Upper Extremity Reconstruction in Tetraplegia

Mayo Clinic is one of the few centers in the United States that offers upper extremity reconstruction for people with tetraplegia. The procedure, which uses standard hand surgical techniques, can help restore hand function and increase patients’ independence after a spinal cord injury.

“There isn’t a lot of awareness of this option. Many people can benefit from this surgery, but only about 10 percent of patients who are candidates actually get it,” says Peter C. Rhee, D.O., a hand surgeon at Mayo Clinic’s campus in Rochester, Minnesota.

Multiple studies have shown that people with tetraplegia prioritize hand function over other functions, such as walking and bowel and bladder control. Outcomes from reconstructive surgery depend on the patient’s level of injury and degree of disability. Upper extremity reconstruction uses a combination of joint fusions, tenodesis, and tendon and nerve transfers. Mayo Clinic’s experience and expertise allow for the performance of these procedures in patients with tetraplegia.

“We are using techniques similar to ones we’ve done for years with brachial plexus or peripheral nerve injuries,” Dr. Rhee says. “What’s different about applying those techniques to patients with tetraplegia is their mixed nerve injury pattern. Most hand surgeons don’t have experience treating higher level nerve injuries that originate in the brain or spinal cord.”

The surgery generally takes all day and requires an overnight hospital stay. Patients leave the following day with instructions for a structured rehabilitation program they can do at home. Mayo Clinic specialists are available to answer questions by telephone between follow-up visits.

Because of the extensive post-surgical rehabilitation, Mayo Clinic selects candidates for upper extremity reconstruction carefully, based

Figure. The hand of a patient with long-term tetraplegia, before, during and after surgery.
Mayo Clinic works with baseball players of all levels, from youth leagues to Major League Baseball, to enhance prevention and treatment of ulnar collateral ligament (UCL) injuries, also known as Tommy John injuries (Figure). UCL reconstruction is one of the most common surgeries performed in overhead-throwing athletes, and the incidence of these injuries is rising.

“We’re mobilizing all of our multidisciplinary resources to attack this problem,” says Christopher L. Camp, M.D., an orthopedic surgeon at Mayo Clinic in Rochester, Minnesota. “Once we get a handle on the risk factors, we need to work to reverse the dramatic climb in incidence. We are also working hard to redesign the surgical techniques and find ways to optimize the healing environment to speed up recovery.”

A number of studies have shown significant increases in UCL injuries at all levels. “The most rapid rise in injury rates is actually occurring among players ages 15 to 19,” Dr. Camp notes. “That’s most likely due to overuse from year-round play. These kids sometimes pitch daily, and even on days when they’re not pitching, they’re playing different positions in the field. The arm’s not getting a break.”

Although college and professional teams monitor players’ workloads, pitchers at those levels are throwing harder. “The ligament in isolation can only tolerate a load of 32 to 36 newton meters (N m). In high-end athletes, the throwing motion generates up to 90 N m of torque,” Dr. Camp says. “Bony constraints and muscles take up some of that force, but up to 50 N m is going to the ligament itself with every maximal-effort throw.”

Dr. Rhee cites a patient who had tetraplegia for decades before having upper extremity reconstructive surgery. At a post-surgical checkup, the patient gave Dr. Rhee his right hand. “It was a really nice grip,” Dr. Rhee says. “He told me it was the first time in 40 years that he had used his right hand to shake hands.”

“Almost anyone with upper motor neuron syndrome due to a spinal cord injury, cerebrovascular accident, or traumatic or anoxic brain injuries can benefit at least from an evaluation to learn the options that are available,” he adds. “At Mayo Clinic, we have a system to provide that.”

UCL Injuries: Defining Risk and Improving Treatment

Figure. MRI shows a complete ulnar collateral ligament tear (arrow).
Mayo Clinic’s approach
Surgical reconstruction is the gold standard of care for UCL injuries. But depending on factors such as the patient’s age and extent of injury, Mayo Clinic might consider other approaches.

Nonsurgical options such as guided physical therapy might be recommended for patients with incomplete tears, patients who don’t plan to continue competitive play or for adolescent patients, to avoid surgery during skeletal growth. Mayo Clinic also is researching therapies involving injections of platelet-rich plasma or stem cells, to determine which patients might benefit from those nonsurgical treatments.

