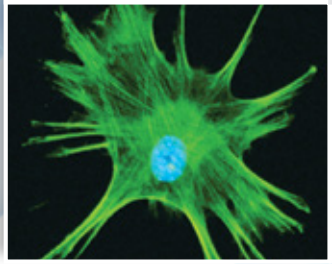
Penn Medicine

PENN ORTHOPAEDICS

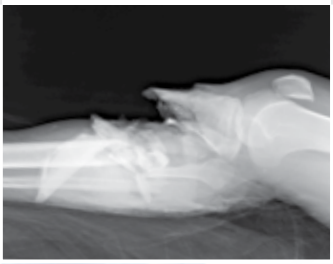
EXCELLENCE *IN MOTION* 2014

WHEN PENN ORTHOPAEDICS MOVES FORWARD, SO DOES EVERYONE ELSE.

Cartilage Engineering – Page 3



Debridement Urgency – Page 12



Vascularized Free Flaps – Page 8

Emergent Arthroplasties – Page 9

INSIDE THIS ISSUE

Introducing >>>

The Penn Center for Human Performance

Page 6

LETTER FROM THE CHAIR

Source: Sabina Louise Pierce

To my Colleagues,

It gives me great pride to present the 2014 edition of ***Excellence in Motion***, the newsletter of Penn Orthopaedics.

This issue arrives at a pivotal time in the history of Penn Orthopaedics, where the past year marked a continuing trend of excellence in academics, research and practice. Penn Orthopaedics not only garnered professional awards and honors this year, but attracted some of the top talent in the region, including Kristy Weber, MD, from Johns Hopkins Medicine. Dr. Weber is now Director of Orthopaedic Oncology/ Chair for Faculty Affairs. These additions reflect our continuing trend of appointing surgeon-scientists to our faculty.

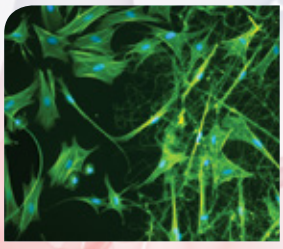
Excellence in Motion offers a synopsis of the advances in orthopaedic and musculoskeletal research and clinical practice now taking place at Penn Medicine, as well as the achievements of the erudite and distinguished men and women of Penn Orthopaedics. In this edition, we report the pioneering work of Robert L. Mauck, PhD, and his colleagues at Penn's McKay Orthopaedic Research Laboratory as they develop the constructs for cartilage engineering; note the applications of the medial femoral condyle free flap for foot and ankle reconstruction; explore a reconsideration of the timing for debridement of open fractures as represented in current clinical guidelines; and discuss a variety of other clinical advances and innovations at Penn Orthopaedics.

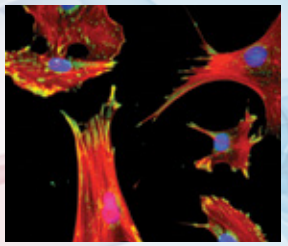
In 2013, construction began for Penn Medicine University City, a facility that will house the Penn Musculoskeletal Center. Slated to open in mid-2014, the multidisciplinary Penn Musculoskeletal Center is designed to create an ideal environment for integrated patient-focused musculoskeletal care and collaboration among health professionals. Additionally, the new Penn Cartilage Center will be established under the direction of James Carey, MD, and will contain the Penn Center for Advanced Cartilage Repair and Osteochondritis Dissecans Treatment.

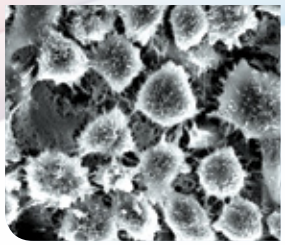
Over and above these advances and developments, we look forward in the year ahead to building stronger, lasting relationships with our referring physicians and peers in the orthopaedic community nationwide.

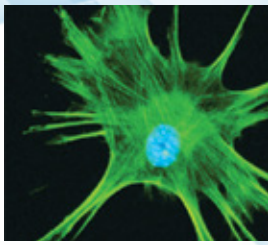
L. Scott Levin, MD, FACS

Chair, Department of Orthopaedic Surgery
Paul B. Magnuson Professor of Bone and Joint Surgery
Professor of Surgery, Division of Plastic Surgery









Cartilage Engineering

in the McKay Orthopaedic Research Laboratory

The development of engineered cartilage has been a focus of the McKay Orthopaedic Research Laboratory at Penn Orthopaedics for more than a decade.

Led by Robert L. Mauck, PhD, Jason A. Burdick, PhD and George R. Dodge, PhD, who, with their clinical colleagues James L. Carey, MD, and David R. Steinberg, MD, specialize in Tissue Engineering and Regenerative Medicine (TERM), researchers at the McKay Laboratory have been investigating methods to overcome the prevailing obstacles to engineered cartilage development, challenges that arise directly from the physiology of cartilage.

The physiology of the hyaline cartilage of the joints predisposes this tissue to permanent and debilitating erosion following injury. Because cartilage has little regenerative capacity, and cells within have little migratory potential and no vascular supplement, the tissue tends to degenerate rather than heal once injured. Once damage occurs in one region, excessive load-bearing on the adjacent cartilage precipitates the continued loss of mechanical properties and biochemical content in adjacent tissue and throughout the joint. Collectively, these events engender the onset of degenerative osteoarthritis.

Cartilage is a unique tissue comprised of cells (chondrocytes) that are sparsely dispersed in a dense extracellular matrix composed of collagen and proteoglycans. Together, the cells and their matrix form a strong, resilient tissue that can withstand the very high loads that are generated with normal daily activities. Since hyaline cartilage (hereinafter *cartilage*) has no vascular supply in adults, however, very little regeneration of the tissue occurs once cartilage is damaged, and so the functional properties of the tissue are not restored over time.

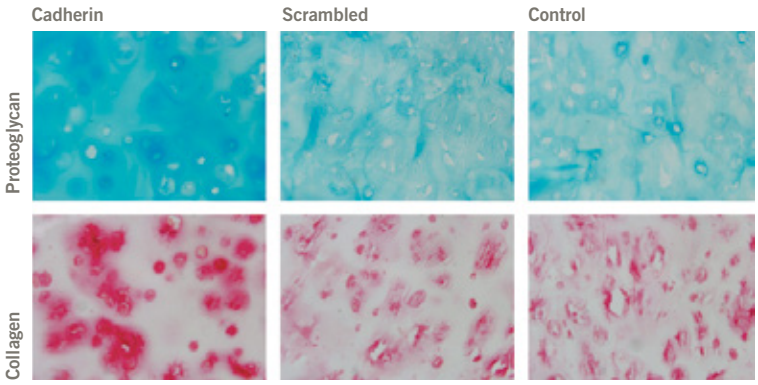
Current surgical strategies to repair native cartilage include the delivery of *ex vivo* autologous chondrocytes (a procedure referred to as autologous chondrocyte implantation, or ACI) and bone marrow stimulation (microfracture). These techniques can improve patient outcomes in the short-term, but have yet to demonstrate functional restoration of cartilage over large areas. To address these limitations and to create a fully functional engineered cartilage product, researchers at McKay aim to recreate both the cellular composition and the mechanical properties of the native tissue. They are not alone in this effort: a recent review of TERM publications authored by Dr. Mauck and Matthew B. Fisher, PhD, found almost 4,000 original articles in 2010 alone focused on regenerative therapeutics for a wide range of tissue damage and disease.

TERM research in engineered cartilage at the McKay Laboratory is following two primary approaches: the generation of scaffold-based and scaffold-free constructs. Scaffold-based methods include the use of natural and synthetic hydrogels infused with chondrocytes or stem cells and other cues (i.e. growth factors) to guide and stimulate cartilage formation. Scaffold-free methods use high cell density cultures in combination with low adhesion surfaces, bioreactors or centrifugation methods to form aggregates, pellets and micro-tissues.

(continued on page 4)

Scaffold-based Constructs

Investigators using scaffold-based constructs at McKay commonly utilize adult mesenchymal stem cells (MSCs). A precursor cell population obtained from patient bone marrow, MSCs are multipotent progenitor cells that can be expanded *in vitro* to clinically relevant numbers for therapeutic application. Most importantly, MSCs can be induced to differentiate into a chondrocyte-like phenotype, and subsequently form tissue similar to the native tissue when combined with novel biomimetic hydrogel microenvironments.



MSC Interactions with Modified HA Hydogels Can Increase Matrix Formation
Proteoglycan (top row) and collagen (bottom row) deposition in HA hydrogels modified with a N-Cadherin peptides, with Scrambled peptides (a negative control), and in unmodified Control HA hydrogels. Scale bar: 100 microns.

The motivation for using progenitor cells arises from the limited number of healthy chondrocytes found in aged cartilage. Furthermore, native tissue chondrocytes, even from healthy young donors, have a tendency to dedifferentiate when expanded *in vitro* (i.e., they lose their cartilage-like matrix production as they divide). This suggests the need for additional physical and chemical cues to guide MSC chondrogenesis and to improve matrix production. Much of the work in the field of scaffold-based cartilage tissue engineering (at McKay and elsewhere) over the last decade has focused on the development of better materials to support the initial chondrogenic event and the rate and distribution of tissue formation.

Despite great progress in this area, MSC-based constructs still tend to reach a plateau in functional maturation at about eight weeks, and have yet to produce tissue that is equivalent to chondrocyte-laden constructs cultured identically. Previous studies at the McKay Laboratory showed that this plateau and the comparative lower properties of MSC-laden constructs were due in part to the lack of tissue elaboration and compromised stem cell health in central regions of constructs that were deprived of nutrients. While this deficit could be partially rescued by increasing nutrient supply as well as improved nutrient access during culture, the mechanical properties of MSC-laden constructs remained significantly lower than chondrocyte-laden constructs.

To determine whether mechanical strength could be enhanced via improvements in the supporting scaffolds for MSC constructs, McKay researchers and their colleagues in Bioengineering turned to hyaluronic acid (HA) hydrogels. Found in native cartilage tissue, HA is a large macromolecule that plays a critical role in anchoring proteoglycans in the cartilage extracellular matrix. HA can also be modified through methacrylation to enable formation of crosslinked hydrogels of varying density, mechanical stiffness and macromolecular diffusivity.

