• The rotary movements (pronation/supination) provided by the unique two-bone, dual intraarticulation structure of the forearm greatly expand the variety of ways in which objects can be positioned and manipulated by the hand.

• Loss of this motion as a result of malunion, prolonged immobilization, and/or proximal or distal radioulnar joint incongruity following trauma to the adult forearm can be disabling.

• The gradual improvement in functional outcomes and decrease in the rate of complications associated with the management of forearm fractures during this century parallels the history of the development of sound, stable techniques of internal skeletal fixation that permit mobility while assuring maintenance of skeletal alignment during fracture union.

• Forearm fractures often are the sequelae of high-energy injury, and a relatively large percentage are open fractures.

• Injury and treatment-related complications include compartment syndrome, neurovascular injury, soft tissue loss, bone loss, refracture after plate removal, and posttraumatic radioulnar synostosis. Infection is unusual, even in the case of an open fracture, partly because of the relative ease of wound debridement and the well-perfused forearm musculature.

Evolutionary Anatomy

• The pattern of evolution at both the elbow and the wrist reflects a transition from stability to mobility.1,2

• The development of bipedalism freed the upper extremity for enhanced manipulative function.

• In conjunction with the increase in brain size and the development of the prehensile thumb, the acquisition of forearm rotation is considered one of the three most important aspects differentiating the most highly developed hominids, as these factors are important in determining the ability to manipulate one’s environment, particularly for tool use.1,3

Skeletal Anatomy

Ulna

• There is a slight apex posterior bow along the entire length of the ulna as seen on a lateral radiograph.

• In the anteroposterior plane the ulna has a slight double curvature, apex lateral in the proximal half and apex medial distally.4,5

• The ulna is triangular in cross section through the majority of its midportion and becomes cylindrical distally. The laterally directed apex of the triangle
corresponds with the insertion of the interosseous ligament. The posterior apex remains essentially subcutaneous as it divides the flexor and extensor musculature on the ulnar border of the forearm and is palpable along the entire length of the bone.

**Radius**

- The radius has a double curvature in both the anteroposterior and lateral planes. The bicipital tuberosity, representing the insertion of the biceps brachii tendon, is at the apex of the smaller, proximal, convex medial curve, whereas the large, distal, convex lateral curve has at its apex the insertion of the pronator teres. This circumstance provides these powerful muscles with longer lever arms through which to produce rotatory torque of the radius. According to Sage’s measurements, the proximal curvature of the radius averages approximately 13 degrees apex medial in the coronal and 13 degrees apex anterior in the sagittal anatomic planes. The distal curvature averages approximately 9.3 degrees apex lateral in the coronal and 6.4 degrees apex posterior in the sagittal plane.
- The large ulnar concavity of the distal curvature of the radius allows for overriding of the ulna without restriction of pronation. Loss of this “radial bow” was shown by Schemitch and Richards to be associated with limitation in both forearm rotation and grip strength.
- Numerous studies have demonstrated a direct relationship between the degree of forearm bone angular and rotational malalignment and restriction of rotational motion.
- The radius rotates about the relatively stationary ulna along an axis that passes roughly through the center of the radial head proximally and the fovea of the ulnar head distally (Figure 33–1).
- Rotation of the radius occurs via axial rotation of the radial head at the proximal radioulnar joint, whereas distally, the motion is a combination of axial rotation and translation of the radius relative to the ulna.
- The association of the radius and ulna is maintained by ligamentous structures at the proximal and distal radioulnar joints and by the interosseous ligament, a ligamentous sheet interconnecting the two bones along their midportion.
- The proximal radioulnar joint is stabilized by the annular and quadrate ligaments proximally and by the interosseous ligament. The quadrate ligament is described as a thin ligamentous structure that covers the capsule at the inferior margin of the annular ligament and attaches to the ulna. Its existence as a discrete entity and its contributions to

![Figure 33–1:](image-url) In supination the palmar ligament supports the triangular fibrocartilage complex (TFCC) and distal radioulnar joint (DRUJ), becoming taunt whereas in pronation the dorsal ligaments bordering the TFCC become taunt to support the DRUJ.
the stability of the proximal radioulnar joint has been
disputed by some authors.24
- The distal radioulnar articulation is stabilized by the
triangular fibrocartilage complex. The complex represents
a combination of structures that are inseparable in
anatomic dissections including the articular disc, the
dorsal and volar radioulnar ligaments, and the sheath of
the extensor carpi ulnaris.27

Muscle-Tendon Units
- Four muscles produce active forearm rotation, two that
originate and insert in the forearm and two that cross
the elbow joint. Both the supinator and biceps insert
on the proximal radial shaft and produce supination.
The pronator teres and pronator quadratus insert on the
midshaft and distal radius, respectively, and produce
pronation.
- Contraction of the brachioradialis encourages neutral
forearm rotation.
- The power of supination exceeds that of pronation by
approximately 15%.28
- Malunion of the radius can decrease the mechanical
efficiency of the muscles, producing forearm rotation
by shortening the lever arms.8
- The forearm musculature is commonly considered as
three separate compartments based on fascial divisions
and nerve supply: the volar or flexor compartment
innervated by the median and ulnar nerves; the dorsal
or extensor compartment innervated by the posterior
interosseous nerve; and the mobile wad of Henry
(brachioradialis and the extensor carpi radialis longus
and brevis) innervated by the radial nerve. The divisions
between the compartments delineate commonly used
and relatively safe intervals for operative exposure.
- Anatomic studies suggest that the fascial divisions
between these compartments are sufficiently plant that
fascial release of one compartment usually decompresses
the remaining two.29,30 As a result, in the treatment of
compartment syndrome of the forearm, pressures in the
dorsal and volar compartments rarely, but
occasionally, remain elevated following release of the volar
forearm musculature.29,30
- Muscle tissue becomes sparse in the distal forearm where
the transition from muscle to tendon is completed.
- On the extensor surface of the distal radius and ulna, the
tendons organize and are confined within compartments
defined by the attachment of the extensor retinaculum
to the dorsal radial and ulnar periosteum. Commonly
referred to by number counting radial to ulnar, the first
dorsal compartment contains the abductor pollicis longus
and the extensor pollicis brevis; the second contains the
radial wrist extensors, the extensor carpi radialis brevis
and longus; the third contains the extensor pollicis longus
as it angles about the fulcrum provided by Lister’s
tubercle; the fourth contains the extensor digitorum
communis and extensor indicis tendons; the fifth contains
the extensor digitii quinti tendon; and the sixth
compartment the extensor carpi ulnaris, lying in a groove
in the ulnar head, just dorsoradial to the ulnar styloid.

