At Mayo Clinic, orthopedic surgeons often specialize in a single joint, allowing them to develop expertise in the range of procedures used to address problems in that area. That simultaneously narrow and wide focus helps to optimize patients’ outcomes.

“Having a practice focused on a single joint allows us to home in on the problems that are causing our patients’ pain,” says Luke S. Spencer Gardner, M.D., an orthopedic surgeon at Mayo Clinic in Jacksonville, Florida.

Historically, hip specialists have had either advanced orthopedic training in open surgery, or sports medicine training in arthroscopy. Mayo’s hip specialists have expertise in both (Figure).

“We’re able to diagnose a range of different pathologies that could be causing hip pain and to offer the correct procedure for that individual patient,” Dr. Spencer Gardner says.

Patients range in age from adolescents to older adults. Their conditions range from pre-arthritic causes of pain — including soft tissue damage, labral tears, femoroacetabular impingement and hip dysplasia — to arthritic degeneration requiring joint replacement.

“Our in-depth knowledge of the hip also allows us to differentiate problems in that joint from problems arising elsewhere,” Dr. Spencer Gardner says. The experience of subspecialized musculoskeletal radiologists and the wider expertise of Mayo’s musculoskeletal physicians and orthopedic surgeons allow for precise diagnosis.

**Matching patients to procedures**

Mayo Clinic is able to manage hip conditions ranging from mild to severe. “Hip pain that is not caused by arthritis can often be addressed arthroscopically,” Dr. Spencer Gardner says. “But sometimes, these patients also have larger structural problems that need to be addressed — for example, hip dysplasia with an associated labral tear. In that case we can do both an arthroscopic and an open surgery in a single stage.”

**Figure.** A. Preoperative X-ray shows acetabular dysplasia. The blue line indicates abnormal alignment of the acetabulum. B. X-ray after periacetabular osteotomy demonstrates normal alignment of the acetabulum. C. Intraoperative image during hip arthroscopy shows suture passage through a torn labrum during labral repair.
In addition to avoiding a second round of anesthesia and postoperative recovery, a combined procedure can improve outcomes. “You get better visualization of a labral tear arthroscopically, which allows you to repair the labrum with less dissection than would be possible with an open surgical approach,” Dr. Spencer Gardner says. “Being facile in both arthroscopic and open surgery allows us in a single stage to address each part of a patient’s pathology in the optimal manner.”

For all patients with hip conditions, Mayo can provide specialized physical and occupational therapy to aid in the recovery process.

Continuous improvement is a cornerstone of Mayo Clinic’s approach to care. A study of outcomes from combined open and arthroscopic orthopedic procedures at Mayo Clinic is underway. “The keys to good surgical outcomes are making the right diagnosis, performing the procedure that appropriately addresses that individual patient’s problems and providing a high level of ongoing care,” Dr. Spencer Gardner says. “At Mayo, we are committed to every one of these stages because ultimately they translate to improved patient outcomes.”

Despite recent improvements in surgical techniques and materials, approximately 25% of rotator cuff injuries fail to heal. Mayo Clinic is pursuing a regenerative medicine approach for improved treatment of these debilitating injuries.

“We have come a long way over the last 20 years from a mechanical engineering standpoint, with new kinds of anchors, suture materials and surgical techniques. But now we’re realizing that the problem isn’t mechanical — it’s biologic,” says John M. Tokish, M.D., an orthopedic surgeon at Mayo Clinic’s campus in Scottsdale, Arizona.

Mayo’s Center for Regenerative Medicine is working to develop electrospun fibers that, when surgically inserted, can promote tendon healing. Having created fiber structures in the laboratory that mimic the native tendon, the researchers are using animal models to investigate ways to embed growth factor products in those patches (Figure). “Because of the orthobiologics revolution, we’re beginning to understand the basic science behind what exactly signals a tendon to heal,” Dr. Tokish says. “We’ve learned that we can add adjunctive materials that provide the necessary biochemical environment to get that tendon to regenerate. That used to be science fiction. But for now, at least in the lab, it’s reality.”

Promoting tendon healing and regeneration
Electrospinning is used to create fibers that, like a tendon’s fibers, are measured on the nanolevel. The fibers can be arranged in varying directions.

“We know that the ability of tissues to regenerate often depends on the direction of their fibers,” Dr. Tokish says. “Electrospinning allows us to place materials that are commonly used, and biologically accepted, within a magnetic field. Depending on the magnet’s field strength and the direction of its spin, we can create nanofibers to be layered parallel to each other or intersecting, or really in any shape and direction we want. In the laboratory we can use a number of these different complementary fields to create a structure that mimics the native tendon.”

