstanding reputation of the lab and its ability to be a premiere educational center has been realized, nationally and internationally," said Dr. Levin. "This is one of the most unique facilities in the country."

(A) Medical students, residents, and visiting and attending physicians practice complex surgical procedures during a session in the Penn Human Tissue Laboratory. (B/C) Dr. Levin leads instruction in microvascular surgery.

"We would rather learn from a simulated environment than in the operating room."

– L. SCOTT LEVIN, MD, FACS, CHAIR OF THE DEPARTMENT OF ORTHOPAEDIC SURGERY AND PROFESSOR OF SURGERY (DIVISION OF PLASTIC SURGERY).



(A) Lindsay Ess, Penn's first VCA recipient, six years following surgery. (B) Zion Harvey, world's first pediatric VCA recipient, one and a half years following surgery

LIFE-CHANGING SURGERY:
PENN HAND TRANSPLANT PROGRAM

Due to its complexity and the requirement for a coordinated effort of a highly skilled, multidisciplinary team of surgeons, Vascularized Composite Allotransplantation (VCA) remains a procedure conducted at a select few health systems. Penn's Hand Transplant Program is a joint venture of Penn Orthopaedics, the Penn Transplant Institute, and Penn Plastic Surgery. The Penn Medicine team is proud to have performed three of these life-changing surgeries.

Because hand transplantation surgery involves many types of tissues, including skin, muscle, bone, cartilage, nerves and blood vessels, various surgical specialists are needed. Under the leadership of Penn Hand Transplant Program director **L. Scott Levin, MD, FACS**, Chair of the Department of Orthopaedics and Professor of Surgery (Division of Plastic Surgery), each specialist performs different parts of the procedure. That includes connecting arteries and veins using microvascular techniques, to attaching muscles and repairing nerves. The Gift of Life Donor Program works with the hand transplant team to find appropriate organs.

Patient Updates

For those with hand or arm amputations, hand transplants can significantly improve quality of life by restoring independent function.

Penn's Hand Transplant Program performed its first bilateral hand transplantation procedure on a quadruple amputee adult patient Lindsay Ess in 2011. Prior to surgery, Lindsay was dependent on her mother to help her with many everyday activities. Now, six years following surgery, Lindsay lives on her own with complete autonomy. Over and above Lindsay's ability to now be self-reliant, she essentially lives the life of any other average person her age — even competing in crossfit weightlifting competitions.

The benefits of VCA may be even more valuable when the patient is a young child. Yet few institutions worldwide have the expertise to conduct hand transplants for either adults or children. In July 2015, Zion Harvey became the world's first successful pediatric recipient of a bilateral hand transplant through a procedure conducted by specialists from the Penn Hand Transplant Program, Children's Hospital of Philadelphia (CHOP), and Shriners Hospital for Children.

Zion was eight years old at the time of the surgery and was on immunosuppressants from an earlier kidney transplant. He had lost his hands and feet at age two due to severe sepsis. The complex hand transplant surgery gave him new hands and forearms. Today, after more than a year of intensive occupational and neurological rehabilitation at CHOP, and Kennedy Krieger Institute near his home in Baltimore, the energetic boy can write, feed himself, throw a ball, and zip his clothes. His new hands have given him back his childhood and will grow with him.

(C) Dr. Levin leading a VCA practice session in the Penn Human Tissue Laboratory. (D) Lindsay Ess, competing in a crossfit competition. (E) Laura Nataf, the first international VCA recipient in the U.S., 4 months following surgery.

"He has no rejection," Dr. Levin said. "He is back in school, playing sports like baseball and basketball. He continues to improve, month after month."

The Penn and CHOP hand transplant team follows Zion, caring for his health and monitoring his progress. "Just like any other transplant patient, his life is normalized to a big degree," said Dr. Levin. The team is also learning much from Zion's experience that will contribute to future work with other children.

In August 2016, Penn's hand transplant program coordinated a team of more than 30 orthopaedic, plastic and transplant surgeons, nurses, anesthesiologists, and others to conduct a third bilateral hand transplant on a 28-year-old French woman —Laura Nataf. She was the first international patient to have the surgery in the U.S. Afterwards, the patient participated in physical and occupational therapy at Penn while she was recuperating in the United States and then continued her therapy regimen when she returned to France.

The Future of Hand Transplantation

The team has been able to refine approaches and reduce the time needed for the operations by practicing in Penn's Human Tissue Lab. The program's first hand transplant took 12 hours. Zion's surgery required 10-1/2 hours. The most recent procedure needed only 8-1/2 hours.

Penn's hand transplant specialists expect to see the adult transplantation program grow and are evaluating additional adult patients, though not pediatric patients at this time. Coverage from insurers will help more patients benefit from the life-changing surgery. The program also has active research interests funded by the Department of Defense and the Wyss Foundation, adding to its international reputation.

"With each successful transplant we learn a lot. Success breeds success. So far, all three of our patients have done well. They have been complex cases and, at times, difficult... but we have an amazing team at Penn Medicine and at the transplant institute. They have stood behind us all the way and that has made all the difference in the world."

– L. SCOTT LEVIN, MD, FACS

(F) Zion Harvey embraces his mother Pattie Ray

PENN ORTHOPAEDICS

SPECIALTY HIGHLIGHTS

Penn Orthopaedics provides patients with the most advanced comprehensive diagnostic, surgical and rehabilitative treatments in nine specialties. The following are recent highlights from each specialty—including the renowned McKay Orthopaedic Research Laboratory and The Children's Hospital of Philadelphia (CHOP).