Neurovascular Anatomy
- Three large nerves enter the forearm at the elbow:
the ulnar, radial and median nerves.
- For the ulnar nerve, the forearm is primarily a conduit to
the hand. It passes from the extensor compartment of the
arm to the flexor compartment of the forearm under
the medial epicondyle of the distal humerus. It then dives
below the flexor carpi ulnaris, under the fascial band
formed by the connection between its humeral and ulnar
heads, innervating this muscle and the ulnar half of the
flexor digitorum profundus. The ulnar nerve is
incorporated into the epimysium of the flexor digitorum
profundus, lying between the flexor carpi ulnaris and
the flexor digitorum superficialis muscles. The ulnar nerve
lies just lateral to the tendon of the flexor carpi ulnaris at
the wrist.
- The remainder of the flexor musculature of the hand
and wrist is innervated by the median nerve. The median
nerve is found medial to the brachial artery, overlying
the brachial muscle at the elbow. After entering the
forearm in the cubital fossa, it passes between the humeral
and ulnar heads of the pronator teres and then disappears
under the superior margin of the flexor digitorum
superficialis between its radial and ulnar origins. It lies
between the superficial and deep digital flexor
musculature, often incorporated into the epimysium of
the flexor digitorum superficialis, until it reaches the
wrist at which point the nerve emerges in a relatively
superficial position between the flexor carpi radialis and
flexor digitorum superficialis tendons.
- The anterior interosseous branch of the median nerve arises
as a separate fascicle well proximal to the elbow and is a
distinct branch at the level of the superior margin of the
flexor digitorum superficialis muscle. This branch supplies
the flexor pollicis longus and the radial half of the flexor
digitorum profundus muscle and the pronator quadratus.
- The radial nerve bifurcates just proximal to the elbow.
Its deep branch, the posterior interosseous nerve, courses
over the radial head and dives between the two heads of
the supinator muscle at the arcade of Frohse, a fibrous
thickening of the fascial margin of the superficial head
of the supinator. The posterior interosseous nerve
typically is separated from the radial shaft by the deep
head of the supinator muscle, but occasionally it lies in
direct contact with the periosteum of the radial neck,
making it particularly susceptible to damage when
internal fixation devices are implanted in this region.31
The posterior interosseous nerve terminates in an
The radial artery passes medial to the biceps tendon and provides sensory branches to the dorsoradial aspect of the wrist and hand. The skin of the forearm is supplied primarily by three nerves: the medial, lateral, and posterior antebrachial cutaneous nerves. The lateral antebrachial cutaneous nerve is the continuation of the musculocutaneous nerve, which emerges from between the biceps brachii and the brachialis muscles on the lateral aspect of the distal arm. This nerve innervates the skin of the lateral half of the anterior aspect of the forearm and the direct lateral aspect of the forearm. The medial antebrachial cutaneous nerve is a branch of the musculocutaneous nerve, which it continues through the forearm lying between the brachialis muscles on the lateral aspect of the distal arm. The brachial artery, which enters the forearm superficial to the brachialis muscle, lateral and adjacent to the median nerve, represents the primary blood supply of the forearm. However, distal branches such as the radial, ulnar and interosseous arteries also are supplied by large collaterals: the radial recurrent, anterior and posterior ulnar recurrent, and interosseous recurrent arteries, respectively. The radial recurrent artery represents the continuation of the radial collateral branch of the profunda brachii artery and travels with the radial nerve onto the anterior aspect of the elbow. The middle collateral branch of the profunda brachii becomes the interosseous recurrent artery on the posterior aspect of the elbow. The anterior and posterior ulnar recurrent arteries are named for their position relative to the elbow joint. They begin as the inferior and superior ulnar collateral arteries, respectively, in the arm.

**Kinesiology**

- It is difficult to separate the forearm and carpal contributions to the total pronation and supination of the hand. Some studies found that when carpal rotation is included, total forearm rotation approaches 260 degrees, whereas isolated distal radioulnar (or forearm) motion is closer to 190 degrees. Pronation is limited by compression of the flexor musculature between the radius and ulna, whereas supination is limited proximally by the restraint of the annular ligament (as reinforced by the anterior fibers of the lateral and medial collateral ligament complexes of the elbow), the quadrate ligament, the tone of the pronator quadratus, and impingement of the ulnar styloid process on the posterior margin of the sigmoid notch of the distal radius.
- Using simple goniometric measurements, pronation averages between 71 and 80 degrees and supination between 80 and 84 degrees. More sophisticated techniques demonstrate a total arc of forearm rotation less than 160 degrees, with supination (75–88 degrees) greater than pronation (70–71 degrees).
- Most simple activities of daily living can be performed within an arc of approximately 50 degrees each of pronation and supination. On the other hand, many activities such as supporting a tray or accepting objects into the hand require near full supination, whereas many other activities such as pressing downward, leaning upon an object, and dribbling a basketball become restricted even with relatively small decreases in pronation.
- As a result of the translational contribution to forearm rotation at the distal radioulnar joint, the axis of rotation is not constant. The so-called instant center of rotation, or the center of rotation at any given position of forearm rotation, translates a few millimeters about the center of the radial and ulnar heads as the forearm courses through a full arc of rotation.
Skin Incision

Operative Exposures

Skin Incision

- The skin of the upper extremity is well vascularized because of the large number of distinct angiosomes (collections of tissue with a distinct arterial supply) and the excellent collateralization. As a result, large flaps can be raised with little risk to skin of adequate quality.

- The skin over the extensor surfaces of the hand, wrist, and elbow is sufficiently lax and elastic that the relaxed skin tension lines can be crossed without causing scar contracture or hypertrophy. On the other hand, incisions should cross the flexor creases of the wrist or elbow obliquely.

- It is preferable to not incise the skin directly over neurovascular structures or tendons in the setting of acute trauma. If excessive swelling prevents closure of the wound, these structures will remain exposed. For forearm compartment release, we incise the skin on the ulnar aspect of the wrist, creating a radially based flap to ensure coverage of the median nerve. Preservation of subcutaneous venous structures should help limit edema formation.

Ulna

- The posterior apex of the ulnar shaft defines the plane between the extensor forearm musculature innervated by the radial nerve and the flexor musculature innervated by the ulnar nerve (Figure 33–2). Incise the skin in line with the ulna. You can start with a 10-cm incision and

- Hotchkiss et al. measured stiffness rather than displacement of the forearm under axial load after radial head excision alone. Both investigations demonstrated that loss of both the triangular fibrocartilage complex and the interosseous ligament was required for marked (>10 mm) proximal migration to occur. Sectioning of only one of these structures resulted in shortening between 4 and 10 mm under axial load. A similar study of Galeazzi fractures reported similar results.

- In the clinical setting, provided the normal curvatures of the radius and ulna are maintained, the integrity of the interosseous ligament usually is sufficient to maintain proximal radial-ulnar joint congruity despite rupture of the annular and quadrate ligaments, as occurs in Monteggia type fracture-dislocations of the forearm. Similarly, provided the interosseous ligament remains intact, substantial proximal migration of the radius following radial head fracture or excision is unusual. Complete dislocation of the distal radial-ulnar joint cannot occur with disruption of the triangular fibrocartilage complex alone. The interosseous ligament must also be at least significantly disrupted. Radioulnar diastasis also indicates damage to the interosseous ligament.

- Ulnar variance increases between 1 and 2 mm with pronation or grasp. A corresponding increase in radiocapitellar contact and force transmission has been measured during pronation. Tightening of the soft tissues with forearm rotation, particularly the interosseous ligament, has been offered as an explanation for these observations.

- Studies differ with regard to the relative proximal migration of the radius with respect to the ulna following radial head resection and serial sectioning of the soft tissue stabilizing structures. One study found little (0.4 mm) whereas another study found substantial (7 mm) relative shortening with radial head excision alone. Both investigations demonstrated that loss of both the triangular fibrocartilage complex and the interosseous ligament was required for marked (>10 mm) proximal migration to occur. Sectioning of only one of these structures resulted in shortening between 4 and 10 mm under axial load. A similar study of Galeazzi fractures reported similar results.

- Hotchkiss et al. measured stiffness rather than displacement of the forearm under axial load after radial head excision alone. Both investigations demonstrated that loss of both the triangular fibrocartilage complex and the interosseous ligament was required for marked (>10 mm) proximal migration to occur. Sectioning of only one of these structures resulted in shortening between 4 and 10 mm under axial load. A similar study of Galeazzi fractures reported similar results.

- Monteggia type fracture-dislocations of the forearm.