Various combinations of fibers are being tested in rat models developed in conjunction with Arizona State University. Before insertion into the models, the fiber patches are imbued with various growth factor products. “What’s really exciting is that we can pre-soak the patch in factors complementary to the individual tendon zones that we need,” Dr. Tokish says. “If it’s muscle, we can embed factors that promote muscle growth in that area of the patch. If it’s the calcified...
cartilage layer on the bone, we can embed factors that encourage that sort of regeneration into that portion of the patch.”

In addition to providing necessary growth factors, the adjunctive materials may well be able to change the tendon’s biochemical environment. “We’ve learned that these materials can encourage the body’s own medicinal signaling cells to be recruited to the area of injury or degenerative tearing and provide the necessary environment for the tendon to regenerate,” Dr. Tokish says. “When we are eventually able to insert the patch into human patients, it may act as a scaffold to encourage not only healing but also regeneration.”

The goal is to apply the system to the treatment of both irreparable tears and severe tendinopathy. “In patients with irreparable tears, the patch by itself or in conjunction with other technologies we currently use may help that new tendon to be incorporated in the body and patients to regain previous function,” Dr. Tokish says.

For patients with severely damaged yet repairable tendons, the biologic system might boost healing and safeguard the surgical repair. “We see a lot of patients in the younger demographic — between the ages of 40 and 60 — who have large rotator tears that are difficult to heal. Unfortunately, the reverse shoulder arthroplasty, which has revolutionized care for older patients, isn’t a good option for younger people,” Dr. Tokish says. “We are some ways away yet from human trials. But we feel that augmenting tendon healing through the regenerative medicine field may be the missing key that will help us to better treat rotator cuff tears.”

### Patient-Specific Instrumentation for Shoulder Arthroplasty

Mayo Clinic uses the latest technology for shoulder replacement surgery, including analytical tools that provide understanding of an individual patient’s glenoid wear pattern. Sophisticated preoperative planning and the use of patient-specific instrumentation are key to optimizing glenoid component choice and position and maximizing surgical outcomes.

“We’ve learned over time that understanding the glenoid bone’s three-dimensional anatomy is enormously helpful in planning shoulder replacement surgery,” says John W. Sperling, M.D., an orthopedic surgeon at Mayo Clinic in Rochester, Minnesota. “These tools allow us to develop a surgical plan based on the individual patient’s anatomy and then to accurately execute that plan once we get to the operating room.”

With the highest-volume shoulder replacement practice in the United States, Mayo Clinic is at the forefront of advances in this complex procedure. In addition to implementing 3D surgical guides based on an individual patient’s anatomy, Mayo’s orthopedic surgeons use recently developed depth controls for glenoid reaming (Figure 1).

**Figure 1.** On the left, photograph shows a 3D glenoid model with a patient-specific guide. In the center, perioperative photograph shows the patient-specific guide matching the patient’s glenoid surface. On the right, perioperative photograph shows a depth control guide for glenoid reaming, to maximize the preservation of glenoid bone.

**Figure 2.** Perioperative photographs show the use of an augmented glenoid baseplate. On the left, an augmented glenoid baseplate is placed in a patient. On the right, the augmented baseplate’s ability to create tilt and provide lateralization are demonstrated.
“A 3D-printed guide attached to the reamer allows for precise preparation of the glenoid surface and maximizes glenoid bone preservation,” Dr. Sperling says. “During surgery, the depth control helps us prepare the glenoid in the manner that we planned preoperatively.”

Initially, patient-specific instrumentation was reserved for patients with complex anatomy, including dysplasia, bone deficiency or deformity secondary to prior trauma. “But due to the benefits we’ve seen, we are broaden our use to the full range of conditions, from minimal glenoid deformity to highly complex underlying shoulder pathologies,” Dr. Sperling says.

Mayo Clinic’s team approach facilitates this individualized orthopedic care. The CT scans needed for pre-surgical planning and patient-specific instrumentation can be pre-scheduled to coordinate with surgical and medical appointments. “The patient experience here is very time efficient,” Dr. Sperling says.

The CT scans are uploaded to a system that uses advanced software to allow the surgeon to plan the orthopedic procedure and order patient-specific surgical guides. “In the operating room, the preoperative plan and patient-specific instrumentation increase the procedure’s efficiency,” Dr. Sperling says. “We can execute our plan to preserve bone and optimize the positioning of the implant.”

**Augmented baseplate for reverse shoulder arthroplasty**

To preserve glenoid bone in patients who have reverse shoulder arthroplasty, Dr. Sperling uses an augmented glenoid baseplate (Figure 2, see page 3).