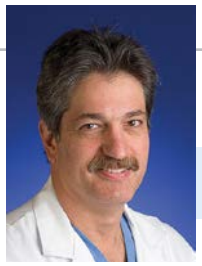
17
LOCATIONS

74
FULL-TIME FACULTY

12,702
TOTAL CASES

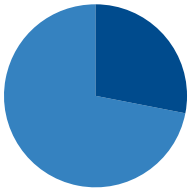
92,105
PATIENT VISITS

» Foot and Ankle



Section Chief:
Keith L. Wapner, MD

- In conjunction with L. Scott Levin, MD, FACS, the Foot and Ankle service continues to utilize vascularized bone grafts and combined bone and myocutaneous aps for reconstruction surgery.
- The Foot and Ankle service is conducting research with Penn Radiology utilizing the new technology of standing, weight bearing CAT scans and Dynamic Ultrasound for evaluation of surgical results.
- Kathryn O'Connor, MD, joined the Foot and Ankle Service in 2016 and practices at the Penn Musculoskeletal Center at Penn Medicine University City.
- Daniel C. Farber, MD, continues to serve as member at large to the Board of the American Academy of Orthopaedic Surgeons. The faculty has also participated on committees for the American Academy of Orthopaedic Surgeons and the American Orthopaedic Foot and Ankle Society.



2016 PATIENT VISITS: 17,868

2016 PATIENT SURGICAL VOLUME: 1,185

- Inpatient: 333
- Outpatient: 852

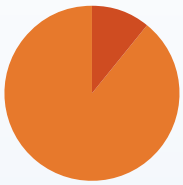
- Keith L. Wapner, MD, has presented 17 talks at national and international meetings including the Chinese Orthopedic Society, the Combined Orthopedic Associations, Cape Town, South Africa and the 5th International Conference on Joint Replacement, Dubai, UAE. Dr. Wapner and Dr. Levin also presented at the American College of Surgeons Annual Meeting on the Advancement of Care for the Diabetic Foot.

Selected Articles // Fryhofer GW, Freedman BR, Hillin CD, Salka NS, Pardes AM, Weiss SN, Farber DC, Soslowsky LJ. **Postinjury biomechanics of Achilles tendon vary by sex and hormone status.** J Appl Physiol (1985). 2016 Nov 1;121(5):1106-1114. doi: 10.1152/japplphysiol.00620.2016. // Freedman BR, Gordon JA, Bhatt PB, Pardes AM, Thomas SJ, Sarver JJ, Riggin CN, Tucker JJ, Williams AW, Zanes RC, Hast MW, Farber DC, Silbernagel KG, Soslowsky LJ. **Nonsurgical treatment and early return to activity leads to improved Achilles tendon fatigue mechanics and functional outcomes during early healing in an animal model.** J Orthop Res. 2016 Apr 2. doi: 10.1002/jor.23253. [Epub ahead of print] // Almonroeder TG, Benson LC, O'Connor KM. **The Influence of a Prefabricated Foot Orthosis on Lower Extremity Mechanics During Running in Individuals With Varying Dynamic Foot Motion.** J Orthop Sports Phys Ther. 2016 Sep;46(9):749-55. doi: 10.2519/jospt.2016.6253. PMID: 27494054 // O'Connor KM, Johnson JE, McCormick JJ, Klein SE. **Clinical and Operative Factors Related to Successful Revision Arthrodesis in the Foot and Ankle. Foot Ankle.** Int. 2016 Aug;37(8):809-15. doi: 10.1177/1071100716642845. PMID: 27044542.

» Hand and Wrist

Section Chief:
David J. Bozentka, MD

- Under the direction of Dr. David R. Steinberg as hand and microsurgical fellowship director, two new Penn hand surgery fellows, Erwin Kruger, MD and Oded Ben-Amotz, MD, started their year of training.
- Dr. David J. Bozentka has been elected to the Academy of Master Clinicians at the Perelman School of Medicine at the University of Pennsylvania. The Academy of Master Clinicians is the highest clinical honor for a Penn Medicine physician. The Academy recognizes outstanding physicians that exemplify the highest standards in patient care and professionalism.
- Dr. Benjamin L Gray is pursuing a Masters of Science in Clinical Epidemiolgy. He has presented on tendon injuries at the American Association for Hand Surgery annual meeting and continues to expand his clinical outcomes research.
- Dr. David Steinberg is the principle investigator for the blinded randomized control trial to compare Tylenol 3 versus Ibuprofen/Acetaminophen for pain control and patient satisfaction after ambulatory hand surgery. The group is actively enrolling patients at this time.