- The posterior apex of the ulnar shaft defines the plane between the extensor forearm musculature innervated by the radial nerve and the flexor musculature innervated by the ulnar nerve (Figure 33–2). Incise the skin in line with the ulna. You can start with a 10-cm incision and
lengthen it as needed after the fracture site is localized and the plate length is selected.

- In the midforearm, it is preferable to expose the volar (flexor or medial) surface rather than the dorsal (extensor or posterior) surface of the ulna to avoid violating the interosseous ligament, which can contribute to the formation of a radioulnar synostosis. Elevate the muscle extraperiosteally from only one side of the bone. Extraperiosteal means that you leave the periosteum on the bone and only elevate the muscle.

- The ulnar nerve and artery lie underneath the flexor carpi ulnaris on top of the flexor digitorum profundus. They are easily avoided provided elevation of the flexor carpi ulnaris is performed close to the bone and does not stray into its substance.

**Radius**

**Dorsal or Thompson Exposure**

- The dorsal (or Thompson) approach has waned in popularity because of the potential for injury to the posterior interosseous nerve, which must be dissected from the substance of the supinator and protected, and the narrow skin bridge, which remains between the incision used for exposure of the radius and that used to expose the ulna when both bones require exposure.

- A straight longitudinal skin incision is made along the line connecting the lateral epicondyle at the elbow with Lister’s tubercle at the wrist while the elbow is in 90 degrees flexion and the forearm is in neutral rotation.

- The internervous interval between the extensor digitorum communis (supplied by the posterior interosseous nerve) and the extensor carpi radialis brevis (supplied by the radial nerve) is most easily identified by locating the point at which the abductor pollicis longus and extensor pollicis brevis emerge from between the mobile wad and the dorsal compartment musculature in the distal half of the forearm.

- The deep fascia is incised directly adjacent to this interval, and the muscles are separated in a distal to proximal direction until their common aponeurosis is encountered. The supinator muscle covering the proximal radius is thereby exposed.

- Use of the proximal portion of the dorsal surface of the radius for plate fixation requires identification and mobilization of the posterior interosseous nerve, because this nerve may lie almost directly adjacent to the bone at this level and potentially could be trapped beneath a plate. The posterior interosseous nerve emerges from between the superficial and deep heads of the supinator muscle approximately 1 cm proximal to the distal limit of this muscle. It can be identified at this point and then dissected free from the muscle, being careful to preserve its muscular branches (Figure 33–3). Following sufficiently proximal mobilization of the nerve, exposure of the radial shaft can be performed by rotating the radius into full supination and detaching the insertion of the supinator from the anterior aspect of the radius.

- Exposure of the midportion of the bone is facilitated by mobilizing and retracting the crossing abductor pollicis longus and extensor pollicis brevis muscles. Exposure of the radius distal to the extensor pollicis brevis is performed in the interval between the radial wrist extensors (extensor carpi radialis brevis and longus muscles) and the extensor pollicis longus muscle, which ultimately produce the tendons occupying the third and second dorsal extensor compartments, respectively.

**Anterior or Henry Exposure**

- Exposure of the anterior surface of the radius is safer and more extensile than a dorsal exposure (Figure 33–4).

- A straight longitudinal incision along a line between the lateral margin of the biceps tendon at the elbow and the radial styloid process at the wrist affords access to the plane between the mobile wad and the flexor musculature of the forearm.
The deep fascia is incised adjacent to the medial border of the brachioradialis, and a plane is developed between this radial nerve-innervated muscle and the median nerve-innervated flexor carpi radialis and pronator teres muscles. Dissection is initiated distally and proceeds proximally following the course of the radial artery.

- Arterial branches to the brachioradialis and the recurrent radial artery arising near the elbow are ligated, and the radial artery is mobilized and retracted medially with the flexor carpi radialis muscle.
- The superficial radial nerve is encountered on the undersurface of the brachioradialis and remains lateral with this muscle.
- Deep dissection is initiated proximally where the biceps tendon is followed toward its insertion on the bicipital tuberosity of the radius. Full supination of the forearm displaces the posterior interosseous nerve laterally and brings the insertion of the supinator muscle anterior. The insertion of the supinator muscle is identified by deepening the muscular plane along the lateral aspect of the biceps tendon. Here you may encounter a bursa between the biceps tendon and the supinator, which further facilitates this dissection.
- The posterior interosseous nerve remains well protected within the substance of the supinator muscle during elevation of its insertion from the radius, provided excessive lateral traction is not applied.
- The insertion of the pronator teres can be detached or the plate can be placed directly on top of the insertion. The body of the flexor digitorum superficialis must be elevated to expose the midportion of the radius.
- In the distal portion of the wound, the pronator quadratus and the flexor pollicis longus are elevated from the bone, usually extraperiosteally.

**Forearm Compartment Release**

- Fascial release for compartment syndrome can be performed through the standard volar Henry-type exposure in the setting of a forearm fracture or through a straight ulnar McConnell-type incision when exposure of the bones is not required (Figure 33–5).63,64
- This ulnar incision provides a flap for median nerve coverage at the wrist and allows exposure of the median and ulnar nerves under the superficial flexor muscles when required. Access to the deep flexor musculature is obtained without dissection through the superficial flexors.

**Treatment**

- Despite numerous descriptions of the relevant anatomy and proper methods of reducing forearm fractures that appeared early in the twentieth century,12,65–73 these fractures remained “problem” fractures and attracted a variety of early attempts at operative treatment.
- Early attempts at internal fixation, although sufficient to hold open reductions, did not preclude the need for external immobilization, resulting in comparably poor functional outcomes in fractures treated by open or closed methods.70,74

---

**Figure 33–4:**
Henry’s extensile exposure to the anterior surface of the radius provides easy access to the entire bone. FCR, flexor carpi radialis; FDP, flexor digitorum profundus; FDS, flexor digitorum superficialis; FPL, flexor pollicis longus.

**Figure 33–5:**
Approach for compartment release.
The development of larger, corrosion-resistant compression plates led to a dramatic decrease in the rate of fracture nonunion while providing sufficient stability for confident early mobilization of the forearm.\textsuperscript{75–78} The dynamic compression plates and the emphasis on immediate mobilization of the limb developed by the AO/ASIF (Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation) in particular made open reduction and internal fixation a predictable treatment for diaphyseal forearm fractures with a rate of nonunion less than 5\% and excellent functional results.

Intramedullary implants are reintroduced periodically but they have inherent weaknesses, including difficulty maintaining rotational alignment, difficulty restoring the anatomic radial bow, the need for supplemental immobilization, a high nonunion rate, and the technical difficulty of device insertion with frequent splitting of the cortex and protrusion of the nail through the cortex or into a joint.\textsuperscript{6,7,79,80} The results of intramedullary nailing of forearm fractures have improved modestly following the introduction of nails of square and triangular cross section intended to better control rotation, improved nail design and insertion techniques intended to restore the anatomic radial bow, and closed nailing under fluoroscopic guidance.\textsuperscript{6,80,81} However, despite these improvements, intramedullary nailing continues to lack the predictability and stability of modern plate and screw fixation that have essentially solved the “problem” of forearm fractures and made plate fixation the treatment of choice.

Isolated fractures of the ulna without associated radioulnar instability (nightstick fracture) usually heal with nonoperative treatment. Operative treatment is considered when there is greater than 50\% translation or greater than 10\textdegree\ angulation of the fracture fragments.

Isolated fractures of the radius are more common than previously recognized, as pointed out by Rettig and Raskin\textsuperscript{82} (Figure 33–6). These fractures benefit from plate fixation unless they are nondisplaced. The distal

\textbf{Figure 33–6:}

Not all isolated radius fractures are Galeazzi injuries. This displaced fracture of the radius shows no displacement of the distal radioulnar joint in either the anteroposterior or lateral plane.
radioulnar joint should be carefully evaluated after the radius is stabilized.

