

Orthopedic Surgery Update

Current trends from the Department of Orthopedic Surgery

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New Directions for Orthopedic Surgery Research

Matthew P. Abdel, M.D., an orthopedic surgeon at Mayo Clinic in Rochester, Minnesota, answers questions about artificial intelligence (AI) and other research goals in Orthopedic Surgery. Dr. Abdel was recently named chair of Mayo Clinic's Orthopedic Surgery Research.

Why is AI a primary focus of Mayo Clinic's orthopedic surgery research?

All of our research priorities are based on the needs of our patients. Our basic science researchers as well as our clinician-investigators are all engaged in research that is directly translatable to clinical practice.

What infrastructure does Mayo Clinic have for building predictive analytics?

In addition to orthopedic surgical subject matter experts, Mayo Clinic has robust data sets for most orthopedic subspecialties. For example, in hip and knee arthroplasty, we have a patient registry that has captured clinical, radiographic, demographic and operative details going back to March 1999. That type of longitudinal data is key to developing the algorithms that drive predictive analytics.

Applying predictive analytics to individual patients requires state-of-the-art imaging. Mayo Clinic also has a long tradition of imaging expertise that will facilitate the development of AI-based applications.

What additional priorities is the research division pursuing?

In addition to AI, our 2030 strategic vision focuses on cartilage regeneration, infection prevention and treatment, fibrosis, arthritis, and orthopedic oncology.

How might research focused on cartilage regeneration benefit patients?

Pharmacological and/or gene therapies that slow the degeneration of cartilage can help individuals avoid joint replacement surgery. Patients are eager for nonsurgical options. Like AI, cartilage regeneration can impact many of the services we provide, including our upper and lower extremity practices, spine practice, pediatric orthopedics, and sports medicine.

What does Mayo Clinic hope to achieve regarding orthopedic infection research?

One particular issue we hope to clarify is whether



Figure. Schematic describes Mayo Clinic's goals for musculoskeletal (MSK) innovation.

AI has a strong potential to improve patient care through the development of predictive analytics to guide surgical decision making. One example is AI analytics to predict whether or not a prosthetic implant is fixed or loose. But the potential applications of AI touch all nine of our Orthopedic Surgery clinical divisions. Our goal is to transform musculoskeletal care through predictive algorithms and AI (Figure).



Matthew Abdel, M.D.

bacteriophages play any role in treating periprosthetic joint infections. As described in *Clinical Infectious Diseases*, Mayo Clinic successfully used phage therapy to treat a 62-year-old man with a history of knee arthroplasty and multiple episodes of prosthetic knee infection — avoiding the need for amputation.

Infections can plague any bone, muscle, ligament, tendon or joint. The prevention and treatment of these orthopedic infections is evolving rapidly, and Mayo Clinic is committed to innovation.

What are Mayo Clinic's goals in fibrosis and arthritis research?

We are working to develop pharmacological modalities that both prevent and treat fibrosis in

the musculoskeletal system. Similarly, learning more about the pathogenesis of arthritis, and how we might slow or prevent its development, is key.

All of our research aims ultimately focus around curing musculoskeletal diseases with innovative diagnostics and therapeutics. Moreover, we want to connect patients to optimal care through predictive analytics and advanced registry technologies.

For more information

Cano EJ, et al. Phage therapy for limb-threatening prosthetic knee *Klebsiella pneumoniae* infection: Case report and in vitro characterization of antibiofilm activity. *Clinical Infectious Diseases*. In press.

Successful Transition to Outpatient Total Joint Arthroplasty



Cameron K. Ledford, M.D.

Mayo Clinic is performing a growing proportion of total hip and knee arthroplasty procedures on an outpatient basis, in line with the orthopedic surgery field's increasing interest in same-day hospital discharge. Successful outpatient joint replacement requires an experienced, multidisciplinary care team and strict adherence to evidence-based protocols.

"We have dedicated the resources necessary to educate patients before their procedures, to execute efficient and safe surgeries, and to provide a rapid recovery, including same-day physical therapy before patients go home," says Cameron K. Ledford, M.D., an orthopedic surgeon at Mayo Clinic in Jacksonville, Florida. "If qualified surgical candidates choose to have an outpatient procedure, our model of care can provide it."

Between 5% and 10% of patients in the United States who have hip or knee arthroplasty have an outpatient procedure. At the Jacksonville campus of Mayo Clinic, that proportion is about 15%.