2016 PATIENT VISITS: 10,386

2016 PATIENT SURGICAL VOLUME: 1,846

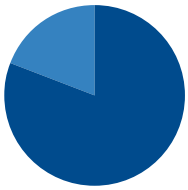
- Inpatient: 201
- Outpatient: 1,645

Selected Publications // Kazmers NH, Thibaudeau S, Levin LS.A **Scapholunate Ligament-Sparing Technique Utilizing the Medial Femoral Condyle Corticocancellous Free Flap to Reconstruct Scaphoid Nonunions With Proximal Pole Avascular Necrosis.** J Hand Surg Am. 2016 Jul 16. // Thibaudeau S, Serebrakian AT, Gerety PA, Levin LS. **An Algorithmic Approach to the Surgical Treatment of Chronic Ischemia of the Hand: A Systematic Review of the Literature.** Plast Reconstr Surg. 2016 May;137(5): // Slaughter J, Bozentka DJ, **Management of Burns.** In Chung KCC, Murray PM, eds. Hand Surgery Update VI, Rosemont, IL; American Society for Surgery of the Hand, 2016. // Fisher MB, Belkin NS, Milby AH, Henning EA, Söegaard N, Kim M, Pfeifer C, Saxena V, Dodge GR, Burdick JA, Schaer TP, Steinberg DR, Mauck RL. **Effects of Mesenchymal Stem Cell and Growth Factor Delivery on Cartilage Repair in a Mini-Pig Model.** Cartilage. 2016 Apr;7(2):174-84. // Saxena V, Kim M, Keah NM, Neuwirth AL, Stoeckl BD, Bickard K, Restle DJ, Salowe R, Wang MY, Steinberg DR, Mauck RL. **Anatomic Mesenchymal Stem Cell-Based Engineered Cartilage Constructs for Biologic Total Joint Replacement.** Tissue Eng Part A. 2016 Feb;22(3-4):386-95.

» Joint Replacement

Section Chief:
Charles L. Nelson, MD

- In May 2016, Penn Orthopaedics held the 4th Annual Philadelphia Revision Hip and Knee CME Course in partnership with the International Congress for Joint Replacement (ICJR). Penn Orthopaedics and ICJR also organized the 4th Annual ORTI—East Orthopaedic Resident Skills Course—designed to provide residents with basic concepts and skills for primary hip and knee replacement.
- Atul Kamath, MD was one of four orthopaedic surgeons internationally to receive the prestigious Hip Society Rothman-Ranawat Traveling Hip Fellowship.
- Gwo-Chin Lee, MD won the best health policy poster award at the American Association of Hip and Knee Surgeons annual meeting in November, 2015.
- Penn Joint Replacement faculty members presented at most major adult reconstruction scientific meetings including the Knee Society Members meeting, the American Association of Hip and Knee Surgeons annual meeting, the American Academy of Orthopaedic Surgeons annual meeting, and the Combined Meeting of Orthopaedic Societies in Capetown, South Africa.



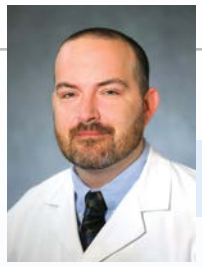
2016 PATIENT VISITS:
23,094

2016 PATIENT SURGICAL VOLUME: 4,155

- Inpatient: **3,364**
- Outpatient: **791**

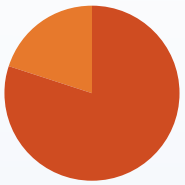
Selected Articles // Elkassabany, N, Ahmed, M, Nelson, CL, Israelite, CL, Badiola, I, Hughes, C, Williams, R, Liu, J. **Risk of Falls after Total Knee Arthroplasty with the Use of Femoral Nerve Block versus Adductor Canal Block; A Double Blinded Randomized Controlled Study.** Anesthesia and Analgesia, 122: 1696-1703, 2016. // Steadman, R, Lim, D, Husain, A, Courtney, PM, Nelson, CL. **Single component revisions are associated with dislocation after revision total hip arthroplasty at intermediate-term follow-up.** Hip International, 26: 233-6, 2016. // Courtney, PM, Rozell, JC, Melnic, CM, Sheth, NP, Nelson, CL. **The effect of malnutrition and obesity on complication rates following primary joint replacement.** J Surg Orthop Adv, 25 (2): 1-6, Summer, 2016. // Sheth, NP, Melnic, CM, Paprosky, WG. **Evaluation and management of chronic hip instability.** Bone Joint J. 2016 98-B (1 Suppl A):: 44-9. // Courtney, PM, Howard M, Goyal, N, Schwarzkkopf, Schnauser, E, Sheth, NP. **How much do patients value total hip and knee arthroplasty? A prospective multi-center study.** J Arthrop. 2016: 562-6. // Courtney, PM, Ashley, BS, Hume, EL, Kamath, AF. **Are bundled payments a viable reimbursement model for revision total joint arthroplasty?** Clin Orthop and Rel Res, 2016, Jun 29, Epub ahead of print. // Wagner, ER, Kamath, AF, Fruth, KM, Harmsen, WS, Berry, DJ. **Effect of body mass index on complications and reoperations after total hip arthroplasty.** J Bone Joint Surg Am 2016: 169-79.

» Neuro Orthopaedics



Section Chief:
Keith D. Baldwin, MD, MPH, MSPT

- Penn Neuro Orthopaedics hosted this year's annual meeting of the Orthopaedic Rehabilitation association on November 12, 2016.
- Represented the Orthopaedic Rehabilitation organization at the National Orthopaedic Leadership Conference for the Board of Orthopaedic Specialties, Presidential line/ Health Policy.
- This year, we maintained Section editorship for the Journal of Bone and Joint Surgery Reviews for the Rehabilitation section, and also wrote the "What's New in Orthopaedic Rehabilitation" article for the Journal of Bone and Joint surgery.
- Partnered with Main Line Health (Bryn Mawr Rehabilitation) to bring excellent neuro orthopaedic care to the suburban community.