UCL surgical repair historically has been considered less successful than reconstruction. But stronger sutures and new anchoring techniques have improved outcomes for UCL repair, particularly for proximal avulsion injuries. Surgical repair can be an option for high school and college athletes who may not have the option of undergoing the prolonged post-reconstruction rehabilitation — which lasts an average of 12 to 18 months.

“That long recovery period can be pretty devastating,” Dr. Camp says. “A high school pitcher who isn’t going to play college baseball has only four seasons. He might lose one or two of them if he has to have UCL reconstruction surgery.”

Mayo Clinic’s team approach ensures that orthopedic surgeons, athletic trainers, physiatrists and radiologists work together to determine the optimal treatment for individual patients.

“We’re aiming to get people on the right treatment pathway at the time of diagnosis,” Dr. Camp says. “If you try a nonsurgical approach for an extended period of time and the patient ultimately has to have surgery, the patient can easily miss two years of play.”

To help prevent UCL injuries, researchers in Mayo Clinic’s Motion Analysis and Orthopedic Biomechanics laboratories are working to identify risk factors — including determining the maximal workloads and optimal throwing mechanics for younger players. Other research focuses on improving reconstructive surgery.

“We are designing a novel reconstruction technique using new types of anchors and sutures, with a goal of maximizing healing potential, maintaining the strength of the construct and reducing the time required to return to play. Preliminary biomechanical analysis is showing very promising results so far,” Dr. Camp says.

An additional effort to quicken return to play involves individualized post-reconstruction rehabilitation. “Historically, we have had a set program that slowly increases the number and velocity of the patient’s throws over a defined period of time. If the patient starts having trouble, we often have to scale back the program,” Dr. Camp says. “We’re now looking at ways to quickly and easily measure the actual workload for each player going through the rehab process. Players who have poor mechanics or increased torque on their elbows might have to slow down a bit, whereas those with better mechanics and less torque can probably progress a little more quickly.

“Mayo’s strength in this area of UCL injuries is that we can take a comprehensive approach,” he adds. “Our patient population and the experience of our surgeons, researchers, therapists, trainers and many more will help us make significant progress in the prevention of these injuries and optimization of surgery treatments when they’re needed.”

Customized Implants for Knee Replacements
Mayo Clinic offers customized prostheses for select patients who need total knee replacement. Each implant has a unique design, based on a CT scan of the patient’s knee. Algorithms convert the scan to a 3D model by mapping the contours of the bone and correcting areas damaged by the disease process.

“A customized implant can function more like a patient’s own knee because it works in unison with the patient’s ligaments and tendons. With an off-the-shelf implant, we have to make compromises to get the soft tissues to work with an implant that isn’t the same size or, more importantly, the same shape as the patient’s natural bone,” says Henry D. Clarke, M.D., an orthopedic surgeon at Mayo Clinic in Phoenix, Arizona, who helped develop the customized system.

The customized implants are designed for people who wish to remain active. “We use them in patients who want to do vigorous physical activity, such as tennis or downhill skiing. As with other knee prostheses, we don’t advise...”
Mayo Clinic’s team approach to treatment of pediatric long bone sarcomas allows for full oncologic resection while preserving limb function. Specialists in orthopedic and radiation oncology, pediatric oncology, pediatric orthopedic surgery, and plastic surgery work together to treat children who need complex tumor surgery.

“At Mayo, our goal is to expand the good results we get in general with knee replacement surgery and reduce the segment of the patient population who feel that things just aren’t quite right following knee replacement,” Dr. Clarke says. “We want to achieve results with knee replacement akin to those we see with hip replacements, where patients are able to forget that they have a prosthetic joint.”

Unlike a conventional knee prosthesis, a customized knee prosthesis is often asymmetric, with different medial and lateral dimensions — mimicking variability in the patient’s anatomy (Figure). Published research has demonstrated that customized total knee arthroplasty improves kinetic function. A study published in the April 2017 issue of the *Journal of Arthroplasty* used mobile fluoroscopy to analyze tibiofemoral kinematics in patients with customized and conventional knee implants. “This study indicated that when patients are climbing steps or squatting, the customized prosthesis functions more like a normal knee,” Dr. Clarke says.