Open Fractures

- Immediate plate fixation of all but the most complex and contaminated forearm fractures is associated with an acceptably low rate of infection in open forearm fractures treated by immediate plate and screw fixation (0%–3%) when perioperative antibiotics are given and thorough wound debridement and delayed primary closure of the traumatic wounds are performed.77,83–86
- When infection occurs, its eradication is not necessarily dependent upon implant removal. As long as all bone fragments and soft tissues are well vascularized, stable internal fixation will facilitate wound care and help maintain length and alignment, range of motion, and overall function, without hindering treatment of the infection.

Fracture-Dislocations of The Forearm (Galeazzi, Monteggia, and Essex-Lopresti Lesions and Their Variants)

- The Galeazzi fracture is a fracture of the radial diaphysis (often the distal third) in association with dislocation of the distal radioulnar joint (Figure 33–7).82
- The Monteggia fracture and its variants represent a fracture of the proximal ulna associated with proximal radioulnar joint disruption (Figure 33–8).87
- The Essex-Lopresti lesion is a fracture of the radial head with rupture of the interosseous ligament of the forearm (Figure 33–9).88
- Bipolar forearm fracture-dislocation or radioulnar dissociation represents a more complex injury with associated disruption of the interosseous ligament.89
- Clinical and anatomic investigations have determined a number of clues indicating distal radioulnar joint disruption that can be detected on radiographs: (1) fracture of the ulnar styloid at its base, (2) widening of the distal radioulnar joint space, (3) dislocation of the radius relative to the ulna seen on a true lateral radiograph, and (4) shortening of the radius beyond 5 mm relative to the distal ulna under a constant applied load (see Figure 33–9).57,90
- Proximally, the radio-humeroulnar joint is dislocated if a line through the radial shaft and head does not bisect the capitellum in all positions of flexion/extension.91,92
- Galeazzi fracture-dislocations are treated with anatomic reduction and plate and screw fixation.93,94 If the ulnar styloid is fractured at its base, it should be repaired. The distal radioulnar joint usually is stable, and the forearm can be mobilized immediately postoperatively.95 If the distal radioulnar joint remains unstable, the forearm can be immobilized in mid-supination for 4 weeks, occasionally with transfixion of the distal ulna to the radius with one or two stout smooth Kirschner wires that often results in the loss of forearm rotation.96
- Anterior and lateral Monteggia fractures (Bado96 types 1, 3, and 4 [which is a fracture of both bones with anterior or lateral dislocation of the radial head from the proximal radioulnar joint]) usually are treated with anatomic reduction and internal fixation of the ulna and early mobilization. Instability or incomplete reduction of the radial head most commonly results from ulnar malalignment. The annular ligament should rarely require exploration or repair.97 Posterior Monteggia lesions (Bado type 2) are more complex and best considered along with elbow fracture-dislocations (Figure 33–10 and Table 33–1).
- With Essex-Lopresti and bipolar fracture-dislocations, the treatment principles include stable anatomic reduction of all fractures,98,99 preservation of radiocapitellar contact with operative fixation or prosthetic replacement, and addressing the soft tissue injury with either direct repair or immobilization in a reduced position (with or without cross pinning).

Compartment Syndrome

- Prompt diagnosis of compartment syndrome is dependent upon clinical suspicion and frequent, careful examination focusing on pain out of proportion to injury, pain with passive stretch of the fingers, and compartment palpation.
- Gelberman et al.29 found a change in two-point discrimination was associated with compartment syndrome. Even better would be detecting a change in threshold (or light-touch sensation), which can be achieved in an objective manner with Semmes-Weinstein monofilaments. Loss of discriminatory sensation (two-point) and weakness usually are late findings.
- A reliable examination is dependent upon patient understanding and cooperation. In a patient with altered mental status (because of associated traumatic injury, intoxication, or narcotic medication), in the presence of associated neurologic deficit, or in any case in which the physician is not confident of his/her examination, serial measurement of intracompartmental forearm pressures is useful.100
- Elevated or rising pressures indicate the need for fasciotomy. The absolute pressure at which fasciotomy is indicated is debated. Pressures above 30 mm Hg are of concern. Forearm fascial release should be strongly considered at pressures above 45 mm Hg.
- Gun shot fractures of the forearm are particularly prone to compartment syndrome. Moed and Fakhouri101
Figure 33–7:
Isolated radius fractures may be associated with dislocation of the distal radioulnar joint. A, The distance of the fracture from the radiocarpal joint is not always predictive of radioulnar instability. This midshaft fracture has a widened and shorted distal radioulnar joint indicating injury to the triangular fibrocartilage complex and interosseous membrane. B, Following plate fixation, the distal radioulnar joint was stable, allowing immediate active motion.
Figure 33–9: Essex-Lopresti lesion is a fracture of the radial head associated with injury to the triangular fibrocartilage complex and the interosseous ligament. This patient also has a transscaphoid perilunate fracture dislocation.

Figure 33–8: Anterior (Bado type I) Monteggia fracture. A, The anterior Monteggia fracture (fracture of the ulnar diaphysis with anterior dislocation of the proximal radioulnar joint) is uncommon in adult patients and usually reflects high-energy injury. B, Persistent subluxation of the proximal radioulnar and radiocapitellar joints nearly always reflects residual malalignment of the ulna. C, Revision of the ulnar fixation achieved better alignment and function of the forearm.
recorded a 15% overall incidence among 60 gunshot fractures of the forearm. Comminuted, severely displaced, and proximal third fractures were more commonly associated with compartment syndrome.

- Compartment release usually is achieved by exposing the radius and ulna for plate fixation.

**Nonunion**

- The current rate of nonunion is less than 5% when proper technique is used in compliant patients.\(^7\)
- Nonunions most often are related to technical errors, such as use of plates of inadequate size (e.g., semitubular plates) or length, inadequate reduction, and failure to bone graft comminuted and open fractures.\(^7,102–105\)
- The majority of nonunions, including most nonunions with segmental bone defects, can be treated successfully with plate and screw fixation and autogenous cancellous bone grafting.
- The key elements of nonunion treatment are realignment (mobilization can be done with osteoperiosteal and/or soft tissue stripping), removal of synovial and fibrous tissues, opening of sclerotic bone ends, autogenous cancellous bone graft (except for hypertrophic nonunions, which do not need bone graft), and stable internal fixation.
The majority of forearm diaphyseal nonunions are atrophic and associated with a segmental bony defect. Because one bone often is intact, the bone cannot be shortened. Therefore, in the majority of forearm nonunions, a plate is applied, bridging the defect with autogenous cancellous bone graft placed in the defect. Some surgeons use structural (corticocancellous) bone grafts, but we have not found this to be necessary.

**Refracture**

Initially the AO/ASIF recommended removal of all implants following fracture healing. However, because removal of forearm plates has been associated with the risk of refracture (either through the old fracture site or a screw hole) and the risks of a second operation (injury to the posterior interosseous nerve in particular), most surgeons no longer remove the plates unless they are causing definable problems. This applies to athletes as well.

The risk of refracture following plate removal is believed to result from a combination of incomplete healing and the osteoporosis that occurs under a plate because of some combination of disruption of the vascular supply to the bone and stress shielding. Risk factors for refracture following plate removal include fracture comminution or the inability to gain compression of fracture fragments, implant size (Chapman Gordon, and Zissimos noted that refracture was less likely following removal of 3.5-mm than 4.5-mm plates), implant removal earlier than 1 year after injury, radiolucency beneath the plate, and inadequate protection following plate removal.