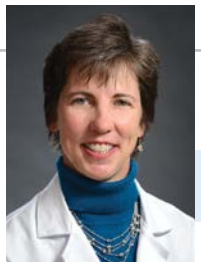
2016 PATIENT VISITS:
554

2015 PATIENT SURGICAL VOLUME: 116

- Inpatient: **93**
- Outpatient: **23**

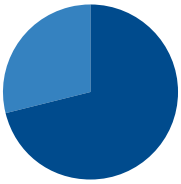
Selected Articles // Georgiadis, AG; Spiegel, DA; Baldwin, KD. **The Cavovarus Foot in Hereditary Motor and Sensory Neuropathies.** J Bone Joint Surg Reviews 2015 Vol 3 (12) epub PMID 274900994. // Refakis, CA; Baldwin, KD; Spiegel, DA; Sankar, WN. **Treatment of the Dislocated Hip in Infants with Spasticity.** J Ped Orthop 2016 Epub ahead of print PMID: 27379781. // Kolman, S; Spiegel, D; Namdari, S; Hosalkar, H; Keenan, MA; Baldwin, K. **What's New in Orthopaedic Rehabilitation.** J Bone Joint Surg A 2015 97 (22) 1892-8. PMID 26582622. // Anari, JB; Spiegel, DA; Baldwin, KD. **Neuromuscular Scoliosis and Pelvic Fixation in 2015: Where do we stand?** World J Orthop 2015 6(8) 564-6 PMID: 26396932. // Kolman, S; Ruzbarsky, JJ; Spiegel DA; Baldwin, KD; **Salvage Options in the Cerebral Palsy Hip: A systematic review.** J Ped Orthop 2015 e pub ahead of print 25887836.

» Orthopaedic Oncology



Section Chief:
Kristy L. Weber, MD

- Kristy L. Weber, MD, Chief of Penn Orthopaedic Oncology, was recently elected as 2nd Vice President of the American Academy of Orthopaedic Surgeons and will serve as President in 2019.
- Multidisciplinary Sarcoma Conference – weekly with 7 departments attending the conference to discuss care of patients (team-based approach).
- The Penn Orthopaedic Oncology service and Children's Hospital of Philadelphia (CHOP) continue to build a collaborative orthopaedic oncology program alongside CHOP oncology surgeon Alex Arkader, MD.
- Penn has now assembled an excellent sarcoma research team with collaboration between Penn Medicine, Penn Vet, and CHOP and are applying for an Abramson Cancer Center (ACC) Translational Center of Excellence grant (TCE).



2016 PATIENT VISITS: 1,002

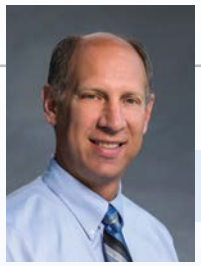
2016 PATIENT SURGICAL VOLUME: 125

- Inpatient: 89
- Outpatient: 36

- Dr. Weber recently served on the Boards of Directors of the Orthopaedic Research Society (ORS - Secretary), Ruth Jackson Orthopaedic Society (RJOS - Past President), Musculoskeletal Tumor Society (MSTS - Past President) and American Orthopaedic Association (AOA - Critical Issues Committee Chair). She also serves on Faculty of ICL at 2016 AAOS meeting on TeamStepps Training (Patient Safety/Teamwork course).
- Dr. Weber and Dr. Mason: Osteosarcoma Immunotherapy. Zoobiquity Conference 6, University of Pennsylvania School of Veterinary Medicine, April 2, 2016.

Selected Articles // Baumann BC, Nagda SN, Kolker JD, Levin WP, Weber KL, Berman AT, Staddon A, Hartner L, Hahn SM, Glatstein E, and Simone CB: **Efficacy and Safety of Stereotactic Body Radiation Therapy for the Treatment of Pulmonary Metastases From Sarcoma: A Potential Alternative to Resection.** J Surg Oncol, 2016. // McGrory B, Weber K, Lynott JA, Richmond JC, Davis CM 3rd, Yates A Jr, Kamath AF, Dasa V, Brown GA, Gerlinger TL, Villanueva T, Piva S, Hebl J, Jevsevar D, Shea KG, Bozic KJ, Shaffer W, Cummins D, Murray JN, Donnelly P, Patel N, Brenton B, Shores P, Woznica A, Linskey E, Severino K: **The American Academy of Orthopaedic Surgeons Evidence-Based Clinical Practice Guideline on Surgical Management of Osteoarthritis of the Knee.** J Bone Joint Surg. 98(8):688-92, 2016. // Ju, B, Weber K, Khoury V: **Ultrasound-guided therapy for Knee and Foot Ganglion Cysts.** J Foot Ankle Surg, June, 2016 (epub ahead of print). // McGrory BJ, Weber KL, Jevsevar DS, Severino K: **Surgical Management of Osteoarthritis of the Knee: Evidence Based Guideline.** J Amer Acad Ortho Surg, June, 2016 (epub ahead of print). // Weber KL, Jevsevar DS, McGrory BJ: **AAOS Clinical Practice Guideline: Surgical Management of Osteoarthritis of the Knee: Evidence Based Guideline.** J Amer Acad Ortho Surg, June, 2016 (epub ahead of print). // Weber KL: **Narrowing the Gender Gap in Orthopaedic Surgery.** Electronic Article on the University of Pennsylvania website (front page), February, 2016. http://www.upenn.edu/spotlights/narrowing-gender-gap-orthopedic-surgery.