Importantly, because HA is native to cartilage, it is inductive to chondrogenesis via interaction with cell surface receptors found on both chondrocytes and MSCs, including CD44 and CD168. Sequential investigations at the McKay Laboratory have found that HA hydrogels fostered chondrogenic differentiation and matrix production; lower-concentration HA constructs were superior to higher concentrations in their capacity to foster MSC-engendered cartilage matrix dispersion; and the addition to the scaffolds of growth factors and agents that promote cell-cell interaction (i.e., N-cadherin mimetic peptides) further promoted cell differentiation and chondrogenesis.

However, even under the above described conditions, matrix elaboration and mechanical property increases have been found to peak at day 56 followed by catabolic declines by day 126, suggesting that instability may be an innate characteristic of MSCs *in vitro*, involving both loss of viability and phenotypic conversion, rather than a characteristic of the biomaterial employed. These findings highlight the limitations of *in vitro* culture, and points toward the need to transition these engineered tissues to the *in vivo* repair environment to assess their long term potential.

To better predict the probability of success of these scaffold-based MSC-seeded constructs upon implantation, recent investigations at the McKay Laboratory have focused on a trajectory-based tissue-engineering approach. Here, the investigators were seeking to determine whether time-dependent increases in construct maturation *in vitro* would provide a reliable predictor of *in vivo* success. Using HA hydrogels laden with MSCs, the researchers showed that integration of the engineered cartilage with native cartilage was not necessarily correlated with how robust the engineered tissue was at the time of implantation (i.e., its maturation state), but rather depended more directly on the trajectory of growth (i.e., its maturation rate). These recent findings provide a proof-of-concept for the use of trajectory-based tissue engineering to enhance treatment outcomes following cartilage injury, and this paradigm is now being tested in a large animal model of cartilage repair.

Scaffold-free Constructs

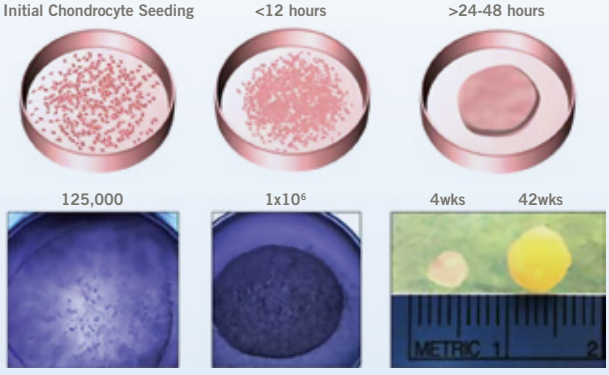
In addition to work focusing on materials to form engineered cartilage, investigations at McKay, led by Dr. Dodge, have also developmentally inspired approaches to form engineered cartilage without a material support. These scaffold-free methods combine high cell density cultures with low adhesion surfaces to form aggregates or micro-tissues resembling how cartilage forms during development. Using this technique, chondrocyte retain their phenotype, have numerous cell-cell interactions initially, and eventually elaborate a natural extra-cellular matrix (ECM) like the native cartilage tissue. Application of real-time mechanical loading to these scaffold-free constructs permits additional enhancement of ECM and thus improved cartilage-like characteristics.

McKay researchers previously developed a scaffold-free approach to cartilage tissue engineering posited on primary chondrocytes situated in hydrogel-coated culture vessels that prevent adhesion, thus promoting a self-aggregating suspension of cells that subsequently forms into a cartilage-like biomass. In this model, chondrocytes are cultured at high density; the tissue culture vessels are coated with poly 2-hydroxyethyl methacrylate (polyHEMA) that prevents cell attachment to the plastic substrate. Within 24 hours, chondrocytes coalesce to form stable constructs called cartilage tissue analogs (CTA) that remain in suspension and progressively increase in mass with time.

Chondrocytes in CTAs possess phenotypic characteristics and deposit ECM that is similar to native cartilage and can be produced from several species, including neonatal porcine, bovine, equine, and human chondrocytes. Moreover, CTAs in culture produce collagen type II but not collagen type I, which would be indicative of their dedifferentiation to a fibroblastic phenotype.

Schematic of CTA Fabrication

Chondrocytes seeded in 96 well plates begin to coalesce within 12h and form stable tissue analogs 24–48h post-seeding. CTAs 4h post-seeding show chondrocytes beginning to coalesce, form a mass and with increasing time, contract (125,000 chondrocytes/CTA), while higher seeding densities (1 million chondrocytes/CTA) result in more complete contraction and formation of a uniform construct. CTAs 4 and 42 weeks post-seeding are cylindrical in shape and relatively uniform in size.



In order to determine patterns of growth and maturation in this scaffold-free engineered cartilage, McKay researchers recently evaluated the temporal development of CTA's mechanical and biochemical properties and the relationship between mechanics and cell–matrix content. Maturing over a period of 24 weeks, the constructs took on cartilage-like characteristics and maintained biochemical integrity. The chondrocytes within the CTA produced a robust extracellular matrix that correlated with increasing mechanical strength and decreasing cell-matrix ratios, leading to properties resembling those of native cartilage. These results demonstrate a unique approach to generating a cartilage-like tissue, while showing increased compressive properties and matrix characteristics consistent with other approaches, including scaffold-based constructs.

To further improve the mechanics of CTAs, studies are currently underway at Penn to explore the effect of hydrodynamic loading and whether these changes would be reflective of *in vivo* maturation in animal models.

Future Outlook

Great progress has been made over the last decade in the engineering of cartilage tissues, both in the McKay Labs at Penn Medicine and across the country. Whether these approaches use material supports or take a scaffold-free approach, engineered tissues that match the properties of native cartilage are now routinely being grown in the laboratory using both native tissue cells and stem cells. Some of the same scaffolding materials used to grow tissues in the lab can also be used directly in the surgical repair of a cartilage defect, recruiting cells from the surrounding native cartilage and underlying bone marrow and directing their differentiation.

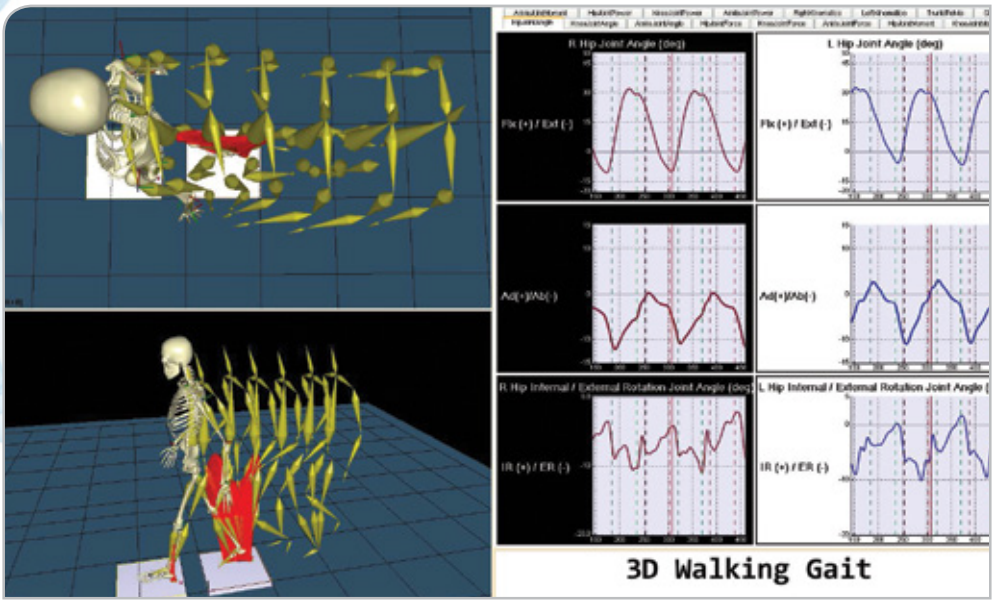
While it is not yet clear which approach will ultimately be most successful, each of these strategies is currently being evaluated in pre-clinical large animal models. Success in these endeavors will allow McKay researchers to transition this technology to human clinical trials one day, hopefully providing an effective new approach to cartilage repair, and relief for the millions of patients worldwide suffering from cartilage damage and osteoarthritis.

PENN ORTHOPAEDICS
CARTILAGE REPAIR SYMPOSIUM

From Repair to Regeneration
April 25-27, 2014 | Philadelphia, PA

Join us for an event dedicated to the latest techniques in cartilage repair—including a hands-on workshop in the Human Tissue Lab.

Learn more at PennMedicine.org/CartilageRepair



Data Output from the Center's
Optical Motion Analysis System

The Penn Center for **Human Performance**

In August 2014, Penn Medicine will open Penn Medicine University City, a new 150,000 square-foot eight-story facility that will house the new Penn Musculoskeletal Center. Designed to create an ideal environment for integrated patient-focused musculoskeletal care, the Center will offer coordinated care from numerous specialties, including orthopaedics, rheumatology, physical medicine and rehabilitation, pain medicine, spine surgery and musculoskeletal radiology.

The Penn Center for Human Performance will be situated within the Penn Musculoskeletal Center as the premiere location for the diagnosis, treatment and rehabilitation of musculoskeletal disorders in the Philadelphia region, and as a resource for patients who suffer from musculoskeletal symptoms seeking to understand their condition, maximize their potential and improve their quality of life.

The Center will be outfitted with state-of-the-art biomechanical, physiological, medical and kinematic testing equipment for the study of human performance, including:

Motion Analysis: A rapid and easy means of ergonomics and function assessment, motion analysis allows clinicians to measure performance in order to determine a patient's functional outcome. Quantitative assessment of function is important in determining the status of patients to aid in the determination of a pharmaceutical or therapeutic treatment regimen. It is also useful in assessing sequential progress of the patient and the effectiveness of the treatment. To maximize the benefits, the Penn Center for Human Performance will utilize two integrated motion analysis systems: an optical system and a force platform system.

The Center's optical motion analysis system consists of four digital cameras that capture complex motion with extreme accuracy to offer unrestricted assessment of movements within the limitations of the patient, all captured in real time. All cameras have a larger sensor area than standard video cameras and operate at up to 200 fps at full resolution, allowing for optimum motion capture. Up to 10,000 fps is possible at reduced resolution.

The Center's force platform system, working in tandem with the optical system, is able to analyze force movement 10 times more accurately than any other force platform system available. Using a new optimized strain gage technology, this system provides researchers average center of pressure accuracy of less than 0.2 mm, and measurement accuracy within 0.1%.