### References


The results of intramedullary nails to treat diaphyseal forearm fractures have not been able to match those achieved with plate and screw fixation.


Documented the effectiveness of the relatively new AO 4.5-mm plates. The results were far better than any previously reported and have only been slightly improved upon since.


86. Moed BR, Kellam JF, Foster RJ et al: Immediate internal fixation of open fractures of the diaphysis of the forearm. *J Bone Joint Surg Am* 68:1008-1017, 1986. The upper extremity is so well vascularized that all but the most complex and severely comminuted fractures can be treated with immediate plate fixation.


96. Bado JL: The Monteggia lesion. *Clin Orthop* 50:71-76, 1967. Although Monteggia lesions had long been described in terms of the direction of radial head displacement, Bado’s numeric classification has become widely used.


Elbow Anatomy and Physical Examination

Christopher J. Veneziano,* Matthew J. Nofziger,† and Robert P. Nirschl‡

Anatomy

- The elbow is a complex joint consisting of three separate articulations: the ulnohumeral, radiocapitellar, and proximal radioulnar joints. Its primary function is to assist the shoulder and wrist in positioning the hand in space. Although not technically a weight-bearing joint, the elbow is subjected to significant loads, especially in laborers and athletes participating in throwing and racquet sports. In order to diagnose and treat elbow injuries, it is essential to understand the anatomy and physiology of the elbow joint.

- The normal range of elbow flexion/extension is approximately 0 to 150 degrees and normal forearm pronation/supination is 80 to 80 degrees. Functional range of motion (ROM) is 30 to 130 degrees of flexion/extension and 50 to 50 degrees of pronation/supination.

Osteology

- The distal humerus terminates at the elbow in medial and lateral columns, epicondyles and condyles. The condyles articulate at the elbow joint as the trochlea medially and the capitellum laterally. The articular surface is angled approximately 30 degrees anterior to the axis of the humeral shaft (Figures 34–1, 34–2, and 34–3).¹

- The medial ridge of the trochlea is larger than the lateral ridge and the capitellum. This gives the articular surface a slight valgus position, approximately 6 degrees, compared to the epicondylar axis.

- The coronoid fossa and olecranon fossa, just proximal to the articular surface, accommodate the coronoid process and olecranon process of the ulna in the extremes of flexion and extension, respectively. They are separated by a thin section of bone or, at times, a fibrous membrane. A smaller, radial fossa accepts the contour of the radial head when the elbow is fully flexed.

- The medial epicondyle is the prominent terminus of the medial supracondylar ridge. It is the point of origin for the flexor/pronator musculature. The distal portion of the medial epicondyle is the origin of the medial (ulnar) collateral ligament complex. The ulnar nerve runs along the smooth posterior portion of the medial epicondyle.

- The lateral epicondyle is the terminus of the lateral supracondylar ridge. It is less prominent than the medial epicondyle and is the point of origin of the extensor musculature and the radial collateral ligament (RCL).
The olecranon and coronoid process coalesce to form the greater sigmoid notch, the articulating portion of the proximal ulna. It commonly is not completely covered with articular cartilage centrally.

The coronoid process, on its lateral aspect, contains the lesser sigmoid (radial) notch (articulates with the radial head), the supinator crest (ulnar origin of the supinator muscle), and the crista supinatoris (insertion of the accessory lateral collateral ligament [LCL]). The medial side of the coronoid provides the insertion site (sublime tubercle) for the anterior bundle of the medial collateral ligament (MCL).

The radial head articulates with the capitellum. Both the head and neck are considered intraarticular structures. Distal to the neck is the radial (bicipital)
tuberosity, which is extraarticular. The radial head is covered with articular cartilage on its surface and along its periphery, which allows it to articulate smoothly in the lesser sigmoid (radial) notch.

**Capsuloligamentous Structures**

- Stability of the elbow results from a combination of its bone structure, the articular congruence of the ulnohumeral joint, and its capsuloligamentous structures.
- The medial collateral ligament complex originates on the distal portion of the medial epicondyle and consists of three bundles: anterior (inserts on the sublime tubercle on the medial surface of the coronoid), posterior (inserts on the medial olecranon), and transverse (Figure 34–4).
- Tension in the ligamentous complex varies throughout elbow ROM because its humeral origin lies posterior to the axis of rotation in flexion/extension. Fibers of the anterior bundle sequentially tighten throughout the ROM from 20 to 120 degrees. The anterior bundle is the primary restraint to valgus stress within this ROM. The radiocapitellar articulation provides a secondary restraint to valgus stress.
- From 0 to 20 degrees flexion (i.e., in full extension), the MCL, capsule, and joint congruity contribute equally to stability. The anterior MCL provides the majority of resistance to valgus stress in flexion. The posterior bundle of the MCL provides minimal stability to valgus stress but contributes somewhat in full flexion and provides constraint to hyperflexion.
- The LCL complex consists of the annular ligament, the RCL, the accessory collateral ligament, and the lateral ulnar collateral ligament (LUCL) (Figure 34–5). There is tension in the LCL throughout motion because of its isometric position. The RCL originates from the lateral epicondyle and inserts along the course of the annular ligament. Because of its isometric position, it is taut throughout flexion. The LUCL is a separate, posterior portion of the RCL, which attaches to the crista supinatoris on the ulna. It is taut only in flexion beyond 110 degrees. It becomes lax in the presence of load or valgus stress. With varus load, the LUCL is taut throughout the ROM. LUCL insufficiency leads to posterolateral rotatory instability (PLRI) of the elbow.
- The annular ligament stabilizes the proximal radioulnar joint. It also plays a role in providing stability to varus stress (Figure 34–6). The accessory collateral ligament is formed from a band of the annular ligament. It also attaches on the crista supinatoris.

**Musculature**

- The muscles on the anterior and posterior aspects of the elbow facilitate flexion and extension. The muscles on the medial side function to flex the wrist and fingers and to pronate the forearm, whereas the muscles on the lateral side extend the wrist and fingers and supinate the forearm (Figure 34–7).
- The triceps is composed of three heads: long (origin at infraglenoid tubercle), lateral (origin from the posterior humerus), and medial or deep (origin from the posterior humerus). It crosses the posterior elbow and inserts broadly on to the posterior olecranon. Laterally, a band courses over the anconeus and attaches to the dorsal fascia of the forearm: this can provide weak elbow extension with essentially complete triceps rupture in some cases. The triceps is innervated by the radial nerve.
- The medial and lateral intermuscular septa separate the triceps (posterior compartment) from the anterior compartment in the distal two thirds of the arm.
- The brachialis and biceps are the muscles overlying the anterior elbow. The brachialis originates from the anterior...
surface of the humerus and inserts on to the proximal ulna, just distal to the tip of the coronoid and on the ulnar tuberosity. It is innervated primarily by the musculocutaneous nerve; the lateral portion receives some supply from the radial nerve.

- The biceps originates as two heads, short (from the coracoid process) and long (from the superior glenoid), and blends into a single tendon distally, which inserts on to the radial (bicipital) tuberosity. It also inserts through the bicipital aponeurosis (lacertus fibrosis) broadly over the common flexor origin and proximal forearm. It is innervated by the musculocutaneous nerve.

- Medially, the flexor/pronator muscles originate from the medial epicondyle and course distally. They fan out laterally to medially as the pronator teres (PT), flexor carpi radialis (FCR), palmaris longus (PL), and flexor carpi ulnaris (FCU) superficially and the flexor digitorum sublimis (FDS) deeply.