"We began the transition to outpatient arthroplasty before the outbreak of COVID-19," Dr. Ledford says. "But the outbreak helped move that transition forward. More patients are asking us if they can have outpatient procedures and avoid any hospitalization."

To qualify for outpatient hip and knee arthroplasty, patients must be in overall good health and motivated to perform physical therapy after surgery. They also must have a supportive environment for postoperative recovery and rehabilitation.

"Patient selection is especially important to

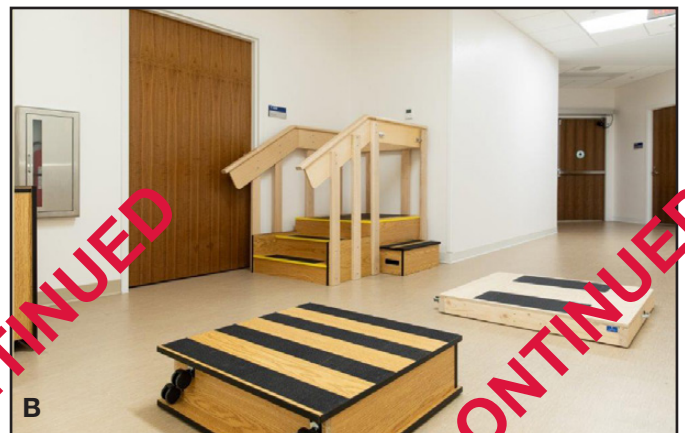
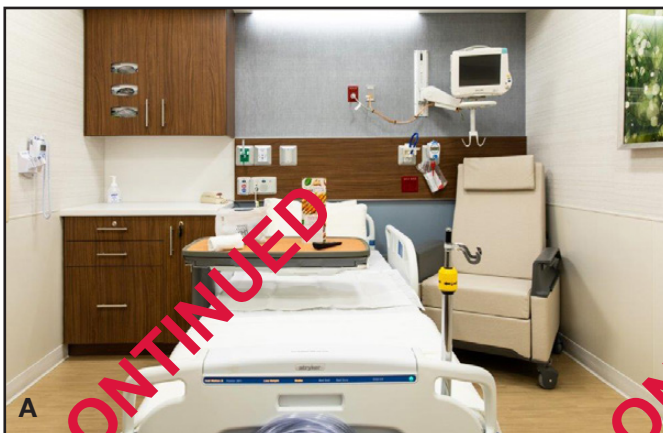


Figure. Photographs show the facilities in a new wing of the short stay unit at Mayo Clinic Hospital in Jacksonville, Florida. A. A room similar to a hospital room is available after outpatient total joint replacement. B. A physical therapy room is used to help patients reach certain milestones before same-day discharge.

optimizing outcomes,” Dr. Ledford says. “Once we identify that a patient is eligible and willing to have outpatient total joint arthroplasty, we provide thorough education on both the type of procedure the patient is having and the expectations for postoperative recovery. Patient motivation is key.”

At Mayo Clinic, outpatient arthroplasty procedures are scheduled in the early morning. “You have to have a clinical and surgical team with expertise and intraoperative resources performing the surgery at a high level,” Dr. Ledford says. “A successful program requires adherence to evidence-based protocols on preoperative patient optimization, blood conservation, wound and pain management, blood clot prevention, and rehabilitation.”

The surgeries are performed using a short-acting spinal anesthesia. Afterward, patients go to a recovery unit and then to a specially designed short stay unit (Figure, see page 2). “Physical therapists work there with patients for one or two hours,” Dr. Ledford says. “Once the patients pass the milestones necessary to safely go home, they’re discharged — usually before dinner.”

He notes that outpatient joint replacement can have positive outcomes similar to inpatient procedures, when the outpatient procedure is executed according to protocols. “Mayo Clinic has a history of successful teamwork and an environment designed to optimize surgical outcomes,” he says. “This outpatient arthroplasty program is an extension of that Mayo Clinic value system.”

3D Printing for Joint Reconstruction in Compromised Bone

Joint reconstruction is particularly challenging in the setting of complex bony defects or radiation therapy (Figure). Mayo Clinic routinely uses 3D-printed models to optimize surgical outcomes for individual patients.