Another unique component of the Center's motion analysis systems is the incorporation of virtual reality. By recreating everyday environments such as the patient's kitchen or living room, researchers are able to more accurately observe the patient's motion through activities of daily living.

Electromyography (EMG) System: This system enables the measurement and processing of surface electromyography and associated signals to evaluate individuals with pathological gait during walking, and the measurement of lower extremity muscle activity during running, jumping and landing. Dynamic muscle firing patterns will be assessed in throwers to determine injury risk and response to treatment.

Metabolic Measurement System: A compact, integrated metabolic measurement system for cardiopulmonary stress testing, indirect calorimetry and maximal O2 consumption measurement.

Neuromuscular Testing: Offering both dynamic and static muscle loading environments, this system presents unlimited possible combinations of techniques and applications in patient examination. This includes an isokinetic mode in a continuous reciprocal motion and impact-free acceleration, which eliminates joint trauma during the achievement of high speeds that correlate to function. The system has the ability to compare patients to a normative database within Penn's clinical population in order to develop individualized goals.

At the Center, patients with musculoskeletal disorders caused by metabolic disease, autoimmune disease, trauma, arthritis and cancer will be evaluated both pre- and post-surgical treatment in an effort to measure the success of the clinical care plan. Patients will receive immediate feedback regarding their physiological and biomechanical disorder and the related medical or surgical treatment plan. Outcomes will be tabulated to make the best recommendations for patients with musculoskeletal pain, with the focus on a return to full and active lifestyle.

The Penn Musculoskeletal Center at Penn Medicine University City is scheduled to open in August, 2014.

PENN ORTHOPAEDICS: **SERVING OUR VETERANS**

at the Philadelphia Veterans Affairs Medical Center

Veterans Affairs (VA) patients often have significant medical comorbidities and multiple surgeries in their histories as a result of their military service, which complicates both reconstructive surgical approaches and wound healing. Recognizing these challenges, Penn Orthopaedics sees more than 5,200 patients each year at the Philadelphia Veterans Affairs Medical Center (VAMC).

Services for patients include triage, outpatient evaluation, scheduling of appropriate testing and consultations, surgery, interaction with primary care providers, liaison with VA referral health centers and post-hospitalization care. More than 450 orthopaedic surgeries take place each year at the VAMC on average, exceeding those of every other specialty.

The VAMC provides health care to 90,000 veterans in the Philadelphia region. Penn Medicine faculty members John Esterhai, MD, Chief of Orthopaedic Surgery at the VAMC, and Drs. Joseph Bernstein, Malcolm Ecker, Ernest Gentchos, Eric Hume, John Kelly, Andrew Kuntz, Neil Sheth, Harvey Smith and David Steinberg provide clinical treatment to VA patients and supervise Penn Orthopaedic's residency program at the VAMC. Penn Orthopaedics Department Chair L. Scott Levin, MD, volunteers his services as well. Post-graduates in the second year of rotation and fifth-year residents in the Department of Orthopaedics at the University of Pennsylvania also serve at the VAMC.

Penn Orthopaedic Research at the VAMC

Drs. Bernstein, Esterhai, Kuntz, Sheth, Smith and Steinberg have each applied for or received research funding through the VA, and collaborate with intra- and extramural physicians and basic scientists at Penn.

Current Penn Orthopaedic Grants at the Philadelphia VAMC include:

- ***Timed-release of local anesthetic from sol gels for post-op pain control*** | PI: Sheth; Co-PIs: Ducheyne, Cowan, Radin ($655,091)
- ***Engineered multi-functional nanofibrous meniscus implants*** | PI: Esterhai; Co-PIs: Mauck, Schaer, Huffman, Burdick ($678,157)
- ***Disk degeneration in the lumbar spine of a small animal model*** | PI: Mauck; Co-PIs: Smith, Elliott, Dodge, Burdick ($739,817)
- ***Cartilage preservation with stem-cell laden hyaluronic acid hydrogels*** | PI: Steinberg; Co-PIs: Mauck, Fisher, Belkin ($1,100,000)
- ***The role of local NSAID administration and inflammation on tendon healing*** | PI: Bernstein; Co-PIs: Mauck, Soslowsky ($1,100,000)

Vascularized Free Flaps in Foot and Ankle Reconstruction

Focus on medial femoral condyle (MFC) flaps

In studies published in 2013, surgeons at Penn Orthopaedics propose that free vascularized bone flaps be the next step in the treatment algorithm following the failure of conventional bone grafting techniques in foot and ankle reconstruction.

Blood supply to the navicular and talus bones of the foot and ankle is notoriously tenuous. Poor native bone vascularity can be caused or exacerbated by trauma, open exposure and surgery, and may lead to osteomyelitis, avascular necrosis (AVN) and persistent nonunion, which are, in turn, the precedent for large bone gaps in the region.

Arthrodesis is the final reconstructive option for failed fracture fixation, osteomyelitis, nonunion, malunion, post-traumatic arthritis or AVN. In the presence of AVN, however, arthrodesis of the navicular and talus can be difficult. Nonunion rates for arthrodesis in less ideal patients with comorbidities have been reported to be as high as 30-40%. Bone grafts such as the autogenous iliac crest can be used to restore bone stock to the fusion site if primary internal fixation fails, but these grafts are susceptible to significant resorption.

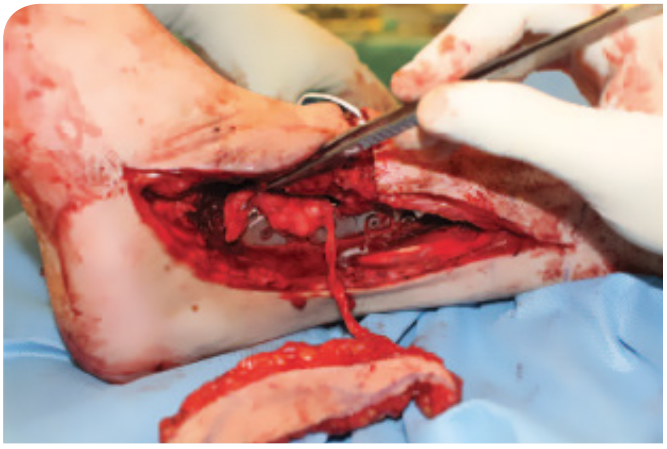
Vascularized Free Flaps Application

At Penn Medicine, vascularized free flaps have become an integral part of extremity reconstruction as an option for patients in this category. There are numerous advantages to the use of vascularized bone flaps when compared to conventional bone grafts. The transfer of living osteocytes promotes primary healing, improved strength and faster union.

In a pair of retrospective studies published in 2013, Keith Wapner, MD and L. Scott Levin, MD, FACS of Penn Orthopaedics demonstrated the versatility of the Medial Femoral Condyle (MFC) and free fibula flap in complex foot and ankle pathology. The studies reviewed the case histories of five patients treated with MFC free flap transfer to the foot and ankle region and seven patients treated with fibula flaps.

Indications included tibiotalar arthrodesis, pantalar arthrodesis, navicular revascularization and persistent nonunion of the talus. The average number of surgical procedures before treatment with vascularized bone flap was 2.2 ± 1.8. These included 11 attempted open reduction and internal fixations, eight debridements, two removals of hardware, two tibiotalar arthrodeses, one subtalar arthrodesis and two pantalar arthrodeses. Five patients had an accompanying significant soft-tissue defect.

No flap failures or thrombotic events occurred in either series. All patients ultimately obtained union and full weight bearing was allowed at 18.7 ± 13.6 weeks after surgery.



Ankle Tibiotalar Joint Arthrodesis with a Free Medial Femoral Condyle Flap

A bone slot has been created in the tibia and talus to allow impaction of the medial femoral condyle free flap. An osteocutaneous medial femoral condyle free flap was harvested. The bone segment was 3 × 2 × 1 cm. The compression plate is placed slightly posterior to the usual location to avoid compression of the vascular pedicle.

Medial Femoral Condyle MFC Flap & Fibula Flap Discussion

The MFC free flap is a valuable method for foot and ankle reconstruction and is currently the ideal source of vascularized periosteum, cortical bone and cancellous bone for smaller (<4cm) defects (supplanting the iliac crest) at Penn Orthopaedics. Unlike the iliac crest, no fractures, hernias or nerve injuries have been reported during harvest of a MFC flap. Reports of successful incorporation of a cutaneous paddle with the MFC flap also broaden the scenarios in which the flap can be used.

The fibula flap remains the preferred option for larger defects (>4cm). Though the MFC has numerous benefits, the traditional fibula flap offers a larger cortical surface area, providing more rigidity when structural support is necessary.

Discussion:

Penn Medicine has successfully used the MFC flap and fibula flap for tibiotalar arthrodesis, pantalar arthrodesis, navicular revascularization and persistent nonunion of the talus. Both flaps are valid options for foot and ankle reconstruction and salvage and should be considered the next step in the treatment algorithm when conventional procedures using standard bone grafting techniques fail.

References // Haddock NT, Alosh H, Easley ME, Levin LS, Wapner KL. **Applications of the Medial Femoral Condyle Free Flap for Foot and Ankle Reconstruction.** Foot Ankle Int. 2013;34:1395-1402. // Haddock, NT, Wapner, KL, Levin LS. **Vascular Bone Transfer Options in the Foot and Ankle: A Retrospective Review and Update on Strategies.** Plast Reconstr Surg. 2013;132:685-693.

Clinical and Cost Burdens of **Emergent Arthroplasties**

A team of surgeons at Penn Orthopaedics have found significantly higher costs and longer, more complicated clinical courses among patients with unplanned and emergent arthroplasties.

At Penn Orthopaedics, 13.6% of hip arthroplasties, including total hip arthroplasties (THAs), are performed on an emergent basis. While the risks and costs associated with elective THA surgeries have been well elucidated, those associated with emergent THAs have not been studied despite their clinical and financial burden and the known risk for perioperative complications associated with these surgeries.