“The augmented component minimizes bone removal compared with eccentric reaming, preserves the best-quality cortical bone and allows for longer screw fixation,” Dr. Sperling says. “Recent research has shown that the routine use of augmented baseplates in reverse arthroplasty, along with preoperative planning, can result in over 50% preservation of glenoid bone compared with the use of a standard glenoid baseplate.”

As the major shoulder arthroplasty center in the United States, Mayo Clinic is committed to continued innovation. “In the future, as preoperative planning and patient-specific instrumentation continue to evolve, we will be able to further customize our procedures for individual patients,” Dr. Sperling says.

**Pedicle Screw Placement: Robotic Assistance for Greater Precision**

Accurate placement of pedicle screws is key to avoiding the potential complications of spinal fusion surgery and improving overall spinal fixation. Mayo Clinic uses the latest robot-assisted technology when indicated to enhance surgical precision in these procedures (Figure).

“Robot-guided surgery is a well-choreographed process that can help ensure reliable and accurate placement of spinal implants,” says Brett A. Freedman, M.D., an orthopedic surgeon at Mayo Clinic in Rochester, Minnesota. “We find that this system offers distinct advantages compared with not only freehand placement but also standard stereotactic navigation.”

Mayo Clinic was an early adopter of robot-assisted technology for spinal fusion surgery. As an orthopedic center of excellence, Mayo is committed to new technology that provides clinical benefits and adds value. “Robot-assisted surgery is just one example,” Dr. Freedman says. “We continually look for validated innovations that help our patients.”

**Ideal paths and trajectories**

Robot-assisted spine surgery uses CT imaging and navigational software to determine the optimal pathway for inserting pedicle screws. Finding that pathway is made challenging by the lack of clearance around the spine and the presence of surrounding neurological structures.

“Robotic assistance gives us real-time imaging that reliably depicts complex anatomy,” Dr. Freedman says. “That’s very important when a patient has not only deformity that changes the shape of bone but also poor-quality bone. We can actually find a path that goes through the patient’s best bone as opposed to softer bone.”

During surgery, the system’s software guides the robotic arm into position, translating the surgical plan onto the surgical field. “The robotic arm
places the guidance tube in the preferred alignment, and each screw can then be placed to a depth and in an alignment that matches its mates, which makes for a better overall construct,” Dr. Freedman says. “A system that robotically aligns the screws’ trajectories makes it easier to insert the spinal rods and induces less stress on the screws we placed.”

In addition, the robotic arm’s stability overcomes problems inherent with standard stereotactic navigation. “Stereotactic navigation requires the surgeon’s hands to be held in a specific position that is mapped to the imaging. However, our hands move — especially when we are preparing and inserting screws — while the robot holds a rock-steady trajectory,” Dr. Freedman says. “Our arms and other appendages are also in the way of the tracking camera that watches the various surgical instruments move. The robot-assisted system gives us an enhanced path of navigation.”

Mayo Clinic continuously assesses new technologies to determine their benefits for patients. “As spine surgeons, we want to innovate to solve problems, validate these solutions, and research the impact they have on clinical outcomes and value-based care,” Dr. Freedman says. “Robotic assistance offers real advantages for the accurate placement of pedicle screws.”

**Mayo Surgeons’ Deployments: Benefits for Military and Civilian Patients**

A sizable number of Mayo Clinic’s orthopedic surgeons are active duty veterans or reservists who have been deployed overseas. Mayo’s military connections serve not only members of the armed forces but also civilian patients once the surgeons return to Mayo.

“The acuity of injuries we see at Mayo, and our patient volumes, make us well prepared for deployment. We also can take new techniques from our military experience back home,” says Nicholas A. Pulos, M.D., a hand surgeon at Mayo Clinic in Rochester, Minnesota, who recently returned from deployment to Kandahar, Afghanistan.

Mayo’s ties to military service stretch back to Dr. William Worrall Mayo, who began his medical practice in Rochester in 1864 as an examining physician for Civil War enlistees. Dr. Pulos, who serves in the United States Navy Reserve, notes that hand surgery emerged as a medical specialty after World War II due to the wartime need for reconstructive surgeries. In addition to hand surgeons, orthopedic surgeons at Mayo Clinic specializing in the spine and hip, as well as plastic surgeons and other specialists, have military experience.

As a salaried organization with a strong founding culture, Mayo Clinic pursues a team-based approach to care. “We put our patients’ interests first and work together as a team rather than as individuals to deliver the care they need,” says Brett A. Freedman, M.D., an orthopedic surgeon at Mayo’s campus in Minnesota, and a decorated United States Army veteran. “We take our Mayo values with us on deployment, and they blend perfectly well with the military.”