“This technology allows us to re-create a patient’s bony defects and surgically correct them to restore joint function,” says Cory G. Couch, M.D., an orthopedic surgeon at Mayo

Clinic in Rochester, Minnesota, with fellowship training in orthopedic oncology and joint reconstruction. “We are able to model and fill in even very large bony defects created by tumors and tumor resections.”

Mayo Clinic has the largest point-of-care additive manufacturing facility in the United States, staffed by radiologists and biomedical engineers. “They work in close conjunction with

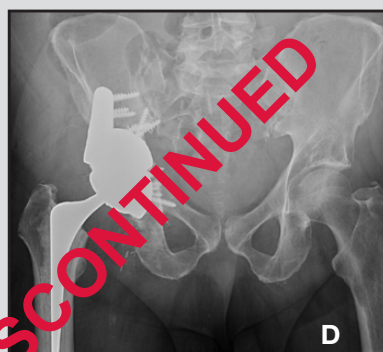
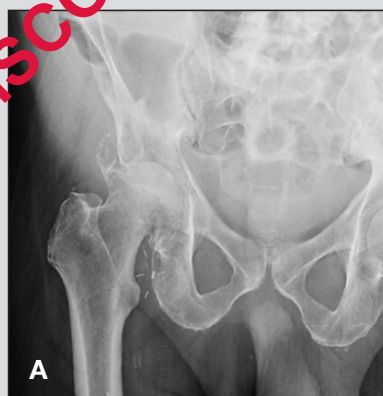


Figure. Images illustrate the case of a 56-year-old man with newly diagnosed metastatic lung carcinoma who presented at Mayo Clinic with excruciating right hip pain and who was unable to walk. A. Anteroposterior X-ray of the right hip reveals pathological acetabular fracture and superior migration of the femoral head into the acetabular defect. B. Obturator oblique X-ray of the pelvis shows a pathological acetabular fracture with loss of the posterior wall and posterior column, and posterior subluxation of the right hip joint. C. Intraoperative photo reveals severe superior and posterior acetabular bone loss. Only the inferior aspect of the acetabulum resembles native anatomical architecture. D. Postoperative X-ray shows the final reconstruction. A highly porous tantalum augment was placed in the superior acetabular defect, followed by insertion of a highly porous tantalum revision shell, obtaining a press fit between the augment and the remaining pubis and ischium. An additional buttress augment, also made of highly porous tantalum, was applied as additional fixation to the intact ilium. A cemented stem total hip arthroplasty was also used, due to plans for future radiation treatments. After surgery, the patient experienced significant pain relief and regained the ability to walk.



Cory G. Couch, M.D.

us," Dr. Couch says. "Complex joint reconstructions require multidisciplinary care from imaging experts and from radiation and medical oncologists, as well as orthopedic surgeons."

The 3D-printing technology is used in complex reconstructions of the knee, hip and pelvis for individuals with sarcoma or metastatic cancer. The technology also facilitates complex joint replacements associated with infection or the failure of a previous replacement joint.

The models are created using individual patients' CT scans or MRIs on both and sterilizable materials. "In the operating room, we have the model on the table right next to the patient. That helps us to identify optimal implant placement or screw fixation," Dr. Couch says.

Arthroplasty and cancer care

Mayo Clinic commonly treats patients with bony defects due to cancer. Radiation and medical oncologists meet regularly with orthopedic surgeons to discuss patients and plan treatment. Surgical reconstruction of the hip or knee may precede or follow radiation treatment.

"We typically make these decisions based on the tumor type and location, but sometimes on a case-by-case basis," Dr. Couch says. "Sometimes having chemotherapy or radiation therapy upfront will reduce the size of the tumor, facilitate removal and optimize the maintenance of function."

Historically, patients having total hip arthroplasty after pelvic radiation experienced high rates of implant loosening when traditional uncemented acetabular components were used. But Mayo Clinic orthopedic researchers have

found that 100% of modern, porous titanium components remained radiologically well fixed 10 years after implantation in patients having total hip arthroplasty after pelvic radiation. As described in the *Journal of Arthroplasty*, the mean overall pelvic radiation dose for the 33 patients in the study exceeded the radiation threshold for dose-related bone effects.

A separate study, described in *The Journal of Bone and Joint Surgery*, found that for patients with periacetabular metastatic disease, acetabular reconstruction using highly porous tantalum components provided a more durable construction and fewer complications compared with procedures using the cemented technique.