“The outcomes we see at Mayo are favorable,” he adds. “Patients with a customized knee replacement do at least as well as I would expect with a conventional knee replacement, and many of them are among my happiest patients after surgery.”

**Disclaimer**

Dr. Clarke reports receiving royalties and consulting payments from Conformis to help design and commercialize these total knee replacement prostheses.

**For more information**

at Mayo Clinic in Rochester, Minnesota.

Care for children with long bone sarcomas starts with pediatric oncology and generally includes chemotherapy. Advanced MRI and CT imaging help Mayo Clinic surgeons plan complex procedures that can last up to 12 hours. Typically, Dr. Houdek resects the tumor in conjunction with Steven L. Moran, M.D., a plastic surgeon who performs vascularized free fibula transfer, and Anthony A. Stans, M.D., a pediatric orthopedic surgeon who performs the structural allograft reconstruction and compression plate fixation.

“The use of vascularized fibula graft has significantly improved outcomes for these patients,” Dr. Houdek says.

The free vascularized fibula transfers combined with structural allograft reconstructions that are performed at Mayo Clinic for limb salvage following oncologic resection in pediatric patients are known as the “Capanna Technique.” In a review published in the March 2016 issue of Clinical Orthopaedics and Related Research, Dr. Houdek and colleagues found that the procedure provided a successful means of limb salvage with an acceptable complication rate.

“It’s common for patients to have post-surgical chemotherapy, and that treatment makes it substantially more likely that a first-time union will fail,” Dr. Houdek says. “We try to lessen that risk by utilizing compression plating and a free vascularized fibular graft. Although this adds time to the case, we feel it is important since it will improve the long-term functional outcome of the children.”

“That’s why it’s so important to have an expert care team,” he adds. “Mayo Clinic is the ideal center because we work as one big team to take care of these kids.”

**For more information**


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**Figure.** A. Coronal MRI illustrates limb salvage treatment of an adolescent girl at Mayo Clinic. A destructive lesion in the proximal tibia was biopsied and confirmed to be an osteosarcoma. B. Following neoadjuvant chemotherapy, the patient had tumor resection and reconstruction, preserving the growth plate and joint. The reconstruction utilized an allograft combined with a vascularized free fibula graft and compression plating. C. At 10-year follow-up, the joint is preserved and the allograft and fibula have healed. The patient has been able to resume all activities including sports.
Mayo Clinic offers a new, less invasive technique for lumbar fusion. Using cortical-based trajectory screws, the surgery can achieve similar results to open lumbar fusion but with a smaller incision and faster recovery.

“This cortical technique allows us to perform lumbar fusion without the extensive soft tissue and muscle dissection that typically takes place with standard lumbar fusion,” says Arjun S. Sebastian, M.D., an orthopedic surgeon at Mayo Clinic in Rochester, Minnesota. “Patients generally bounce back more quickly from surgery, and sometimes go home the day after. These patients tend to do so well after surgery that I have to caution them not to overdo it.”

The less invasive technique can be especially beneficial for people with osteoporosis and patients who need revision surgery. “This type of screw utilizes primarily the cortical tract, so it provides better fixation in osteoporotic bone. In patients with prior lumbar fusion who need the adjacent segment fused, these cortical trajectory screws can be placed in a less invasive way and connected to the old fusion construct with more ease than a traditional pedicle screw,” Dr. Sebastian says.

Surgery using cortical-based trajectory screws is done through a traditional midline incision. The screws obtain a four-point fit between the dorsal cortex at the site of insertion, medially oriented posterior pedicle wall, laterally oriented anterior pedicle wall and curvature of the vertebral body wall (Figure).

The orientation of the screws away from the neural elements potentially lowers the risk of postoperative radiculitis. In addition, the minimally invasive insertion of screws laterally through the pedicle reduces the risk of injury to the medial branch nerve.

“At Mayo we are very focused on patient outcomes,” Dr. Sebastian says. “That’s why we drive ourselves to innovate and adopt new techniques.”

Patients also benefit from Mayo Clinic’s multidisciplinary approach. Every patient scheduled for lumbar fusion has bone mineral density testing. If osteoporosis is identified, an endocrinologist works with the patient to improve bone quality. Mayo’s orthopedic surgeons also meet weekly with neurosurgeons to confer on spinal cases.