- The PT originates as two heads, the superficial (humeral) head from the medial epicondyle and the deep (ulnar) head, and inserts on to the lateral aspect of the middle third of the radius. It functions to pronate the forearm and provides some elbow flexion. It is innervated by the median nerve, which passes between the two heads.
The anconeus originates distally on the more posterior aspect of the lateral epicondyle and inserts on to the posterior interosseous nerve (PIN).

The EDC originates just distal to the ECRL and ECRB on the tip of the lateral epicondyle, and inserts into the extensor mechanism of the dorsal hand and fingers. It functions to extend the fingers. It is innervated by the posterior interosseous nerve (PIN).

The anconeus originates distally on the more posterior aspect of the lateral epicondyle and inserts on to the proximal, dorsal ulna. It functions to extend the elbow and is innervated by the radial nerve.

The extensor digiti minimi originates from the common extensor tendon, just distal to the elbow and inserts into the small finger extensor mechanism. It functions to assist extension of the small finger and is innervated by the PIN.

The supinator originates from two heads. The superficial head originates from the lateral epicondyle, the LCL, and the supinator crest of the ulna. The deep head originates from the supinator crest. Together they insert onto the anterior aspect of the radius. It functions to supinate the forearm and is innervated by the PIN.

**Neurovascular**

The musculocutaneous nerve is derived from the lateral cord of the brachial plexus. It pierces the coracobrachialis muscle 5 to 8 cm distal to the coracoid process and runs distally between the brachialis and biceps. It emerges as the lateral antebrachial cutaneous nerve of the forearm just above the elbow. It innervates the coracobrachialis, brachialis, and biceps.

The radial nerve is derived from the posterior cord of the brachial plexus. It courses around the posterior humerus in the spiral groove then travels anteriorly between the brachialis and BR. It crosses the elbow between them and divides in the cubital fossa anterior to the radiocapitellar joint into the PIN and the superficial radial nerve. The PIN enters the body of the supinator and continues distally on the dorsal aspect of the forearm, whereas the superficial radial nerve continues on the deep surface of BR. The radial nerve innervates the triceps, anconeus, BR, ECRL, and ECRB. The PIN supplies the supinator and the remainder of the finger extensors.

The median nerve is derived from the medial and lateral cords of the brachial plexus. It runs with the brachial artery in the arm, starting on its lateral side. It then passes anterior to the brachial artery to its medial side before reaching the elbow. It crosses the medial side of the elbow, where it lies superficial to brachialis, just deep to the bicapital aponeurosis. It then passes distally between the two heads of the PT into the forearm between the FDS and flexor digitorum profundus (FDP). It innervates the PT, FCR, PL, FDS, and, in most cases (though some variation exists), the FDP-3. Distally, it supplies the index and middle finger lumbricals, the abductor pollicis brevis, opponens pollicis, and (though variations exist) flexor pollicis brevis. The anterior interosseous nerve branches off and supplies the FDP-2 (sometimes also the FDP-3), flexor pollicis longus, and pronator quadratus.

The ulnar nerve is derived from the medial cord of the brachial plexus. It runs medial to the brachial artery in the arm before passing posteriorly through the median
Introduction

History

Initial Examination of the Elbow

Physical Examination

Patient Interview

---

Although the elbow is not a “weight-bearing” joint, large forces are transmitted across it. During heavy lifting, the elbow’s joint reaction forces reach two to three times body weight. Overuse injuries can result from a number of popular sports, such as tennis, golf, baseball, and weight lifting, as well as activities of daily living.

---

A thorough history is crucial in assessing an elbow injury and can provide a working differential diagnosis to guide the subsequent physical examination. The examiner should obtain the following information from the patient:

- **What is the character of the pain?** Pain is the most common complaint. Define its location and severity, exacerbating activities, and the mechanism of injury. Is the pain radiating or worse at night? The physician may consider referral of pain from the cervical spine or possibly a double crush neurologic injury. Does the pain involve several joints, possibly suggesting joint diseases (e.g., rheumatoid arthritis or osteoarthritis)?

- **Where is the pain?** This question probably determines the most important characteristic from a diagnostic standpoint. Common causes of lateral pain include tennis elbow, radiocapitellar injury, and radial tunnel syndrome. Medial pain usually results from injury to the flexor-pronator origin, the MCL, ulnar nerve compression or subluxation, or rarely, from a snapping triceps tendon. Posterior pain may be associated with triceps tendinopathy or posterior impingement of the olecranon in its fossa from hypertrophic spurs. Anterior pain often represents distal biceps pathology, anterior capsule strain, median nerve entrapment, or osteoarthritis. Localizing the pain can allow further questions that focus on structures in that anatomic region.

- **Are there any exacerbating activities?** Specific motions or activities stress specific structures, resulting in pain or injury. Medial elbow pain that occurs during the late cocking or acceleration phases of throwing, when valgus forces are maximized, often results from injury to the MCL. In acute injuries there may be an associated pop and sharp pain with an inability to continue throwing. Other times there is a gradual onset with progressively increasing pain during or after heavy throwing. There may be associated complaints of ulnar nerve paresthesias, caused by inflammation about the MCL, thus irritating the nerve as it passes through the cubital tunnel, or by valgus laxity, which causes traction on the nerve. These paresthesias are characterized mainly by medial elbow pain radiating to the ring and little finger. They also may produce a heavy or clumsy feeling in the hand after throwing.

Symptoms of ulnar nerve irritation can be associated with repetitive or prolonged elbow flexion, valgus force, forceful triceps activity (i.e., weight lifting), or direct pressure, with pain often worst at night or upon awakening. Repetitive forearm rotation, wrist motion, gripping, or lifting stresses the tendons
of the extensor and flexor-pronator muscle masses. These actions are commonly seen in occupations such as carpentry, plumbing, and textile production, and in sports such as golf, throwing and racket sports.

- Valgus forces in throwing can cause repetitive microtrauma, usually affecting the capitellum (osteocondritis dissecans) and, in adolescents, cause stress fractures of the medial epicondyle (Little Leaguer's elbow). Usually asymptomatic, a snapping medial head of the triceps can cause symptoms with repetitive elbow motion, as can a snapping synovial plica over the radial head.8,13
- Postactivity ache or pain at rest typically results from joint effusion and synovitis but may be associated with nerve compression.9
- Systemic inflammatory disorders, tumors, or infections may cause pain not related to activity.8
- Elbow pain may be caused by tendinopathies, peripheral nerve entrapment, or cervical radiculopathy.9
- Coldness or swelling of the hand may indicate a vascular injury or obstruction (i.e., brachial artery or vein obstruction).8

**What is the severity and duration of symptoms?** How long has the patient had the problem? Does the severity of symptoms fluctuate? These questions can give an indication of the seriousness of the condition or to the amount of functional compromise for the patient.8,10

**What was the mechanism of injury?** Was there an acute episode of pain, swelling, or ecchymosis associated with a specific traumatic event? Was it direct or indirect trauma, that is, a fall directly on the elbow or outstretched hand, or is there a history of repetitive microtrauma or recent change or increase in activity level?8,10

**Are there mechanical complaints?** There may be loss of motion, locking, catching, instability, or recurrent effusions.