"Advances in medical care and radiotherapy mean that more cancer patients are living longer," Dr. Couch says. "Restoring patients' joints allows them to return to walking soon after surgery. The goal is for these patients to spend the remainder of their lives doing the things they want to do, relatively pain-free."

For more information

Wellings EP, et al. Contemporary porous titanium acetabular components for total hip arthroplasty after pelvic radiation. *Journal of Arthroplasty*. 2021;36:1714.

Houdek MT, et al. Comparison of porous tantalum acetabular implants and Harrington reconstruction for metastatic disease of the acetabulum. *The Journal of Bone and Joint Surgery*. 2020;102:1239.

Sports Analytics: Identifying At-Risk Athletes Before Injuries Occur



Christopher L. Camp, M.D.

Sports analytics can provide information about not only an athlete's likely future performance but also that individual's risk of sports injury. Mayo Clinic orthopedic surgeons work closely with professional athletes to discern how to avoid those risks and how to best treat injuries when they occur.

One example of this is Mayo Clinic's relationship with the Minnesota Twins. Among other projects, Mayo specialists are working with the major league baseball team on the prevention of injuries of the medial ulnar collateral ligament of the elbow, also known as Tommy John injuries (Figure, see page 5).

"A Tommy John injury is one of the most common and significant injuries in baseball. It often requires surgery with 12 to 18 months until full recovery," says Christopher L. Camp, M.D., a sports medicine orthopedic surgeon at Mayo

Clinic in Rochester, Minnesota, and medical director and director of high performance of the Twins. "Everyone involved with a team has a vested interest in identifying individuals who may be at risk of a Tommy John injury before it happens."

The potential benefits of these efforts extend beyond professional sports. "We can eventually use this information to help college, high school and youth athletes," Dr. Camp says. "More Tommy John injuries actually occur in nonprofessional athletes than professionals. Right now, we have a lot more data on professional athletes. But we want to take advantage of that information and apply it to a larger population."

Multidisciplinary and holistic approach

Mayo Clinic's multidisciplinary approach

to patient care is also typical of professional athletic organizations. “Pro teams have a lot of high-caliber medical and performance specialists, including athletic trainers, physical and massage therapists, strength conditioning coaches, sports psychologists, and nutritionists, as well as physicians,” Dr. Camp says. “The goal of any multidisciplinary approach is to coordinate all these efforts and care not only for injured players but also for healthy players, to help them achieve optimal performance.”

That team approach is key to tackling issues such as a Tommy John injury. “The rates of Tommy John injury are rising rapidly. It’s a complex problem that will probably have relatively complex solutions,” Dr. Camp says. “There’s no single cause. We have to take a holistic approach, looking at players’ health, at how they perform on the field and what they’ve done in the off-season.”

Risk factors include throwing too many pitches, throwing too hard and throwing with poor mechanics. “Since we’re not going to be able to tell players to stop throwing so hard, we have to figure out how to optimize throwing mechanics and throwing volume,” Dr. Camp

says. “That might mean a pitcher throwing for fewer innings or having more-frequent breaks. It might mean changing the preparation that occurs in the off-season or even focusing on subtle changes in how a player utilizes different pitches.”

Mayo Clinic is also applying analytics to the prevention of soft tissue injuries. “Those injuries are actually much more common than Tommy John injuries. The No. 1 injury in professional baseball is a hamstring injury,” Dr. Camp says. “Regardless of the type of injury or the level of play, the goal is to use research and analytics appropriately to augment players’ health, avoid injury and improve performance.”

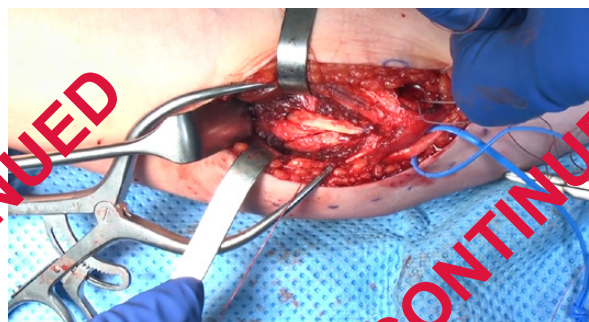


Figure. Surgical photograph shows a completed reconstruction of the medial ulnar collateral ligament, also known as Tommy John surgery.