» Research



Section Chief:
Louis J. Soslowsky, PhD

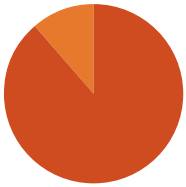
- Robert L Mauck, PhD was named Mary Black Ralston Professor for Education and Research in Orthopaedic Surgery.
- Eileen M. Shore, Ph.D. served as section editor for Rare Diseases – Current Osteoporosis Reports.
- The Penn Center for Musculoskeletal Disorders was the recipient of five more years of continued support from the NIH P30 grant.
- Xiaowei Sherry Liu, PhD co-taught new course "Musculoskeletal Biology and Bioengineering."

Selected Articles // Han WM*, Heo SJ*, Driscoll TP, Delucca JF, McLeod CM, Smith LJ, Duncan RL, Mauck RL+, Elliott DM+, **Microstructural heterogeneity in native and engineered fibrocartilage directs tissue micromechanics and mechanobiology,** 2016, Nature Materials, 15(4):477-84. *co-first authors, +co-corresponding authors. // Cote AJ*, McLeod CM*, Farrell MJ, McClanahan PD, Dunagin MC, Raj A+, Mauck RL+, **Single Cell Differences in Matrix Gene Expression Do Not Predict Matrix Deposition.** 2016, Nature Communications, 7:10865. *co-first authors, +co-corresponding authors. // Singh, L., Brennan, T.A., Russell, E., Kim, J-H., Chen, Q., Johnson, F.B., Pignolo, R.J.: **Aging alters bone-fat reciprocity by shifting in vivo mesenchymal precursor cell fate toward an adipogenic lineage.** Bone 85:29-36, 2016. // Wang, H., Lindborg, C.M., Lounev, V., Kim, J-H., McCarrick-Walmsley, R., Xu, M., Mangiavini, L., Groppe, J.C., Shore, E.M., Schipani, E., Kaplan, F.S., Pignolo, R.J.: **Cellular hypoxia promotes heterotopic ossification by amplifying BMP signaling.** Journal of Bone and Mineral Research Online Apr 20, 2016. Notes: DOI: 10.1002/jbmr.2848. // Chakkalakal, S.A., K. Uchibe, M. Convente, D. Zhang, A. Economides, F.S. Kaplan, M. Pacifici, M. Iwamoto, E.M. Shore (2016). **Palovarotene inhibits heterotopic ossification and maintains limb mobility and growth in mice with the human ACVR1R206H FOP mutation.** JBMR, epub February 20, 2016. // Pacifici, M. and E.M. Shore. **Common mutations in ALK2/ACVR1, a multi-faceted receptor, have roles in distinct pediatric musculoskeletal and neural disorders.** Cytokine and Growth Factor Reviews 27, 93-104. // Rooney, S.I., Soslowsky, L.J.: **Genetic Response of Rat Supraspinatus Tendon and Muscle to Exercise.** Plos One Oct; 10(10) 2015 (PMC4598142). // Connizzo, B., Han, L., Birk, D.E., Soslowsky, L.J.: **Collagen V-heterozygous and -null supraspinatus tendons exhibit altered dynamic mechanical behaviour at multiple hierarchical scales.** Interface Focus; 6;6(1) 2016 (PMC4686235).

» Shoulder & Elbow

Section Chief:
David L. Glaser, MD

- Penn Shoulder and Elbow Service Director of Research Andrew F. Kuntz, MD, serving as PI, received an ASES research grant to study the "Effects of Aging on Tendon Cell Metabolism" including "Effects of Autologous Juvenile, Adult, and Aged Tenocyte-Seeded Nanofibrous Scaffolds in Rotator Cuff Repair" funded by the Penn Institute on Aging, presented at 2016 ORS Annual Meeting by Julianne Huegel, PhD, and received the New Investigator Research Award honors. Clinical studies include multimodal pain control, outpatient shoulder arthroplasty, long term outcomes of prosthetic implants and cost efficiency in delivering health care. Penn selected as study site to investigate 10-year outcomes of Integra Titan Reverse Shoulder Prosthesis.
- G. Russell Huffman, MD, MPH, completed his 40th Tommy John with his novel technique using 2 cortical buttons, including having a patient 3 years out drafted by the Cincinnati Reds.
- The Penn shoulder and elbow faculty presented 14 abstracts at national meetings, giving 13 talks at international, national, regional, and local meetings in 2016.