To better understand the costs and risks associated with emergent surgeries, clinicians at Penn Orthopaedics performed a study at their institution's Level I trauma center to address four questions:

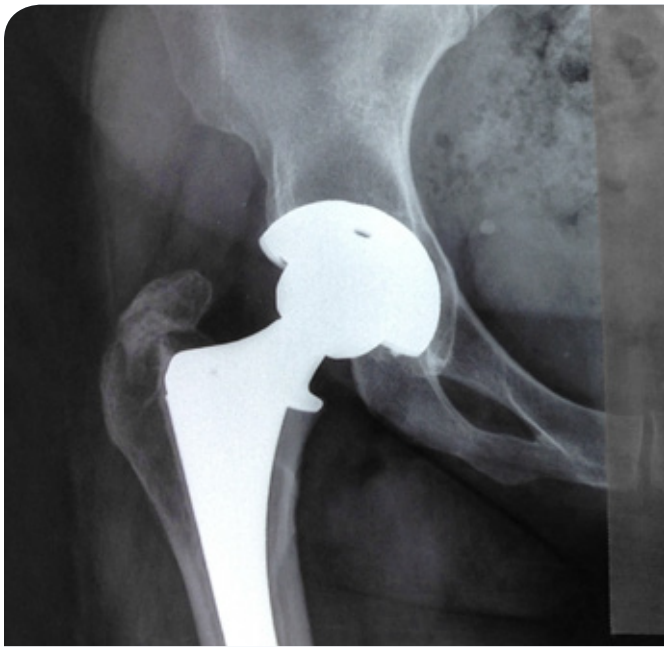
1. **The institutional costs associated with these surgeries**
2. **The influence of timing of surgery on perioperative outcomes**
3. **The diagnoses associated with unplanned surgery**
4. **The effect of insurance status on admission types (emergent vs. elective hip arthroplasty)**

The authors prospectively followed 419 patients admitted to the Level I trauma center at Penn Medicine in 2011 for procedures including primary THA, hemiarthroplasty and revision arthroplasty, and for treatments including periprosthetic fractures, dislocations and infections. A total of 57 patients treated urgently on an emergent basis were compared with 362 patients treated electively. Demographics, admission diagnoses, complications and costs were recorded and analyzed statistically.

Financial Burden

By comparison to elective surgeries, emergent arthroplasty and urgent surgeries at Penn Medicine were associated with significantly increased financial burdens:

- The median total costs were 24% greater for patients admitted for emergent hip arthroplasties than for elective surgeries.
- Median total charges were 31% greater for patients with emergent admissions.



Clinical Burden

At Penn Orthopaedics, a significant distinction existed with regard to clinical burden between patients having elective THA surgeries and those having emergent arthroplasties:

- Patients with emergent admissions had a 67% longer median hospital stay than did patients with elective admissions.
- Significantly higher rates of morbidity were seen in patients with emergent admissions, though mortality rates were equivalent between groups.

Patient Demographics

- The emergent surgery group also had an older median age; diminished likelihood of commercial insurance; greater probability of having been transferred from another hospital; and greater prospects for revision surgery.

Discussion:

Hip arthroplasties are rarely performed as truly emergent surgeries, but a large number are performed on an urgent or unplanned basis. The true risks and financial and clinical burdens associated with the care of patients having emergent surgery have not been well studied. The design for the study, however, provides a realistic profile of emergent and elective arthroplasties at a tertiary medical center and important overall trends regarding the burdens of caring for these patients.

This study prompts the need for further research to understand the indications for emergent procedures and to develop treatment algorithms to effectively manage the subset of patients undergoing emergent arthroplasties.

Reference // Kamath, AF, Austin, DC, Berman PB Israelite, CL. **Unplanned Hip Arthroplasty Imposes Clinical and Cost Burdens on Treating Institutions.** Clin Orthop Relat Res 2013;471:4012–4019.

Indications and Contraindications for Vascularized Composite Allotransplantation (VCA) in Quadrimembral Amputees

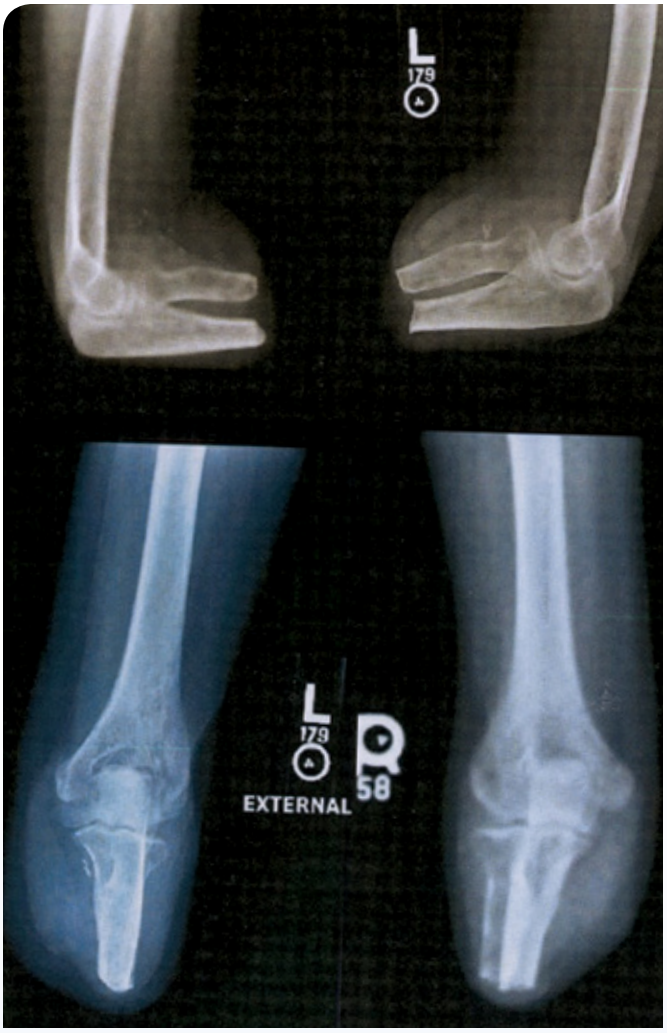
Quadrimembral amputees may benefit greatly from hand transplantation.

Patients with quadrimembral amputation carry a rare and devastating diagnosis. The loss limits the patient's ability to interact with their environment and can severely affect their ability to perform Activities of Daily Living (ADL). In addition, unique problems are caused by the significant loss of body mass such as the increased need for energy expenditure for mobilization and ambulation, as well as increased sweating which interferes with prosthetic fitting.

The care of these patients must embrace not only their physical condition and the unusual sequelae of multiple amputations, but also their psychosocial needs. The innate desire for independence and wholeness must be addressed with sympathy and depth of understanding within the framework of the possible.

"At Penn, we have the level of surgical and academic expertise required to not only offer complicated VCA procedures, but also the capabilities to help establish the standards of care for this emerging field."

—L. Scott Levin, MD, FACS,
Director of the Penn Hand Transplant Program
Chairman of the Department of Orthopaedic Surgery

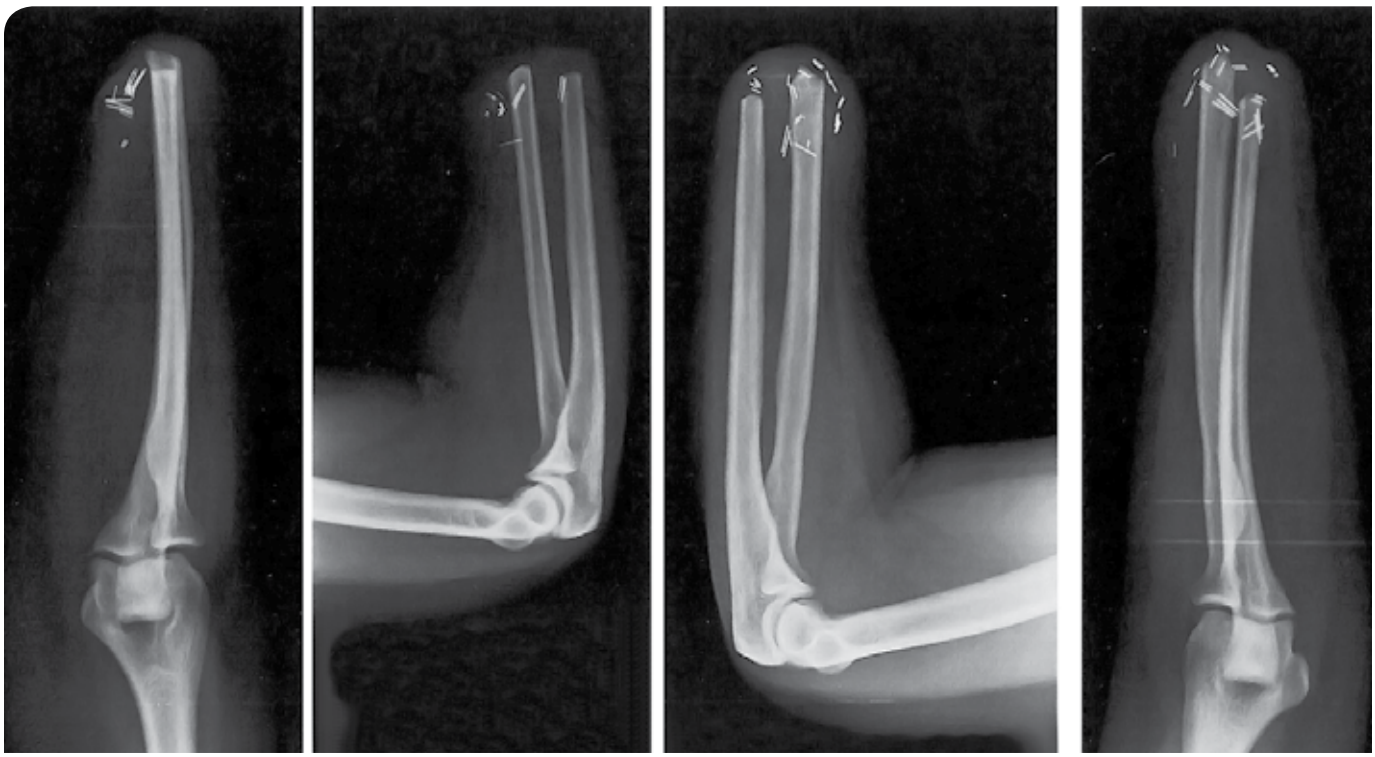


A 27-year-old with bilateral below-elbow and knee amputations suffered septic shock and ischemia-induced extremity necrosis after an abdominal procedure. The patient required a free scapular flap to the right knee for limb optimization and coverage.

At the current time, the possibilities for a subset of patients with quadrimembral amputation include hand transplantation, a procedure that has been performed successfully at Penn Orthopaedics. However, little information exists in the journal canon concerning quadrimembral amputees, and until a report issued from Penn Medicine in 2013, none concerned hand transplantation.