With a large orthopedic practice, Mayo Clinic can transition patients to care from other experienced specialists when staff are deployed. “Even though all Mayo employees aren’t able to serve in a combat zone, they do contribute by helping their colleagues and families while the deployed physicians are overseas,” says Paul M. Hudspeth, M.D., an orthopedic surgeon at Mayo’s campus in Minnesota and a decorated United States Arm veteran who has served several deployments in Iraq and Afghanistan.

“Mayo is very supportive of deployment,” Dr. Pulos adds. “As an all-volunteer force, the military relies on reservists, including physicians at Mayo Clinic, to go out on active duty and help service members.”
Multidisciplinary and Coordinated Approach to Limb Lengthening Care

The causes of limb deformities are variable and often complex. Mayo Clinic’s Limb Lengthening and Regeneration Clinic in Minnesota takes a multidisciplinary approach aimed at maximizing function while managing any underlying disorders.

“Many of these patients require attention from more than just an orthopedic surgeon, because many limb deformities involve more than just bone. Access to the resources of multiple specialists in multiple fields is really beneficial,” says Stephen (Andy) A. Sems, M.D., an orthopedic surgeon at Mayo Clinic in Rochester, Minnesota.

Managing care for both children and adults, the limb lengthening clinic brings together experts in several orthopedic surgery subspecialties, including orthopedic trauma, pediatric orthopedics and orthopedic oncology. Plastic and reconstructive surgeons, medical geneticists, endocrinologists and radiologists also are part of the team. Individualized treatment recommendations are made based on the combined input of all team members. The treatment options are as varied as the sources of the deformities (Figure, see page 7), and external or internal fixation can be provided, depending on the individual patient’s needs.
The patient experience
Mayo requests referring physicians to send as much information as possible about patients before they are seen at the limb lengthening clinic. “We gather a group of specialists, based on a patient’s individual situation, to review that information,” Dr. Sems says. “We then try to set up a flow of consultations with individual specialists, to minimize the patient’s trips to Mayo.”

For example, a patient with an underlying metabolic disorder would see an endocrinologist as well as various surgeons. “The limb deformity might require soft tissue procedures, such as flaps or nerve releases, which would need the involvement of a microvascular surgeon,” Dr. Sems says. “Depending on where the deformity occurs, we have foot and ankle surgeons, and hand and upper extremity surgeons. If the deformity involves a residual amputation, we have a specialist with experience in those conditions.”

Each of these specialists routinely sees patients in the limb lengthening clinic. Having a core group of specialists helps ensure that the team has experience with patients’ varied conditions, even rare disorders. “We don’t just put in a referral to endocrinology. For example, there are two endocrinologists we typically work with, along with two specific hand surgeons, one foot and ankle surgeon, two pediatric surgeons, and one geneticist,” Dr. Sems says. “Our familiarity with one another creates a sense of teamwork and an understanding of these patients.”

As a major tertiary center, Mayo Clinic offers the full range of treatment options. These include lengthening rods, external fixation, and other implantable devices made from metals or polyether ether ketone (PEEK) polymers that can change limb angles.

“New technology has revolutionized how limb lengthening is approached,” Dr. Sems says. “Many of our patients tell us after treatment that this is the first time they’ve had a functioning or well-aligned limb in as long as they can remember. Allowing our surgeons to focus on their areas of expertise contributes to giving patients the best possible outcomes.”

For more information
Limb Lengthening and Regeneration Clinic in Minnesota. Mayo Clinic.
Education Opportunities

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

Controversies in Wrist Surgery 2021 and Pre-Conference Advanced Wrist Arthroscopy Lab
April 22-25, 2021
This course is designed for orthopedic and plastic surgeons with significant hand practices, and covers the spectrum of disorders of the wrist and distal radioulnar joint. The format will be case oriented, covering topics in areas including bony and soft tissue trauma, degenerative disease, and inflammatory arthritis. Videotaped surgery clips and cadaveric surgical dissection will be used to demonstrate complicated surgical procedures.

Orthopedic Infectious Diseases — LIVESTREAM
May 21-22, 2021
Designed for infectious disease practitioners, this course is dedicated entirely to the challenges of managing orthopedic infections. It will feature highly interactive, case-based modules delivered by subject matter experts addressing diagnostic and therapeutic challenges.

9th Annual Comprehensive Sports Medicine Update and Board Review 2021
June 16-19, 2021
This award-winning course provides a comprehensive review of all subjects contained in the sports medicine board examination. The faculty includes internationally recognized experts in the field of sports medicine.

30th Annual Mayo Clinic Symposium on Sports Medicine — 2021
Nov. 5-6, 2021
This course features evidence-based and cutting-edge diagnostic and treatment strategies for sports-related and musculoskeletal conditions. The program is multidisciplinary, with expert lecturers representing a spectrum of sports medicine fields.