2016 PATIENT VISITS: 7,373

2016 PATIENT SURGICAL VOLUME: 967

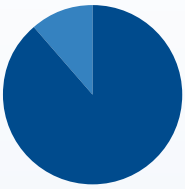
- Inpatient: 245
- Outpatient: 722

Selected Articles // Tucker, J.J., Riggin, C.N., Connizzo, B.K., Mauck, R.L., Steinberg, D.R., Kuntz, A.F., Soslowsky, L.J. and Bernstein, J., 2016. **Effect of overuse- induced tendinopathy on tendon healing in a rat supraspinatus repair model**. Journal of Orthopaedic Research, 34(1), pp.161-166. // Rooney, S.I., Baskin, R., Torino, D.J., Vafa, R.P., Khandekar, P.S., Kuntz, A.F. and Soslowsky, L.J., 2016. **Ibuprofen Differentially Affects Supraspinatus Muscle and Tendon Adaptations to Exercise in a Rat Model**. The American journal of sports medicine, 44(9), pp.2237-2245. // Huegel, J., Kim, D.H., Cirone, J.M., Pardes, A.M., Morris, T.R., Nuss, C.A., Mauck, R.L., Soslowsky, L.J. and Kuntz, A.F., 2016. **Autologous tendon- derived cell- seeded nanofibrous scaffolds improve rotator cuff repair in an age- dependent fashion**. Journal of Orthopaedic Research. // Steinberger, Z., Xu, H., Kazmers, N.H., Thibaudeau, S., Huffman, R.G. and Levin, L.S., 2016. 2510: **Elbow vascularized composite allotransplantation-Surgical anatomy and technique**. Vascularized Composite Allotransplantation, 3(1-2), pp.35-37. // Wessel, L., Sykes, J., Anari, J.B. and Glaser, D., 2016. **Indications and Techniques for Double-Row Fixation**. In Elite Techniques in Shoulder Arthroscopy (pp. 211-226). Springer International Publishing.// Jing Zhao, MD; Zhenggang Guo, MD, PhD; Xiaowen Liu, MD; David L Glaser, MD; Nabil M Elkassabany, MD, MSCE; JIABIN LIU, MD, PhD **The development and application of risk stratification index system for outpatient shoulder arthroscopy patient management, a single academic center's experience**. Journal of Shoulder and Elbow Surgery in press.

» Spine

Section Chief:
Vincent Arlet, MD

- Penn Orthopaedics is now the only Adult Hospital in the Philadelphia region with EOS imaging capability. With EOS, patients get five times less radiation than with conventional Xrays, and surgeons are able to customize preop planning required for patients with spinal deformity and sagittal imbalance. EOS imaging will enable Penn to expand its Spinal deformity center to treat Adult patients, older Adolescent Scoliosis patients, and patients with increasingly complex spine conditions.
- Harvey E. Smith, MD was the recipient of the Career Development Award from the Biomedical Laboratory Research & Development Service of the VA Office of Research and Development and will serve as principal investigator. Dr. Smith was also awarded the "25 JMRI Papers That Have Stood the Test of Time" designation at the JMRI 25th Anniversary Celebration in Singapore. Dr. Smith became a member of three national professional and scientific societies in 2016: The Orthopedic and Rehabilitation Devices Panel Advisory Committee of the Food and Drug Administration (Advisory Committee), the American Orthopaedic Association, and the Hospital University of Pennsylvania Medical Legal Committee.



2016 PATIENT VISITS: 2552

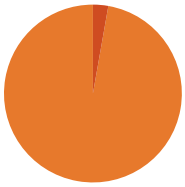
2016 PATIENT SURGICAL VOLUME: 426

- Inpatient: 378
- Outpatient: 48

Selected Articles // Saville PA, Kadam AB, Smith HE, **Arlet V. Anterior hyperlordotic cages: early experience and radiographic results.** J Neurosurg Spine. 2016 Dec;25(6):713-719. // Saville PA, Anari JB, Smith HE, **Arlet V. Vertebral body fracture after TLIF: a new complication.** Eur Spine J. 2016 May;25 Suppl 1:230-8. doi: 10.1007/s00586-016-4517-1. // Saville PA, Anari J, Smith HE, Arlet V: **Vertebral body fracture after TLIF: a new complication.** European Spine Journal March 2016 // Saville P, Kadam A, Smith HE, Arlet V: **Anterior Hyperlordotic Cages: Early Experience and Radiographic Results.** Global Spine Journal 6(S 01), April 2016. // Wigner N, Saville P, Kadam A, Smith HE, Arlet V: **Overpowering Posterior Instrumentation and Fusion using a Modified Anterior Lumbar Interbody Fusion Technique, An Experience of 11 Cases.** Global Spine Journal 6(S 01), April 2016. // Gullbrand SE, Ashinsky BG, Martin JT, Pickup S, Smith LJ, Mauck RL, Smith HE: **Correlations Between Quantitative T2 and T1 MRI, Mechanical Properties and Biochemical Composition in a Rabbit Lumbar Intervertebral Disc Degeneration Model.** Journal of Orthopaedic Research 2016 Notes: in press. // Martin JT, Milby AH, Pfeifer CG, Kim DH, Smith LJ, Elliott DM, Smith HE, Mauck RL: **In vivo Performance of an Acellular Disc-Like Angle Ply Structure (DAPS) for Total Disc Replacement in a Small Animal Model.** Journal of Orthopaedic Research 2016 Notes: in press. // Mok JM, Martinez M, Smith HE, Sciubba DM, Passias PG, Schoenfeld AJ, Isaacs RE, Vaccaro AR, Radcliff KE: **Impact of a Bundled Payment System on Resource Utilization During Spine Surgery.** International Journal of Spine Surgery 2016 Notes: In Press. // Radcliff K, Smith HE, Kalantar B, Isaacs R, Woods B, Vaccaro AR, Brannon J: **Feasibility of Endoscopic Inspection of Pedicle Wall Integrity in a Live Surgery Model.** International Journal of Spine Surgery 2016 Notes: in press. // Milby AH, Smith HE: **Cervical spine fusion in rheumatoid arthritis. 50 Studies Every Spine Surgeon Should Know.** Vaccaro AR, Wilson JR, Fisher CG (eds.). 2016. // Woodard CC, Smith HE: **Posterior Approach to the Cervical Spine and Craniocervical Junction.** Surgical Atlas of Spinal Operations, 2nd edition. Vaccaro AR, Eck J (eds.). 2016.