Issued by a group of specialists from Penn Orthopaedics, Penn Plastic Surgery, Transplant Surgery and Penn Surgery, the report involved a retrospective review of five quadrimembral amputees evaluated for transplantation at Penn to assess their respective indications and contraindications for hand transplantation, with a secondary focus on the potential benefit of Vascularized Composite Allotransplantation (VCA) in this population.

Combining microsurgery with the pharmaceutical advancements of immunosuppression, VCA has made transplantation of donor hands a reality, and may be an alternative to the traditional upper extremity prosthetic and rehabilitative treatment regimen for quadrimembral amputees. In a recent



A 43-year-old woman with bilateral below-knee and elbow amputations resulting from septic shock after an abdominal procedure.

review of hand transplants performed over an 11-year period, the International Registry on Hand and Composite Tissue Transplantation reported that all patients developed protective sensibility, 90% developed tactile sensation and >82% had discriminative sensibility. Recovery of intrinsic and extrinsic motor function allowed patients to perform most activities of daily living, and 75% of recipients reported an improvement in quality of life; many have returned to work.

In reviewing the small quadrimembral population at Penn as potential transplant candidates, the study group recognized the importance of maintaining the traditional multidisciplinary, thorough and rigorous evaluation process for hand transplantation. Chief among their considerations was ensuring that patients are appropriate candidates; that the chosen patients understood the surgery and its postoperative requirements; and that they were able to tolerate the physical, psychological and social aspects of transplantation.

Following a thorough evaluation of the five, two patients were selected as potential transplant candidates. The two demonstrated strong psychosocial support systems, a thorough understanding of hand transplantation, along with its risks and postoperative requirements. Physiologically, they were medically stable, able to tolerate immunosuppression and free of infection in residual limbs. Further, they did not have contraindications to transplantation, including hepatic/renal insufficiency, drug dependency, lack of a support system or noncompliant behaviors. Both had completed a full regimen of rehabilitation along with prosthetic fitting and utilization.

PENN MEDICINE RECEIVES $2 MILLION GRANT

In September, Penn Medicine was awarded a $2 million grant from the U.S. Department of Defense to support VCA and research studies aimed at improving transplant procedures for patients suffering traumatic injuries, such as limb loss and severe burns.

Discussion:

This investigation is the only study to date focusing on quadrimembral amputees, highlighting their challenges, exploring their changing demographics and with a strong desire to find new therapies. Traditionally, rehabilitation and prosthetic fitting have been the mainstay of treatment for patients with multiple amputations. With the advent of microsurgical Vascularized Composite Allotransplantation, hand and upper-extremity transplantation, as an innovative and life-changing therapeutic, may also be considered in the treatment of quadrimembral amputees.

References // Foroohar A, Elliott RM, Fei DR, Steinberg DJ, Bozentka DJ, Chang B, Kovach SJ, Shaked A, Levin LS. **Quadrimembral Amputation: Indications and Contraindications for Vascularized Composite Allotransplantation.** Transplant Proc 2011;43:3521-3528.

Urgency for Operative Debridement
in Open Long-Bone Fractures: Emerging Concepts

A team of researchers at Penn Orthopaedics find little support in current literature for the historical "six hour rule" for debridement of open long bone fractures to prevent infection.

The existing clinical guidelines recommending emergent surgical debridement of open fractures within six hours of injury are believed to have originated with a study performed in guinea pigs in 1898.

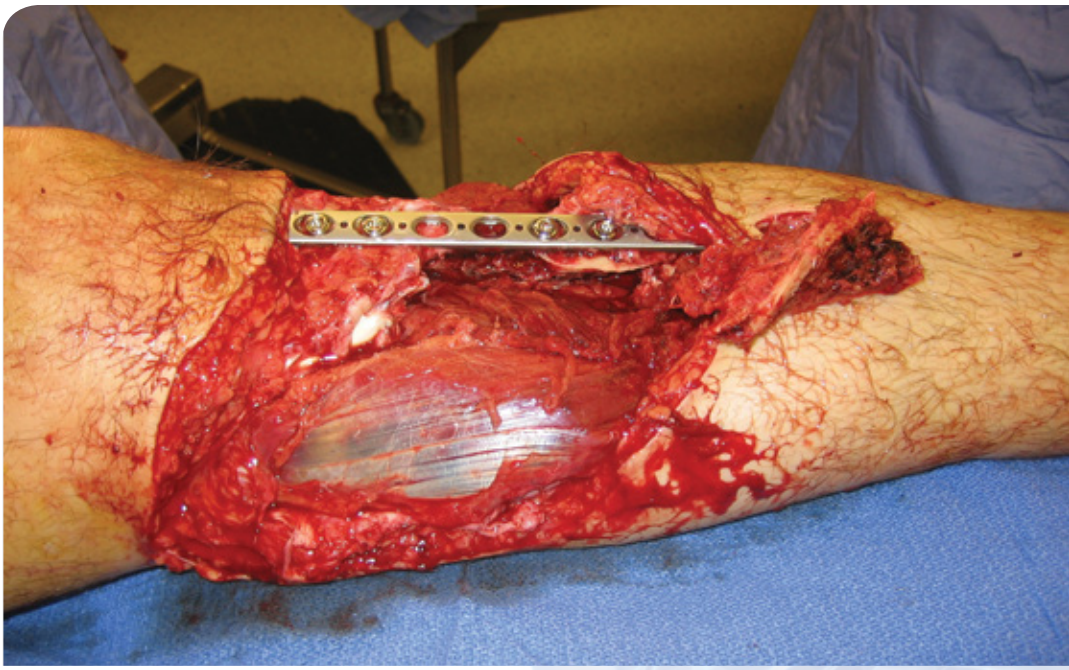
While the expedient and appropriate treatment of these severe injuries remains the goal, Penn Medicine researchers have found circumstances in which delayed initial debridement beyond six hours may have little impact in creating infectious complications. A team of investigators at Penn Orthopaedics aggregated, reviewed and analyzed 16 independent high-level studies to evaluate the association between time to initial operative debridement of open fractures and the development of infectious complications. Their findings suggest the need to re-evaluate the standard "six hour rule."

The meta-analysis [of a total of 3,539 open fractures] revealed no association between later debridement times and higher infection rates when all infections (including deep infections) were considered or when more severe open fracture injuries were considered.

The investigators reviewed the MEDLINE, EMBASE and Cochrane computerized literature databases and searched bibliographies to find randomized, controlled trials and cohort studies (retrospective and prospective) evaluating the association between time to operative debridement and infection after open fractures. Descriptive and quantitative data was then extracted and a meta-analysis of patient cohorts who underwent early or delayed debridement was performed. Eventually, six prospective and ten retrospective cohort studies (a total of 3,539 open fractures) were included.

The meta-analysis revealed no association between later debridement times and higher infection rates when all infections (including deep infections) were considered or when more severe open fracture injuries were considered. Moreover, no significant difference in infection rate occurred between open fractures debrided early or late according to any of the time thresholds used in the included studies.

Type III B Open tibia sustained via fall with no neurovascular compromise. Patient transferred from level III hospital to Penn Orthopaedics Trauma and Fracture and taken for initial debridement 12 hours after injury.



Aggressive initial debridement of open type III B tibia fracture and provisional stabilization. This initial debridement has been shown to be critical to successful outcomes.

Sensitivity analyses demonstrated no difference in infection rate between early and late debridement in subgroups defined according to the Gustilo-Anderson classification, level of evidence, depth of infection, or anatomic location.

Discussion:

In this review, late surgical debridement was not associated with a higher infection rate in patients with open fractures. Even patients with severe injuries, classified as Gustilo-Anderson type-III fractures, did not have a higher infection rate with late initial debridement under the conditions associated with after-hours surgery.

Delay of debridement of open fractures may be unavoidable or even warranted in some circumstances. It has been suggested that abiding by the historical "six hour rule" may offer a disservice to patients when initial fracture care is provided by hospitals unprepared to accommodate these severe injuries, particularly outside normal working hours when surgical conditions are often less than optimal. Under these circumstances, transfer to specialty hospitals may offer the patient an improved injury outcome even if debridement occurs outside the six hour guideline.

While this study cannot be considered to conclusively invalidate the "six hour rule," it provides sufficient equipoise to justify prospective investigations into the timing of initial debridement of open fractures. It is important to realize that additional carefully conducted studies are needed and that purposeful delay of treatment of patients with open fractures is not recommended.

Infection Results for Late Debridement

- **No significant difference in the overall infection rate**
- **No significant difference in deep infection rate**
- **No significant difference in infection rate for type-I and II fractures**
- **No significant difference in infection rate for type-III fractures**
- **No significant difference in infection rates was detected when the studies were analyzed according to the time thresholds for early and late debridement used by the primary authors with use of any of the following cutoffs:**
  - Five hours (OR, 0.96; 95% CI, 0.54 to 1.71; p = 0.88)
  - Six hours (OR, 0.81; 95% CI, 0.53 to 1.24; p = 0.34)
  - Eight hours (OR, 1.15; 95% CI, 0.51 to 2.59; p = 0.73)
  - Twelve hours (OR, 1.04; 95% CI, 0.62 to 1.73; p = 0.789)

Reference // Schenker ML, Yannascoli S, Baldwin K, Ahn J, Mehta S. **Does Timing to Operative Debridement Affect Infectious Complications in Open Long-Bone Fractures?** A Systematic Review. J Bone Joint Surg Am. 2012;94:1057-1064.

What's New
in Orthopaedic Rehabilitation?

The importance of functional outcome documentation under the Affordable Care Act

With the approaching enactment of the Affordable Care Act, a team of clinicians representing orthopaedic research, neuro-orthopaedics and orthopaedic surgery at Penn Medicine offered a comprehensive retrospective overview of presentations and advances in prominent areas of orthopaedic rehabilitation during 2013.

The field of rehabilitation studies, the team noted, utilizes biomechanics and biology in a unique manner that focuses on improving the patient's functional outcome and overall well-being. Documenting functional outcomes for orthopaedic surgery will likely become increasingly important when the Affordable Care Act is fully implemented, and the partnership between orthopaedics and rehabilitative medicine will be even more essential moving forward.

FUNCTIONAL OUTCOME ADVANCES

The authors reviewed a variety of areas of clinical interest in orthopaedics including the following:

Weight-Bearing

The team took note of a study by Hustedt, *et al*, that analyzed various methods of training and compliance with regard to touch-down weight-bearing (25 lb. [11.3 kg]) and partial weight-bearing (75 lb. [34 kg]) including (1) verbal cues, (2) use of a typical bathroom scale, and (3) use of a biofeedback device after participants took fifty consecutive steps.