“We share ideas and knowledge,” Dr. Sebastian says. “This type of collaboration leads to the adoption of new techniques that leads to better patient care and outcomes.”

Figure. A. Preoperative radiograph demonstrates a degenerative spondylolisthesis at L3-L4 with partial disk collapse. The patient presented at Mayo Clinic with severe osteoporosis and neurogenic claudication secondary to tricompartmental lumbar stenosis. B and C. Postoperative radiographs demonstrate restoration of disk height and correction of spondylolisthesis. Four months after surgery, the patient has had complete resolution of her back and lower extremity pain, and has returned to her normal activities.
Education Opportunities

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

**Microvascular Surgery Skills Training**
Aug. 6-10, 2018, in Rochester, Minn.
Limited to four attendees per session, this training course in microvascular surgical techniques allows each attendee to receive extensive, individualized training. The instruction incorporates demonstrations, microvascular skills practice and detailed handouts. Attendees will work with the course instructor to schedule a week that is well-suited to individual skills.

**International Shoulder Group 2018**
Aug. 12-13, 2018, in Rochester, Minn.
This course features collaborative interactions among clinicians, researchers and engineers. Discussions and diverse programming cover computational, observational and interventional shoulder research that impacts clinical practice.

**Microvascular Surgery Skills Training**
Sept. 24-28, 2018, in Rochester, Minn.
Limited to four attendees per session, this training course in microvascular surgical techniques allows each attendee to receive extensive, individualized training. The instruction incorporates demonstrations, microvascular skills practice and detailed handouts. Attendees will work with the course instructor to schedule a week that is well-suited to individual skills.

**Mayo Clinic Opioid Conference: Evidence, Clinical Considerations and Best Practice 2018**
Oct. 25-26, 2018, in Kohler, Wis.
This conference highlights the shift in guidelines and public concern regarding the use of opioids in medical practice and provides the most up-to-date information about the appropriate indication for opioids in clinical practice. Topics cover the basics of opioids, evidence-based guidelines for opioids, medication monitoring, tapering and legal considerations. Other issues to be covered include opioid addiction, difficult patient conversations and guidelines to standardize the practice of opioid prescribing.

**28th Annual Mayo Clinic Symposium on Sports Medicine 2018**
Nov. 9-10, 2018, in Rochester, Minn.
This course features evidence-based, 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. Multiple educational formats are used, including case presentations, interactive question and answer sessions, and live demonstrations of physical examination, anatomy, ultrasound and arthroscopy.

**Mayo Clinic Multidisciplinary Spine Care Conference 2018**
Nov. 16-17, 2018, Amelia Island, Fla.
This course is designed to enhance physician and midlevel comfort in the management of patients with diverse spinal disorders and conditions. Discussions focus on technological advancements, controversial spine topics, complications and socio-economic issues. The course provides a mixture of didactic, case-based and evidence-based guideline review, as well as an opportunity for panel discussion.

(continued)
Education Opportunities (continued)

Comprehensive Shoulder and Elbow Course: Current Concepts and Controversies 2019
This course provides information on the latest treatment options for shoulder and elbow arthroplasty, arthroscopy, fracture and reconstruction. The focus is on the best current practice in diagnosis, treatment and new technology. Faculty with international expertise in shoulder and elbow surgery discusses how to optimize surgical techniques and how to avoid complications.

3rd Annual Sports Medicine for the Primary Care Clinician 2019
March 1-3, 2019, in Orlando, Fla.
This conference is designed to give attendees the confidence to accurately diagnose and treat sports-related conditions and the knowledge to determine appropriate testing and referral criteria. Topics include musculoskeletal conditions and procedural techniques that primary care clinicians can utilize for athletes and active individuals.

Mayo Clinic Course on Shoulder Tendon Transfers and Complex Rotator Cuff Repair 2019
April 25-27, 2019, 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 principles, surgical techniques and outcomes of tendon transfers around the shoulder joint and scapula are highlighted. The course also covers advanced arthroscopically assisted tendon transfers and alternative salvage procedures such as reconstruction of the superior capsule, reverse shoulder arthroplasty and shoulder-scapulothoracic fusion.