» Sports Medicine

Section Chief:
Brian J. Sennett, MD



2016 PATIENT VISITS: 13,737

2016 PATIENT SURGICAL VOLUME: 1,683

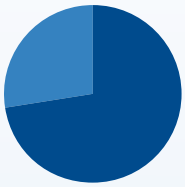
- Inpatient: 50
- Outpatient: 1,633

- The Penn Center for the Female Athlete, directed by Kate E. Temme, MD and Ellen K. Casey, MD, CAQSM, FACSM (joined faculty 2016), will be the first full clinical and academic center of its kind. Many educational and research initiatives are underway including Dr. Casey's NIH grant "Exploring the Modulatory Role of Sex Hormones along the Neuromechanical Axis in Females".
- John Vasudevan, MD served as medical director for the Tri-rock Philly Triathlon held in June, 2016, Rahul Kapur, MD continues to serve as the medical director for the Penn Relays, and Alexis S. Tingan, MD, CAQSM (joined faculty 2016), will serve as the Philadelphia Love Run Half-Marathon medical director. Dr. Sennett continues to serve as a medical advisor to the Philadelphia 76ers.
- The Penn Center for Advanced Cartilage Repair and Osteochondritis Dissecans Treatment is now recognized as one of the pre-eminent cartilage restoration centers nationally – becoming #3 in the nation for volume of autologous chondrocyte implantation surgeries. James L. Carey, MD, MPH, Robert L Mauck, PhD, and Jason A. Burdick, PhD have been awarded the $250,000 AOSSM Biologics II Research Grant focusing on the "Acellular Bioactive and Dynamic Nanofibrous Scaffolds to Promote Cartilage Repair." The Penn Center for Cartilage Symposium, run by Course Directors Drs. Carey and Mauck, has become an international course attended by a record 197 participants.
- The third annual Penn Medicine's Advances in Throwing Conference was held on January 21, 2017, featuring a multidisciplinary approach to the evaluation and treatment of pathologies related to the throwing athlete, under the leadership of Co-Directors Miltiadis Zgonis, MD and Kyle Schaefer, ATC.

Selected Articles // Carey JL, Wall EJ, Grimm NL, Ganley TJ, Edmonds EW, Anderson AF, Polousky J, Murnaghan ML, Nissen CW, Weiss J, Lyon RM, Chambers HG. **Novel arthroscopic classification of osteochondritis dissecans of the knee: a multicenter reliability study.**; Research in OsteoChondritis of the Knee (ROCK) Group. Am J Sports Med. 2016; 44:1694-8. // Garcia GH, Wu HH, Park MJ, Tjoumakaris FP, Tucker BS, Kelly JD 4th, Sennett BJ. **Depression Symptomatology and Anterior Cruciate Ligament Injury: Incidence and Effect on Functional Outcome--A Prospective Cohort Study.** Am J Sports Med. 2016 Mar;44(3):572-9.PMID: 26628516. // Saxena V, D'Aquilla K, Marcoon S, Krishnamoorthy G, Gordon JA, Carey JL, Borthakur A, Kneeland JB, Kelly JD 4th, Reddy R, Sennett BJ. **T1 Magnetic Resonance Imaging to Assess Cartilage Damage After Primary Shoulder Dislocation.** Am J Sports Med. 2016 Jul 27. PMID: 27466221. // Garcia GH, Wu HH, Liu JN, Huffman GR, Kelly JD. **4th Outcomes of the Remplissage Procedure and Its Effects on Return to Sports: Average 5-Year Follow-up.** Am J Sports Med. 2016 May;44(5):1124-30. doi: 10.1177/0363546515626199. Epub 2016 Feb 17. PMID: 26888881 // McHale KJ, Rozell JC, Milby AH, Carey JL, Sennett BJ. **Outcomes of Lisfranc Injuries in the National Football League.** Am J Sports Med. 2016 Jul;44(7):1810-7.PMID: 27166291.

» Trauma and Fracture

Section Chief:
Samir Mehta, MD



2016 PATIENT VISITS: 5,982

2016 PATIENT SURGICAL VOLUME: 1,505

- Inpatient: 1,095
- Outpatient: 410

- Orthopaedic trauma and fracture faculty have engaged in leadership positions at a national and international level. Samir Mehta, MD, serves on the AO Foundation Community Development Committee, Orthopaedic Trauma Association Health Policy Committee and Education Committee, and as vice Chair, CORD of the American Orthopaedic Association. Jaimo Ahn, MD, PhD, serves on the American Orthopaedic Association Fellowship / Leadership Committee, Foundation for Orthopaedic Trauma Board of Directors and as research chair, and as an NIH consultant reviewer. Dr. Mehta and Dr Ahn as well as Derek J. Donegan, MD, all serve as journal reviewers for CORR, JBJS, JOT, and COP.
- In 2016, Dr. Donegan received the AO North America – Howard Rosen Teaching Award and the American Health Council – Best in Health Care Award. Dr. Mehta received the Chairman's Award and was named medical director of the Biedermann Orthopaedic Lab with the goal of quickly turning research into results for patients.
- Penn Orthopaedic Trauma and Fracture was awarded several grants in 2016 including the REGAIN Trial from PCORI, HEALTH, FAITH, METRC consortium, FOT, and Synthes.