Hustedt and colleagues found that overall compliance was better during partial weight-bearing as compared with touch-down weight-bearing, with significant improvements seen in touch-down weight-bearing when a biofeedback device or a bathroom scale was used. The authors noted that the study challenged the conventional thinking that age plays a significant role in weight-bearing compliance and instead suggests that compliance is associated with specific training methods.

Pain Management

The authors reviewed a study by Padua, *et al*. Following 139 patients after lower-extremity orthopaedic surgery, Padua and co-authors found that individuals with more severe pain reported lower physical and mental quality-of-life scores. In 38.6% of patients, pain interfered with rehabilitation, and in 18.5% of patients, pain was the reason for the discontinuation

of physical therapy. These findings were reflected in a separate study by Mathiesen, *et al*, that determined that patients using a comprehensive multimodal pain regimen (including pre- and intra-operative medications) were able to reduce the consumption of opioids, became mobilized earlier, and had a lower intensity of nausea, sedation and dizziness on postoperative days 1 through 6.

Adequate pain control, the team concluded, translates into early participation in rehabilitation, timely discharge from the inpatient hospital setting and increased patient satisfaction.

Additional Advances

Additional areas of clinical interest in orthopaedics reviewed by the team:

- Pre-injury functional status as both a predictor of outcome and an indication for earlier surgery in the orthopaedic trauma patient
- Important diagnostic factors for delayed fracture union and nonunion
- Surgical and nonsurgical treatments for Achilles tendon healing and appropriate postoperative rehabilitation
- Pediatric rehabilitation medicine and surgery
- Spinal Cord Injury Rehabilitation
- Dynamic electromyography and motion analysis
- Amputation and prosthetics
- Heterotopic ossification of the upper extremity

Discussion:

In light of the enactment of the Affordable Care Act, with its potential use of quality metrics and readmission assessments as a means of assessing or denying payment for care, the authors stressed the increasing importance of documenting functional outcomes for orthopaedic surgery. Going forward under the fully implemented Affordable Care Act, the authors noted the relevance of the overall functional outcome of the patient to the fields of orthopaedic surgery and rehabilitative medicine and the importance of their essential partnership.

Reference // Baldwin K, Yannascoli SM, Namdari S, Spiegel, DA, Kennan MA. **Specialty Update: What's New in Orthopaedic Rehabilitation.** J Bone Joint Surg 2013;22:2072-2077.

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.

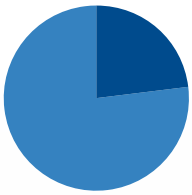
10 LOCATIONS | **49** FULL-TIME FACULTY | **9,086** TOTAL CASES | **78,940** PATIENT VISITS

>> Foot and Ankle

Section Chief: Keith L. Wapner, MD

- Keith L. Wapner, MD was named one of the Top 26 North American Foot and Ankle Surgeons of 2013 by *Orthopedics This Week*.
- Findings on the use of vascularized bone grafts for salvage of foot and ankle fusion cases were presented by Dr. Wapner and L. Scott Levin, MD, FACS at the *Surgical Complications Course* of the American Orthopedic Foot and Ankle Society and at the Chinese Orthopedic Society Meeting.
- Daniel C. Farber, MD joined the Penn Orthopaedics faculty after serving as head of the foot and ankle service at the University of Maryland for ten years. Dr. Farber is the current chairman of the Fellowship Committee for the American Orthopedic Foot and Ankle Society.

Keith L. Wapner, MD



2013 PATIENT VOLUMES
TOTAL: 1,004
Inpatient: 232
Outpatient: 772

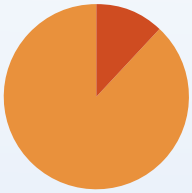
Selected Articles // Haddock, NT, Wapner, KL, Levin LS. **Vascular Bone Transfer Options in the Foot and Ankle: A Retrospective Review and Update on Strategies**. Plast Reconstr Surg 2013;132:685-693. // Haddock NT, Alosh H, Easley ME, Levin LS, Wapner KL. **Applications of the Medial Femoral Condyle Free Flap for Foot and Ankle Reconstruction**. Foot Ankle Int 2013;34:1395-1402.

>> Hand and Wrist Service

Section Chief: David J. Bozentka, MD

- The service has received grants from NIH and OREF to research ground-breaking technology in the treatment of hand, wrist and elbow disorders and trauma.
- The First Annual *Penn Microsurgical Skills Cadaver Course* was held at the Penn Human Tissue Lab in November, 2013. The cadaver-based course involved dissections for local flaps, regional flaps and free tissue transfer procedures.
- Recipient of the American Society for Surgery of the Hand (ASSH) and the American Foundation for Surgery of the Hand (AFSH) two-year Hand and Upper Limb Fellowship Grant which funds post-graduate clinical and research fellowships.
- David Steinberg, MD, initiated bench research to evaluate healing response and subchondral bone remodeling in the treatment of focal cartilage lesions.

Penn Human Tissue Laboratory



2013 PATIENT VOLUMES
TOTAL: 1,362
Inpatient: 166
Outpatient: 1,195

Selected Articles // Connizzo BK, Yannascoli SM, Tucker JJ, Caro AC, Riggin CN, Mauck RL, Soslowsky LJ, Steinberg DR, Bernstein J. **The Detrimental Effects of Systemic Ibuprofen Delivery on Tendon Healing Are Time-Dependent.** Clin Orthop Relat Res. 2013;Aug 28. // Park MJ, Pappas N, Kim J, Bozentka D. **Rate of Clinically Significant Posttraumatic Arthritis After Small Finger Intra-Articular Carpometacarpal Fractures.** Orthopedics 2013;36:e1042-e1046. // David Steinberg D, Levin LS, Bozentka D, Shaked A. **Quadrimembral Amputation: Indications and Contraindications for Vascularized Composite Allotransplantation.** Transplant Proc. 2011;43:3521-3528. // Haddock NT, Chang B, Bozentka DJ, Steinberg DR, Levin LS. **Technical Implications in Proximal Forearm Transplantation.** Tech Hand Up Extrem Surg. 2013;17:228-231.

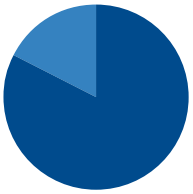
Ongoing Clinical Trials // David Bozentka. **Rate of Clinically Significant Posttraumatic Arthritis After Small Finger Intra-Articular Carpometacarpal Fractures.** // David Bozentka. **A Clinical Trial for the Surgical Treatment of Elderly Distal Radius Fractures (WRIST).**

>> Joint Replacement

Section Chief: Charles L. Nelson, MD

- Penn Orthopaedics is designated as a **Blue Distinction Center of Excellence: Hip Program & Knee Program** with successful renewal and ongoing management, and is recognized by **The Joint Commission** as a Disease Specific Hip Program and Knee Program.
- Penn Orthopaedics instituted a rigorous standardization of care (including pre-operative medical assessment and risk stratification, DVT prophylactic regimens and multimodal pain management) that has lead to better outcomes and optimization of patient safety.
- In 2013, Penn Orthopaedics launched its inaugural *Philadelphia Revision Hip and Knee CME Course* in partnership with the International Congress for Joint Replacement. The two-day didactic and hands-on cadaveric course was created to provide evaluation and management skills for orthopaedic surgeons with limited hip and knee arthroplasty revision experience.

Designated as a Blue Distinction® Center for Knee and Hip Replacement



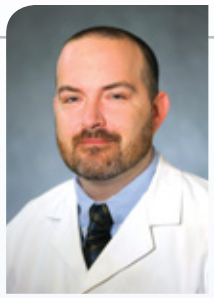
2013 PATIENT VOLUMES
TOTAL: 2,907
- Inpatient: 2,403
- Outpatient: 504

Selected Articles // Kamath, AF, Austin, DC, Berman PB, Israelite CL. **Unplanned Hip Arthroplasty Imposes Clinical and Cost Burdens on Treating Institutions.** Clin Orthop Relat Res 2013;471:4012-4019. // Nelson C, Lee GC. **Acetabular Revisions Using Trabecular Metal Cups and Augments.** J Arthroplasty. 2009;24:64-68. // Lee GC. **Do Ceramic Femoral Heads Reduce Taper Fretting Corrosion in Hip Arthroplasty? A Retrieval Study.** Clin Orthop Relat Res 2013;471:3270-3282.

JOIN US FOR THE 2ND ANNUAL
PHILADELPHIA REVISION COURSE
May 2-3, 2014
Philadelphia, PA
ICJR | International Congress for Joint Reconstruction
For more information or to register, visit www.icjr.net.

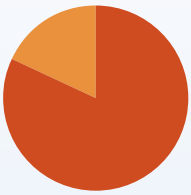
>> Neuro-Orthopaedics

The Neuro-Orthopaedic service at Penn Orthopaedics treats the musculoskeletal complications of brain injury, stroke, anoxia, central nervous system disorders and other disorders and injuries, and provides adult transitional care for patients with neurologic diseases which are congenital or otherwise start in childhood. The objective of Penn Neuro-Orthopaedics is recovering mobility and improving performance and quality of life for the patient.



Keith D. Baldwin, MD, MPH, MSPT

- Keith D. Baldwin, MD, MPH, MSPT joined the Neuro-Orthopaedic Service following the retirement of Mary Ann Keenan, MD. A graduate of the University of Medicine and Dentistry of New Jersey, Robert Wood Johnson School of Medicine, Dr. Baldwin is trained in physical therapy and specializes in the treatment of adults and children with neuromuscular disorders, including deformity caused by spasticity of upper motor neuron disease, and weakness caused by lower motor neuron disease. He practices at Penn Medicine and The Children's Hospital of Philadelphia.
- Dr. Baldwin was named health policy chair for the Orthopaedic Rehabilitation Association, and became the section editor for rehabilitation for the *Journal of Joint and Bone Surgery* reviews.