Young Adult Hip and Pelvic Conditions: Comprehensive Approach for Optimal Care

The hip and pelvic problems experienced by young adults have multiple and often complex etiologies (Figure 1, see page 6). Treatment options vary, further complicating decisions about the optimal approach for an individual patient. Mayo Clinic addresses these issues through a multidisciplinary Young Hip Clinic.

“Bringing together a number of different specialties allows for a comprehensive approach,” says Rafael J. Sierra, M.D., chair of Adult Reconstruction, Orthopedic Surgery, at Mayo Clinic in Rochester, Minnesota. “We are able to provide a spectrum of treatment options, including operative and nonoperative management, that are individualized to the patient.”

Hip dysplasia and femoroacetabular impingement (FAI) are the most common conditions treated. But specialists in the Young Hip Clinic also treat pelvic conditions, including sacroiliac joint pain, athletic pubalgia and buttock pain from various etiologies, including ischiofemoral impingement. “We see patients who have been labeled as having hip pain, but their pain could be a combination of factors including pelvic-associated pain,” Dr. Sierra says.

Precise diagnosis of young athletic hip and

pelvic injuries can be challenging. “Many different injuries can present with similar symptoms,” says Aaron J. Krych, M.D., co-chair of Sports Medicine, Orthopedic Surgery, at Mayo Clinic’s campus in Minnesota. “In addition, the same injury can require very different management, depending on the patient’s activity requirements and goals.”

The Young Hip Clinic treatment team also includes orthopedic surgeons with expertise in trauma care, physical medicine and rehabilitation specialists, and physical therapists.

Defining and treating an individual’s pathology

Imaging is key to managing complex hip and pelvic conditions (Figure 2, see page 6). Nonoperative specialists in Sports Medicine at Mayo Clinic — Jacob L. Sellon, M.D.; Jeffrey M. Payne, M.D.; and Elliea (Ellie) J. Jelsing, M.D. — have expertise in ultrasound evaluation of painful joints as well as joint injections. Mayo Clinic has also developed high-definition and 3D CT and MRI to evaluate hip and pelvic injuries.

“Each patient presents with unique pathology,” Dr. Krych says. “State-of-the-art imaging



Rafael J. Sierra, M.D.



Aaron J. Krych, M.D.

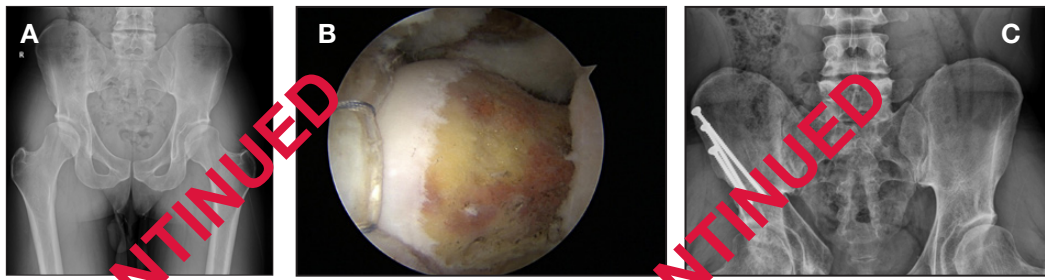


Figure 1. A. Preoperative X-ray illustrates the complex condition of 26-year-old man with combined hip dysplasia and impingement due to femoral head-neck junction abnormality and femoral retroversion. B. Intraoperative image shows hip arthroscopy performed after labral repair and femoral head-neck junction osteochondroplasty. C. An X-ray taken four months after treatment shows correction after periacetabular osteotomy, cam resection and derotational femoral osteotomy.

allows us to evaluate the primary root of the problem and the secondary consequences of that pathology, and then to recommend the treatment needed to relieve pain, restore function and prevent future injury.”

Nonsurgical treatment is initially pursued if feasible. When surgery is needed, specialists consult to determine whether an arthroscopic or open approach would be more beneficial. At Mayo Clinic’s campus in Minnesota, the adult reconstruction and sports medicine divisions are located on adjacent floors in the same building.

“We are able to connect regularly to review images, see patients, and decide if an arthroscopic or open approach is appropriate,” Dr. Sierra says. “If a sports medicine physician thinks a patient needs to see a surgeon who does open hip surgery, that’s often possible on the same day.”