Selected Articles // Scolaro JA, Broghammer FH, Donegan DJ. **Intramedullary Tibial Nail Fixation of Simple Intraarticular Distal Tibia Fractures**. J Orthop Trauma. 2016 Nov;30 Suppl 4:S12-S16. // Bernstein J, Kupperman E, Kandel LA, Ahn J. **Shared Decision Making, Fast and Slow: Implications for Informed Consent, Resource Utilization, and Patient Satisfaction in Orthopaedic Surgery**. Journal of the American Academy of Orthopaedic Surgeons, 24:495-502. 2016. // Neuman MD, Mehta S, Bannister ER, Hesketh PJ, Horan AD, Elkassabany NM. **Pilot Randomized Controlled Trial of Spinal Versus General Anesthesia for Hip Fracture Surgery**. J Am Geriatr Soc. 2016 Dec;64(12):2604-2606. // Swart E, Laratta J, Slobogean G, Mehta S. **Operative Treatment of Rib Fractures in Flail Chest Injuries: A Meta-analysis and Cost-Effectiveness Analysis**. J Orthop Trauma. 2017 Feb;31(2):64-70. // Schenker ML, Baldwin KD, Israelite CL, Levin LS, Mehta S, Ahn J. **Selecting the Best and Brightest: A Structured Approach to Orthopedic Resident Selection**. J Surg Educ. 2016 Sep-Oct;73(5):879-85.

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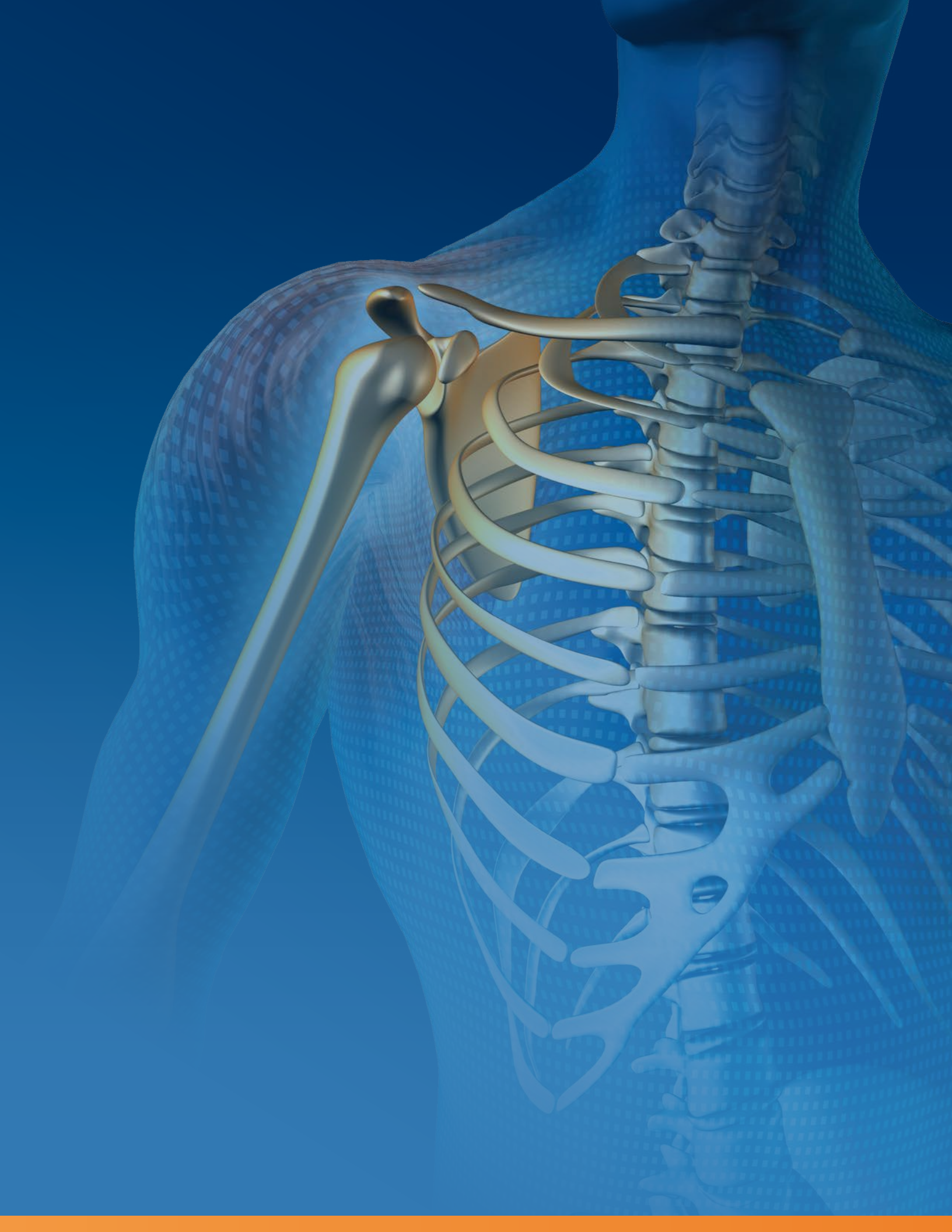

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