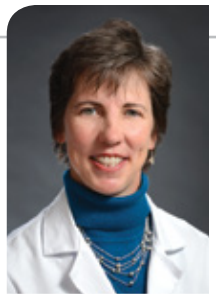
2013 PATIENT VOLUMES
TOTAL: 200*
- Inpatient: 164
- Outpatient: 36

**Includes volume from The Children's Hospital of Philadelphia*

Selected Articles // Baldwin K, Yannascoli SM, Namdari S, Spiegel DA, Keenan MA. **What's New in Orthopaedic Rehabilitation.** J Bone Joint Surg Am 2013;95:2071-2077. // Namdari S, Baldwin K, Horneff JG, Keenan MA. **Orthopedic Evaluation and Surgical Treatment of the Spastic Shoulder.** Orthop Clin North Am 2013;44:605-614. // Lee EK, Namdari S, Hosalkar HS, Keenan MA, Baldwin KD. **Clinical Results of the Excision of Heterotopic Bone Around the Elbow: A Systematic Review.** J Shoulder Elbow Surg 2013;22:716-722. // Ruzbarsky JJ, Beck NA, Baldwin KD, Sankar WN, Flynn JM, Spiegel DA. **Risk Factors and Complications in Hip Reconstruction for Nonambulatory Patients with Cerebral Palsy.** J Child Orthop 2013;7:487-500.

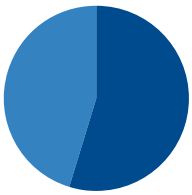
>> Orthopaedic Oncology

Section Chief: Kristy L. Weber, MD



Kristy L. Weber, MD

- Kristy L. Weber, MD joined the Penn Orthopaedics faculty as Chief of Orthopaedic Oncology in 2013 after serving in a similar role at Johns Hopkins Medicine. She is developing a world-class multidisciplinary clinical team of physicians to treat sarcoma patients beyond the limits of conventional medicine by offering patients more options to improve their lives. Dr. Weber was appointed president of the Musculoskeletal Tumor Society for 2014.
- Closely allied to the Abramson Cancer Center, the Roberts Proton Therapy Center and the Joan Karnell Cancer Center, the Orthopaedic Oncology service develops individualized treatment and recovery plans to support and assist patients from diagnosis through recovery.
- Dr. Weber presented at major orthopaedic cancer organization and institution meetings, including the Musculoskeletal Tumor Society, the Orthopaedic Research Society Clinical Research Forum and the Hawaii Orthopaedic Association.



2013 PATIENT VOLUMES
TOTAL: 62*

- Inpatient: 34
- Outpatient: 28

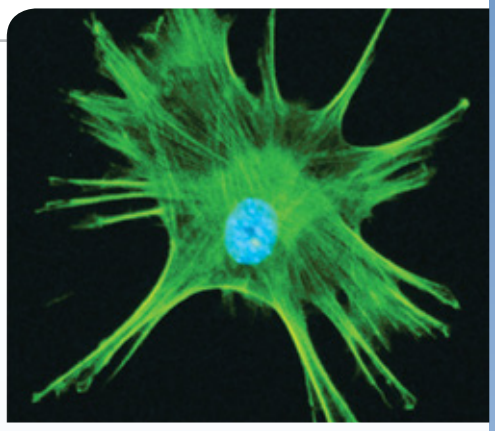
**Includes volume from April to December 2013*

Selected Articles // Lau WM, Doucet M, Huang D, Weber KL, Kominsky SL: **CITED2 Modulates Estrogen Receptor Transcriptional Activity in Breast Cancer Cells.** Biochem Biophys Res Commun 2013;437;261-266. // Lau WM, Doucet M, Stadel R, Huang D, Weber KL, Kominsky SL. **ENPP1: A Potential Facilitator of Breast Cancer Bone Metastasis.** PLoS One July 5, 2013. // Weber K , Kominsky, SL. **Concepts and Surgical Treatment of Metastatic Bone Disease.** In: Rosen CJ, ed. Primer on the Metabolic Bone Diseases and Disorders of Mineral Metabolism. 8th ed. Ames, IA: John Wiley & Sons, Inc; 2013: Turkelson C, Weber KL. The Scientific Foundations of Healthcare Guidelines. In: O'Keefe RJ, Jacobs JJ, Chu CR, and Einhorn TA, eds. Orthopaedic Basic Science: Foundations of Clinical Practice, 4th ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2013, Chapter 30, pp 469-481.

>> Research

Section Chief: Louis J. Soslowsky, PhD

The McKay Orthopaedic Research Laboratory consists of independent research laboratories with approximately 100 researchers, including eight primary faculty. The McKay Lab has 15,000 square feet devoted to research and another 4,300 square feet at the associated Translational Musculoskeletal Research Center at the Philadelphia VA Medical Center.



Mesenchymal Stem Cell

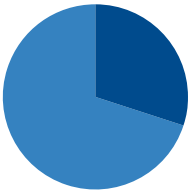
- Research expenditures total more than $8.5M per annum, supported largely through extramural funding including grants from the National Institutes of Health (NIH), other governmental agencies, private foundations and industry.
- The Penn Center for Musculoskeletal Disorders NIH P30 Center grant was renewed with a perfect score of "10"—one of only five in the entire country.
- McKay's NIH T32 Institutional Training Grant was renewed in 2013 with a perfect score of "10." In its 38th year, this grant is among the longest continuous NIH musculoskeletal training grant awards to any institution in the nation.
- The McKay Lab is ranked 4th in NIH funding among Orthopaedic Departments nationally and continually ranks in the top five.

Selected Articles // Freedman BR, Sarver JJ, Buckley MR, Voleti PD, Soslowsky LJ. **Biomechanical and Structural Response of Healing Achilles Tendon to Fatigue Loading Following Acute Injury.** J Biomech, in press, 2013. // Lan S, Luo S, Huh B K, Chandra A, Altman AR, Qin L., Liu XS. **3D Image Registration is Critical to Ensure Accurate Detection of Longitudinal Changes in Trabecular Bone Density, Microstructure, and Stiffness Measurements in Rat Tibiae by *In Vivo* Micro Computed Tomography.** Bone 2013; 56:83-90. // Singh L, Brennan TA, Kim JH, Egan KP, McMillan EA, Chen Q, Hankenson KD, Zhang Y, Emerson SG, Johnson FB, Pignolo RJ. **Long-term Functional Engraftment of Mesenchymal Progenitor Cells in a Mouse Model of Accelerated Aging.** Stem Cells 2013;31:607-611. // Zhang X, Zhu J, Li Y, Lin T, Siclari VA, Chandra A, Candela EM, Koyama E, Enomoto-Iwamoto M, Qin L. **Epidermal Growth Factor Receptor (EGFR) Signaling Regulates Epiphyseal Cartilage Development through Catenin-dependent and -independent Pathways.** J Biol Chem 2013;288:32229-32240. // Regard, JB, Malhotra D, Gvozdenovic-Jeremic J, Josey M, Chen M, Weinstein LS, Lu J, Shore EM, Kaplan FS, Yang Y. **Activation of Hedgehog Signaling by Loss of GNAS Causes Heterotopic Ossification.** Nature Medicine 2013;19:1505-1512. // Chiaro JA, Baron MD, Del Alcazar CM, O'Donnell P, Shore EM, Elliott DM, Ponder KP, Haskins ME, Smith LJ. **Postnatal Progression of Bone Disease in the Cervical Spines of Mucopolysaccharidosis I Dogs.** 2013;55:78-83.

>> Shoulder and Elbow

Section Chief: David L. Glaser, MD

- Faculty at the Penn Shoulder and Elbow service collaborate closely with researchers from the McKay Research Lab to form one of the largest, basic science, shoulder research laboratories in the nation.
- The Shoulder and Elbow service was the recipient of a variety of research grants in 2013, including NIH and industry grants.
- Two members of the Penn Shoulder and Elbow faculty have served as president of the American Society of Shoulder and Elbow Therapists.
- Penn Shoulder and Elbow faculty presented at 64 international, national, regional and local orthopaedic organizations and meetings in 2013.
- Penn Shoulder and Elbow faculty also participated in a number of national committees in 2013, including the Arthroscopy Association of North America (education and research); the American Academy of Orthopaedic Surgeons subcommittee (2011-2014); and the Accreditation Committee for Graduate Medical Education (nationally accredited fellowship).



2013 PATIENT VOLUMES
TOTAL: 865
Inpatient: 262
Outpatient: 604

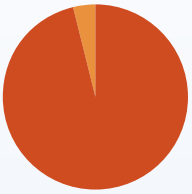
- The Penn Shoulder and Elbow faculty published articles in more than 20 peer-reviewed journals in 2013.

Selected Articles // Namdari S. Hsu JE. Barron M. Huffman GR. Glaser D. **Clinical Immediate Postoperative Radiographs After Shoulder Arthroplasty Are Often Poor Quality and Do Not Alter Care.** Orthopaedics & Related Research. 471(4):1257-62, 2013 Apr. // Reuther KE. Thomas SJ. Sarver JJ. Tucker JJ. Lee CS. Gray CF. Glaser DL. Soslowsky LJ. **Effect of Return to Overuse Activity Following an Isolated Supraspinatus Tendon Tear on Adjacent Intact Tendons and Glenoid Cartilage in a Rat Model.** Journal of Orthopaedic Research. 31(5):710-5, 2013 May // Peltz CD. Hsu JE. Zgonis MH. Trasolini NA. Glaser DL. Soslowsky LJ. **Intra-Articular Changes Precede Extra-Articular Changes in the Biceps Tendon After Rotator Cuff Tears in a Rat Model.** Journal of Shoulder & Elbow Surgery. 21(7):873-81, 2012 Jul. // Namdari S. Baldwin K. Kovatch K. Huffman GR. Glaser D. **Fifty Most Cited Articles in Orthopedic Shoulder Surgery.** [Review] Journal of Shoulder & Elbow Surgery. 21(12):1796-802, 2012 Dec // Hsu JE, Ricchetti ET, Huffman GR, Iannotti JP, Glaser DL. **Addressing Glenoid Bone Deficiency and Asymmetric Posterior Erosion in Shoulder Arthroplasty.** J Shoulder Elbow Surg. 2013 Sep;22(9):1298-308.

>> Spine

Section Chief: Vincent Arlet, MD

- Led by Vincent Arlet, MD, a world-renowned specialist in the correction of spinal deformity, Penn Orthopaedics has become a center of excellence for adult spinal deformities. Currently, more than 100 adult spine deformity patients are being treated in a partnership between Orthopaedic Surgery and Neurosurgery at Penn Medicine.
- University HealthSystem Consortium ranks the Penn Orthopaedics Spine service in the top 10 for spine surgery mortality for the most cases performed (1,105 cases*).
- In 2013, Harvey Smith, MD, joined the Spine Service as the head of Orthopedic Spine at the Philadelphia VA Hospital and Penn Presbyterian Medical Center.
- Dr. Harvey Smith was a recipient of the prestigious AO Spine North America Fellowship Research Award, a Cervical Spine Research Society Basic Science award and a research grant from the Cervical Spine Research Society.