Both approaches might be necessary — for example, for individuals with hip dysplasia and secondary intra-articular joint damage. Mayo Clinic has orthopedic surgeons with experience in periacetabular osteotomy (PAO) and other open surgeries as well as hip arthroscopy. “Together, an open and an arthroscopic approach can treat current symptoms and prevent further deterioration of the joint or

be performed under a single anesthesia. But if the patient’s condition is very complex, two surgeries in a single setting might take too long. In that case, we separate the procedures by at least a month.”

Most people treated in the Young Hip Clinic report significant relief from pain. “We know that three-fourths of people with untreated hip dysplasia will experience some hip degeneration and arthritis within 20 years,” Dr. Sierra says. “Ultimately, we want to help these patients avoid hip replacements. Our research has shown that treatment at a young age cannot only relieve immediate pain but also can change the natural history of the condition.”

Cutting-edge research and clinical trials

Research and clinical trials are important aspects of Mayo Clinic’s efforts to manage hip conditions. A study redefining the natural history of osteoarthritis in people with hip dysplasia and impingement received the John Charnley Award in 2017. In the January 2021 issue of *American Journal of Sports Medicine*, Mayo orthopedic surgeons defined the incidence of FAI in the general population and the increase in diagnoses of FAI between 2000 and 2016.

Patients treated at the Young Hip Clinic might also be eligible to participate in clinical trials. Mayo Clinic is leading a randomized trial evaluating treatment outcomes for individuals with hip dysplasia who have concomitant hip arthroscopy during PAO compared with patients treated with PAO alone.

“Right now, we don’t completely grasp whether arthroscopy is always beneficial with PAO. This trial will advance the science of treating these conditions,” Dr. Sierra says. Mayo Clinic is also participating in a multi-center clinical trial, funded by the Department of Defense, that is investigating predictors of outcomes for FAI.

In addition, Mayo’s orthopedic surgeons are working to improve surgical techniques. One

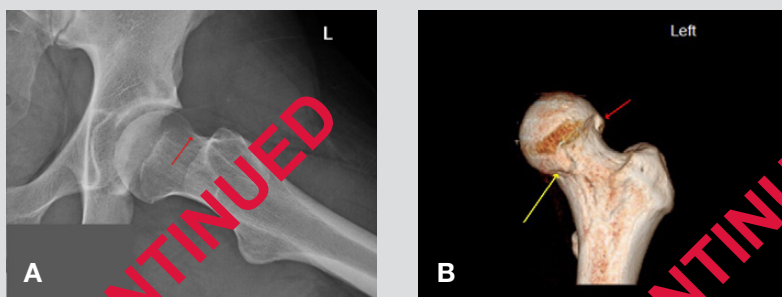


Figure 2. Images illustrate the advantages of 3D imaging for the management of complex hip conditions. A. An X-ray shows what appears to be a good cam resection (red arrow) in a 24-year-old man who presented at Mayo Clinic with continued hip pain after two hip arthroscopy procedures performed elsewhere. B. A 3D CT scan of the same hip shows large areas of residual cam impingement (yellow and red arrows).

project involves the use of 3D-printed surgical guides for patients having PAO. In another effort, Mayo's engineering specialists are working to develop finite element analysis to improve the positioning of the hip during surgery to better prevent arthritis.

"What's truly unique about the Young Hip Clinic is the number and range of specialties that we utilize," Dr. Sierra says. "It's a new, holistic approach to care for these patients."

For more information

Wyles CC, et al. The John Charnley Award: Redefining the natural history of osteoarthritis in patients with hip dysplasia and

impingement. *Clinical Orthopaedics and Related Research*. 2017;475:336.

Hale RF, et al. Incidence of femoroacetabular impingement and surgical management trends over time. *American Journal of Sports Medicine*. 2021;49:35.

Mayo Clinic. Clinical Trial of Concomitant Hip Arthroscopy During PAO. ClinicalTrials.gov.

Washington University School of Medicine. Identification of Predictors for Clinical Outcomes in Femoroacetabular Impingement Surgery (DOD FAI-2). ClinicalTrials.gov.

Ankle Injuries: Seeking Stability and a Return to Activity

Ankle injuries are fairly common and often debilitating, preventing individuals from resuming their normal levels of activity. And treatment modalities are evolving. At Mayo Clinic, orthopedic surgeons specializing in trauma take a personalized approach for patients of all ages and activity levels.