- **Loss of motion, locking, and catching.** Elbow motion and forearm rotation may be limited by intraarticular and extraarticular pathologies affecting many articulations: the ulnohumeral, radiohumeral, proximal radioulnar, forearm, or distal radioulnar articulations. Loss of motion may not be functionally limiting (functional range 30–130 degrees extension-flexion, 50–50 degrees pronation-supination) but may suggest past or present injury. Loose bodies commonly arising from osteochondritis dissecans, or osteophytes from posterior impingement may produce symptoms of catching or locking, whereas osteoarthritis often produces crepitus.8,10

- **Instability.** Instability may occur with injuries to the major stabilizing ligaments, that is, the MCL and LCL complexes. Instability also may occur with severe arthritis secondary to bone loss. The alteration in elbow biomechanics may cause pain, synovitis, and osteophyte formation. Chronic MCL laxity, commonly seen in pitchers, allows the medial olecranon to impinge on the olecranon fossa during terminal extension or the follow-through phase of overhand throwing, causing elbow pain and swelling. Injury to the LCL, whether occurring acutely in an elbow dislocation or “sprain” or iatrogenically induced as a complication of lateral elbow surgery, can cause PLRI. Symptoms may include feelings of elbow instability, locking, catching, or snapping when the elbow is extended with the forearm supinated, or with elbow flexion from an extended position coupled with pronation, manifested as an uncomfortable “clunk” as the joint relocates from a subluxed position.8,10,13

### Initial Physical Examination

**Observation**

- The patient must be suitably undressed to allow full examination of the trunk and neck down to the hand and full comparison of both upper limbs. Note any focal ecchymosis, swelling, atrophy, asymmetry, or gross deformity. Full body posture should be observed for possible referral of symptoms, especially in patients with a history of insidious onset of elbow pain.10
- The carrying angle (the angle formed by the long axis of the humerus and the long axis of the ulna) is best viewed when the elbow is straight and the forearm is fully supinated (Figure 34–8). The normal valgus carrying angle in males is 5 to 10 degrees and in females is 10 to 15 degrees. A carrying angle less than 5–10 degrees is called **cubitus varus** and an angle greater than 10–15 degrees is called **cubitus valgus**. The normal carrying angle changes linearly depending on the degree of extension or flexion, ultimately reaching varus in full flexion. Discrepancy in carrying angles may indicate former trauma (i.e., a fracture), growth disturbance (i.e., epiphyseal injury to the distal humerus), or chronic valgus overload leading to valgus deformity secondary to bony remodeling. Chronic valgus overload is seen in baseball pitchers who started throwing competitively before they reached skeletal maturity. In general, carrying angle differences are of cosmetic rather than functional significance.8,10,12
- Ecchymosis may indicate an area of direct trauma, signifying contusion or tendon injury. However, ligaments on the opposite side of the impact also may be injured secondary to tension overload.8
- The anconeus soft spot (lateral infracondylar recess) is the most sensitive area to detect a joint effusion, whether secondary to hemarthrosis, synovitis, infection, dislocation, or fracture. This is the triangular area...
outlined by the radial head, tip of the olecranon, and lateral epicondyle (Figure 34–9). This is also an ideal location for joint aspiration or injection of the elbow joint. The anatomic position that allows for maximum joint capacity, as seen with a tense effusion, is with the elbow held at approximately 70 to 80 degrees flexion. More discrete swelling over the olecranon process usually results from olecranon bursitis.\(^8\,10\)

- Discrepancy in muscle girth when comparing contralateral limbs may be a sign of disuse atrophy secondary to injury, or a sign of hypertrophy as often seen in athletes, such as pitchers or throwers who have a greater forearm muscle mass on the dominant side.\(^8\,14\)

ulna and the medial and lateral epicondyles of the humerus at 90 degrees flexion (Figure 34–10). With the elbow fully extended, these points should form a straight line. This relationship can be altered by intraarticular pathology, including fracture, malunion, or an unreduced elbow dislocation.\(^8\,10\)

- The normal osseous landmarks of the elbow form an isosceles triangle between the olecranon process of the ulna and the medial and lateral epicondyles of the humerus at 90 degrees flexion. In full extension, these points should form a straight line. (From Magee DJ: Orthopaedic physical assessment, ed 3. Philadelphia, 1997, WB Saunders.)
Examination

- **It is essential to start the physical examination with the neck and shoulder to rule out radiculopathy, referred pain, or shoulder weakness, especially if the history indicates elbow symptoms of insidious onset.**

  - **Range of motion.** Perform both active and passive ROM, remembering to do active movements first and painful movements last. Normal active elbow flexion is approximately 140 to 150 degrees flexion, with movement usually stopped by contact between the soft tissues of the forearm and the arm.

  - Full active extension may range from 0 to 10 degrees hyperextension, depending on the patient’s degree of ligamentous laxity. Hyperextension is more common in women and is considered normal if it is symmetric with the contralateral elbow and the patient has no history of trauma. Pain with hyperextension of the elbow may be a sign of posterior impingement between osteophytes on the olecranon and the walls of the olecranon fossa. This phenomenon is most common in patients exposed to repetitive hyperextension overload, such as gymnasts and throwing athletes.

  - Full extension often is the first parameter lost after injury and may be a sensitive indicator of intrarticular pathology. However, terminal extension is not required for many daily activities, and loss of flexion often is believed to be more disabling. The functional range of flexion–extension motion, necessary for most activities of daily living (hand to mouth, hand to buttocks) is within the range from 30 to 130 degrees.

  - Active supination and pronation should approach 80 degrees in both directions, measured with the arm at the side to prevent the patient from using shoulder motion (adduction or abduction) to compensate for any deficiencies of forearm rotation. However, the functional ROM needed for most daily activities is only 50 degrees of supination and pronation.

  - Wrist ROM should be included in the examination because of the shared musculature between wrist and elbow. Any specific movements or positions causing patient complaint recorded in the history should be included in the examination. Mechanical blocks to motion may suggest an osseous blockage (abrupt endpoint) or soft tissue interposition or capsular contraction (rubbery endpoint). \(^{10,13,15}\)

  - If active ROM is limited, passive motion should be attempted to test endpoints. \(^{10}\)

- **Motor strength.** Motor strength is tested through resisted isometric movements of the muscles of the elbow complex. Elbow flexion power is greatest at 90 to 110 degrees flexion and in supination or neutral forearm rotation. In normal subjects, flexion strength is 30% greater than extension strength, and pronation strength approximately 75% that of supination strength, with the dominant arm commonly 5% to 10% stronger than the nondominant side. Weak and pain-free isometric contraction may signify a myotendinous injury, but without a history of trauma suggests a neurologic origin. \(^{8,10,12}\)

- **Palpation.** Palpation is a key part of the examination of the elbow in forming a differential diagnosis. In palpating the elbow, the examiner tries to elicit point tenderness or searches for abnormalities, including changes in temperature or texture, or any suspicious masses. The painful regions are palpated last and always compared to the uninjured side. \(^{10,15}\)

  - The anterior elbow, or antebrachial fossa, bounded laterally by the BR and medially by the PT, contains many important structures. Both the median and lateral antebrachial cutaneous nerves course within the fossa but are not palpable. Rarely, entrapment of the median nerve deep to the lacertus fibrosis (bicipital aponeurosis) occurs, and then a Tinel sign may be elicited. The biceps tendon can be easily palpated within the fossa, especially as it is placed under tension with resisted elbow flexion and supination. Pain to palpation can be a sign of strain or tendinosis. The coronoid process of the ulna and radial head can be palpated for potential abnormality. The anterior capsule can be strained in a hyperextension injury and produce tenderness to palpation along its origin on the distal humerus. Palpation of a strained brachialis muscle, especially through resisted elbow flexion in pronation, can produce pain.

  - The pulse of the brachial artery can be palpated as it crosses the elbow joint just medial to the biceps tendon.

  - Important structures that take origin from the medial epicondyle include the wrist flexor-pronator muscle mass and the MCL. The anterior band of the MCL can be palpated from its origin on the humerus to its insertion on the ulna at the base of the coronoid (sublum border) with the elbow positioned in 30 to 60 degrees flexion.

  - Tenderness to palpation of the flexor-pronator mass just distal and anterior to the medial epicondyle usually signifies a tendinopathy of the PT and/or the FCR, also called golfer’s elbow or medial tennis elbow.