2013 PATIENT VOLUMES
TOTAL: 248
Inpatient: 239
Outpatient: 9

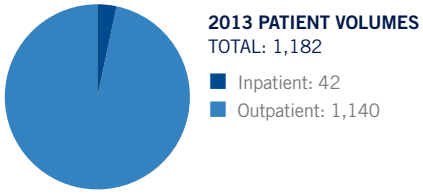
**Includes Neurosurgery volume*

Selected Articles // Arlet V, Liljenqvist U, Miladi L, Aebi M. **New Concepts in Scoliosis Treatment.** Eur Spine J 2013;22 Suppl 2:S79-S80. // Sullivan MP, McCormick JD, Arlet V. **Vertebral Artery Injury and Severely Displaced Odontoid Fracture: The Case for Early Reduction.** Eur Spine J. 2013;22:2149-2153. // Cho W, Mason JR, Smith JS, Shimer AL, Wilson AS, Shaffrey CI, Shen FH, Novicoff WM, Fu KM, Heller JE, Arlet V. **Failure of Lumbopelvic Fixation After Long Construct Fusions iån Patients with Adult Spinal Deformity: Clinical and Radiographic Risk Factors: Clinical Article.** J. Neurosurg Spine. 2013;19:445-453. // Ibraheim OA, Abdulmonem A, Baaj J, Zahrani TA, Arlet V. **Esmolol Versus Dexmedetomidine in Scoliosis Surgery: Study on Intraoperative Blood Loss and Hemodynamic Changes**. Middle East J Anesthesiol. 2013;22:27-33. // Hamilton DK, Smith JS, Nguyen T, Arlet V, Kasliwal MK, Shaffrey CI. **Sexual Function in Older Adults Following Thoracolumbar to Pelvic Instrumentation for Spinal Deformity.** J Neurosurg Spine. 2013;19:95-100. // Arlet V. Commentary. Evid Based Spine Care J. 2012;3:7-8. // Fu KM, Smith JS, Burton DC, Kebaish KM, Shaffrey CI, Schwab F, Lafage V, Arlet V, *et al*. **Revision Extension to the Pelvis Versus Primary Spinopelvic Instrumentation in Adult Deformity: Comparison of Clinical Outcomes and Complications.** World Neurosurg. 2013 Feb 21. // Arlet V, Aebi M. **Junctional Spinal Disorders in Operated Adult Spinal Deformities: Present Understanding and Future Perspectives.** Eur Spine J. 2013;22 (Suppl 2):S276-S295. // Arlet V, Milby AH, Wetzel FT. **Right Foraminal Disk Protrusion at L3- L4.** Orthopedics. 2013;36:46-47.

>> Sports Medicine

Section Chief: Brian J. Sennett, MD

- Penn Sports Medicine was chosen to be the official sports medicine provider of the Philadelphia 76ers, with Brian J. Sennett, MD selected as head team physician.
- The Penn Center for Advanced Cartilage Repair and Osteochondritis Dissecans Treatment was established as a Type I Center at Penn Medicine, providing diagnostics, non-operative and operative care, and basic science and clinical research. The Center is among a select few clinics in the nation dedicated to cartilage repair, and one of the first to focus on osteochondritis dissecans (OCD) a rare knee condition caused when fragments of bone and cartilage separate.
- Penn Sports Medicine added three additional faculty members: Drs. Miltiadis Zgonis, Kate Temme and John Vasudeven. Dr. Zgonis completed his residency at Penn Orthopaedics and his sports medicine fellowship at Duke University. Dr. Zgonis will be developing the basic science sports medicine research program. Drs. Temme and Vasudeven are fellowship trained in sports medicine. Dr. Temme is currently developing a Women's Sports Medicine Service.
- James L. Carey, MD is a part of the Multicenter ACL Revision Study (MARS) Group, which is performing a series of cohort studies to evaluate the various effects of ACL revision surgery.
- The Penn Sports Medicine Fellowship was established in August 2013. The Fellowship combines the talents of the Adult Sports Medicine Faculty at Penn Medicine with the Pediatric Sports Medicine Faculty at the Children's Hospital of Philadelphia to deliver one of the most comprehensive Adult and Pediatric Sports Medicine Fellowships in the country.

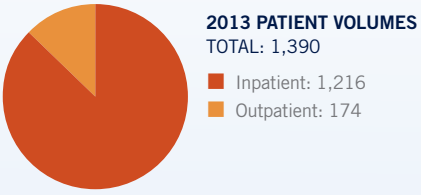


Selected Articles // Huffman R, Sheth N, Sennett B, Mauck R. **Meniscus Tissue Engineering on the Nanoscale: From Basic Principles to Clinical Application.** J Knee Surg 2009;22:45-59. // Huffman R, Sennett B. **Anterior Cruciate Ligament Reconstruction in Patients Aged > 40 Years: A Case-Control Study.** Phys Sportsmed 2013;41:30-34. // Huffman R, Mauck R. **Tissue Engineering with Meniscus Cells Derived from Surgical Debris.** Osteoarthritis Cartilage 2009;17:336-45. // Austin D, Park M, Gans I, Carey J, Kelly JD. Association of Metabolic Syndrome and Adhesive Capsulitis. J Shoulder Elbow Surgery. Dec 2013."

>> Trauma and Fractures

Section Chief: Samir Mehta, MD

- Penn Orthopaedics' trauma and fracture services are available 24/7/365, including pelvic and acetabular fractures, management of bone defects, soft tissue reconstruction, periprosthetic fractures and hip preservation.
- The service has several prospectively funded clinical research trials including sponsorship through the Department of Defense, the American Orthopaedics Foundation and private endowments.
- Faculty from the Penn Orthopaedics Trauma and Fracture service completed medical missions in Nicaragua, Haiti and China.
- Faculty serve in key roles with several orthopaedic societies, including the American Academy of Orthopaedic Surgeons, the American Orthopaedic Association, the Orthopaedic Trauma Association, the Foundation for Orthopaedic Trauma and the Musculoskeletal Infection Society.



Selected Articles // Schenker ML, Yannascoli S, Baldwin KD, Ahn, J, Mehta S. **Does Timing to Operative Debridement Affect Infectious Complications in Open Long-Bone Fractures? A Systematic Review.** J Bone Joint Surg Am. 2012;94:1057-1064. // Neuman MD, Donegan DJ, Mehta S. **Comparative Effectiveness of Joint Reconstruction and Fixation for Femoral Neck Fracture: Inpatient and 30-Day Mortality.** Am J Orthop. 2013;42:E42-E47. // Clement RC, Carr BG, Kallan MJ, Reilly PM, Mehta S. **Who Needs an Orthopedic Trauma Surgeon? An Analysis of US National Injury Patterns.** J Trauma Acute Care Surg. 2013;75:687-692. // Horneff JG 3rd, Scolaro JA, Jafari SM, Mirza A, Parvizi J, Mehta S. **Intramedullary Nailing Versus Locked Plate for Treating Supracondylar Periprosthetic Femur Fractures.** Orthopedics. 2013;36:e561-e566. // Miedel E, Dishowitz MI, Myers MH, Dopkin D, Yu YY, Miclau TS, Marcucio R, Ahn J, Hankenson KD. **Disruption of Thrombospondin-2 Accelerates Ischemic Fracture Healing.** J Orthop Res. 2013;31:935-943. // Patel NM, Yoon RS, Koerner JD, Donegan DJ, Liporace FA. **Timing of Diaphyseal Femur Fracture Nailing: is the Difference Night and Day?** Injury. 2013 Oct 25.

Penn Medicine
3600 Market Street
Suite 210
Philadelphia, PA 19104

Non-Profit Org
U.S. Postage
PAID
Permit No. 2563
Phila., PA 19104

PENN ORTHOPAEDICS

EXCELLENCE *IN MOTION* 2014

FACULTY

CHAIR

L. Scott Levin, MD, FACS

VICE-CHAIRS

Brian J. Sennett, MD
Louis J. Soslowsky, PhD
Kristy L. Weber, MD

CHIEFS

Vincent Arlet, MD
David J. Bozentka, MD
David L. Glaser, MD
Frederick Kaplan, MD
Samir Mehta, MD
Charles L. Nelson, MD
Keith L. Wapner, MD

FULL-TIME FACULTY

Jaimo Ahn, MD, PhD
Vincent Arlet, MD
Keith D. Baldwin, MD, MPH, MSPT
David J. Bozentka, MD
James L. Carey, MD, MPH
Wen Chao, MD
George R Dodge, PhD
Derek J. Donegan, MD
John L. Esterhai Jr., MD
Daniel C. Farber, MD
David L. Glaser, MD

FULL-TIME FACULTY (cont'd)

R. Bruce Heppenstall, MD
G. Russell Huffman, MD, MPH
Eric L. Hume, MD
Craig Israelite, MD
Rahul Kapur, MD
John D. Kelly IV, MD
Andrew F. Kuntz, MD
Gwo-Chin Lee, MD
Matthew Lewullis, DO
X. (Sherry) Liu, PhD
Robert L. Mauck, PhD
Samir Mehta, MD
David G. Nazarian, MD
Charles L. Nelson, MD
David R. Pashman, MD
Robert J. Pignolo, MD, PhD
Lin Qin, PhD
Michael C. Schettino, MD
Neil P. Sheth, MD
Eileen M. Shore, PhD
Harvey E. Smith, MD
Lachlan J. Smith, PhD
David R. Steinberg, MD
Kate E. Temme, MD
John M. Vasudevan, MD
Kristy L. Weber, MD
Miltiadis H. Zgonis, MD

Penn Orthopaedics Faculty

Penn PhysicianLink®

Consults • Referrals • Transfers

- **Exclusive, Physician-Only Telephone Line:** 877.937.PENN (7366)
- **Online Physician Portal:** PennMedicine.org/PhysicianLink
- **Physician Liaison Services:** Physician.Link@uphs.upenn.edu

For more information on how to make **Penn PhysicianLink** work for your practice and your patients, call **877.937.PENN (7366)** or visit **PennMedicine.org/PhysicianLink**.

LEARN MORE AT PENNMEDICINE.ORG/ORTHO