"We have a very high volume of ankle fractures — up to 250 patients a year — with many seen during the winter when people slip and fall on ice," says Brandon J. Yuan, M.D., an orthopedic surgeon at Mayo Clinic in Rochester, Minnesota, with fellowship training in trauma.

One unresolved issue in ankle fracture care is the need for fixation of the posterior malleolus during surgical fixation of ankle fractures, particularly when the fragment is small. Mayo Clinic is launching a clinical trial to evaluate operative versus nonoperative interventions for individuals with posterior malleolar fractures that involve less than 25% of the articular surface.

Increasing attention is also being paid to the long-term stability of an individual's ankle after treatment for fracture. "We are focusing more on the role of the deltoid ligament. For some patients, deltoid repair is important to providing

ankle stability," Dr. Yuan says.

Treatment modalities are also evolving for the syndesmosis. "Our thinking has shifted. We're focusing more on the rotational and translational instability associated with the syndesmosis, and the role that suture fixation or ligament repair can have in restoring normal motion, as opposed to screw fixation," Dr. Yuan says. "Our goal is for patients to get back to what feels like a normal ankle, especially because syndesmotic injuries are common and occur in people who are younger and of working age (Figure)."

At a major orthopedic surgery center, Mayo Clinic has physical therapists with extensive experience with ankle rehabilitation. "A multidisciplinary approach is key to helping patients regain function," Dr. Yuan says. "Our care starts with orthopedic traumatologists but continues through all aspects of the patient's medical care and recovery."

For more information

Clinical trials: A Study to Evaluate Operative versus Non-operative Intervention of Posterior Malleolar Fractures Involving Less than 25% of the Articular Surface. Mayo Clinic.



Brandon J. Yuan, M.D.



Figure. A. The radiograph demonstrates an unstable ankle fracture with a syndesmotic injury. B. Postoperative follow-up radiograph demonstrates successful fracture fixation and syndesmotic repair. C. Long-term follow-up radiograph demonstrates successful fracture fixation and syndesmotic repair.

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John W. Sperling, M.D.

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Education Opportunities

For more information or to register for courses, visit <https://ce.mayo.edu/group/orthopedic-surgery>, call 800-323-2688 or email cme@mayo.edu.

30th Annual Mayo Clinic Symposium on Sports Medicine – 2021

Nov. 5-6, 2021, in Rochester, Minn.

This course features evidence-based and cutting-edge diagnosis and treatment strategies for sports-related and musculoskeletal conditions. The program is multidisciplinary, with expert lecturers representing a spectrum of sports medicine fields.

Comprehensive Shoulder and Elbow Course: Current Concepts and Controversies 2022

Feb. 17-19, 2022, in Scottsdale, Ariz.

This expanded three-day course provides the latest treatment options for shoulder and elbow arthroscopy, arthroplasty and fracture fixation. An internationally recognized faculty will provide participants with key insights and practical tips in treating the full spectrum of shoulder and elbow disorders. The unique course setting allows a high level of personal interaction with the faculty to help participants optimize surgical techniques and avoid complications.

Mayo Clinic Advancements in Surgical & Medical Management of the Spine 2022

Feb. 19-23, 2022, in Kohala Coast, Hawaii

This course covers current and emerging topics driving national change in the quality and delivery of spinal care, with a focus on the aging spine. The wide and varied curriculum will provide updates via didactics, case presentations and a daily mystery case known as Spine Curve Ball.

6th Annual Mayo Clinic Sports Medicine for the Clinician 2022

March 4-6, 2022, in Orlando, Fla.

This course focuses on the diagnosis and treatment of sports-related conditions as well as injuries sustained during recreational physical activities. Appropriate testing and referral criteria will be covered, along with specific skills in physical exams and imaging interpretation.

Mayo Clinic Course on Shoulder Tendon Transfer and Complex Rotator Cuff Repair 2022

April 28-30, 2022, in Rochester, Minn.

This course provides cutting-edge presentations, cadaver demonstrations and cadaver-based workshops on the management of complex rotator cuff tears and conditions affecting the scapulothoracic joint. The course will highlight the principles, surgical techniques and outcomes of tendon transfers around the shoulder joint and scapula, advanced arthroscopically assisted tendon transfers and alternative salvage procedures such as reconstruction of the superior capsule, reverse shoulder arthroplasty and shoulder/scapulothoracic fusion.