  - The ulnar nerve, located just posterior to the medial epicondyle, runs in the cubital tunnel, deep to a fascial covering or retinaculum, before passing between the two heads of the FCU. Pathologic thickening of this retinaculum may cause sites of nerve compression, which can be diagnosed with a positive Tinel’s sign and elbow flexion test. Flexing and extending the elbow during palpation helps detect any nerve subluxation at or just proximal to the epicondyle, which may predispose a patient to ulnar neuritis. \(^{10,15–17}\)
“Tennis elbow,” or degenerative tendinosis of the ECRB, is the most common cause of lateral elbow pain. Point tenderness over the ECRB origin, just anterior and distal to the tip of the lateral epicondyle, is diagnostic. When palpating the elbow, it is important to remember that the ECRL originates above the epicondyle along the epicondylar ridge. If the EDC is involved (in 30% of patients with lateral tennis elbow), tenderness also will be present just posterior and distal to the tip of the lateral epicondyle.

Included in the differential diagnosis of lateral elbow pain is radial tunnel syndrome, caused by compression of the PIN as it passes between the two heads of the supinator muscle under the arcade of Frohse. This commonly leads to pain and tenderness within the extensor mass. Tenderness to palpation can be localized to the area just distal to the radial head along the proximal edge of the supinator. Provocative tests, described later, are useful in differentiating lateral tennis elbow from radial tunnel syndrome.

The anconeus soft spot, described earlier, not only is a sensitive area to detect joint effusions or hemarthrosis but also can be used to palpate the capitellum, which may become tender from osteochondral injury. Supination and pronation of the forearm aids in palpation of both the radial head and the annular ligament. Crepitus and/or pain to palpation during rotation may represent a radial head fracture, radiocapitellar arthritis, chondromalacia, plica, osteochondritis dissecans, or a loose body.

The triceps muscle, olecranon fossa, olecranon process, and its bursa can be palpated at the posterior aspect of the elbow. Flexing the elbow to approximately 30 degrees relaxes the triceps muscle and allows access to the olecranon process as it is delivered from the olecranon fossa. This allows palpation of any olecranon exostosis or loose bodies as are seen with chronic hyperextension overload, especially in throwing athletes. The olecranon bursa overlying the olecranon process may feel thickened, warm, tender, or distended with fluid and may contain “rice bodies,” fragments of fibrous tissue that can act as further irritants to the bursa. Tenderness along the triceps tendon may represent tendinosis or “posterior tennis elbow” as a result from repetitive overload, whereas a defect or gap in the substance suggests rupture.

Instability and Provocative Tests

- The patient history should help direct the examiner to perform any special tests relevant to confirming a diagnosis. When elbow instability is suspected, stress tests can be performed to evaluate for ligamentous injury.
- The anterior band of the MCL is the primary stabilizer during valgus stress in flexion, whereas the osseous architecture and the anterior joint capsule provides a large degree of elbow stability in extension. Valgus instability can be detected by applying a valgus force to the patient’s elbow with the humerus stabilized in external rotation, and the elbow flexed 25 to 30 degrees (Figure 34–11). One hand can be used to stabilize the elbow while the other hand is used to palpate the ligament and joint line to detect tenderness or gapping (Figure 34–12). Placing the patient in the supine position offers easier control for maximum external rotation of the humerus, while in the seated or standing position the examiner uses his/her torso to stabilize the patient’s arm, thus freeing up both hands to further stabilize and palpate the medial joint line.

Figure 34–11: Testing for valgus instability.
allowing some laxity but maintaining a solid endpoint, and complete tears (grade 3) demonstrating gross valgus laxity without a firm endpoint.\textsuperscript{13,15}

- True instability of the anterior MCL is present during both pronation and supination of the forearm. When valgus instability in supination resolves in pronation, PLRI should be suspected.\textsuperscript{12,15}

- Attenuation of the LCL complex with true varus laxity, a much less common injury, is tested similar to the valgus stress test, except with the humerus stabilized in internal rotation, and the forearm supinated, while adduction stress is applied to the elbow (Figure 34–13).\textsuperscript{10,15}

- PLRI, caused by insufficiency of the LUCL, is a rotatory subluxation. When valgus stress is applied with the forearm in supination and the elbow near full extension, the radius and ulna rotate together as a unit away from the humerus. There is subluxation of the ulna from the trochlea and posterior subluxation of the radius off the capitellum. Pronation of the forearm and flexion of the elbow reduces PLRI. Pure varus laxity occurs only rarely, most likely because of the restraint from the LCL in combination with the osseous architecture of the ulnohumeral articulation.\textsuperscript{6,15,21}

Provocative Tests

- \textit{Provocative tests}, which place specific structures under stress, help to determine which structure in an anatomic region is symptomatic.\textsuperscript{9} A presumed diagnosis of lateral tennis elbow is tested by stressing the ECRB through resisted wrist extension. First, the patient holds the elbow in extension and is asked to make a fist, pronate the forearm, and extend the wrist while the examiner resists the motion (Figure 34–14).\textsuperscript{9,10} A positive sign is pain at the origin of the ECRB. Coonrad described a positive “coffee cup test,” or pain with picking up a cup of liquid, as pathognomonic for lateral tennis elbow.\textsuperscript{9}

- EDC involvement can be tested, using the same position of elbow extension and forearm pronation but with the wrist now at neutral, by resisting extension of the middle finger. Pain at the origin of the EDC is suggestive of a tendinosis.\textsuperscript{9,10} This maneuver may also increase compression on the radial nerve, possibly exacerbating symptoms of radial tunnel syndrome. However, in contradistinction to tennis elbow, the pain of radial tunnel syndrome is localized more distally.\textsuperscript{9}
Provocative testing of the supinator may be more helpful in differentiating lateral tennis elbow from radial tunnel syndrome. This test is carried out through resisted supination from a fully pronated position with the elbow held in extension (to eliminate the supination effects of biceps). Symptoms are reproduced if there is PIN compression at the arcade of Frohse.9,10

The differential diagnosis of lateral elbow pain includes radiocapitellar arthritis, synovitis, and a symptomatic radiocapitellar plica. All of these conditions typically lead to a more diffuse pain that can be reproduced through passive rotation of the forearm with axial compression. It is important to be aware of coexistent pathologic conditions (<5% in our experience) that may be present along with lateral tennis elbow, including intraarticular injury, synovitis, plica, or posterolateral chondromalacia.9

Tendinosis of the flexor-pronator muscle mass, or medial tennis elbow, usually affects the PT and FCR. Symptoms can be reproduced through the resisted wrist flexion test and resisted pronation test.9,10 The resisted wrist flexion test is more specific for FCR involvement and involves resisted wrist flexion with the elbow slightly flexed and forearm supinated (Figure 34–15). Provoked pain is localized to the origin of the FCR. When the PT is involved, resisted pronation with the elbow extended and forearm in neutral rotation produces pain at the origin of this tendon. Paresthesias in the median nerve distribution that occur with resisted forearm pronation suggest entrapment of the median nerve as it passes through the two heads of the PT (pronator syndrome).

Cubital tunnel syndrome may occur as an isolated entity or may coexist with other medial elbow pathology, such as MCL insufficiency, which leads to traction on the ulnar nerve, medial tennis elbow, or medial and/or posterior compartment osteophytes causing friction or compression on the nerve.9 While the patient with cubital tunnel syndrome flexes and extends the elbow, the examiner palpates the medial epicondyle to test for ulnar nerve subluxation. The nerve can be palpated as it dislocates from the cubital tunnel anteriorly with elbow flexion.9 The elbow flexion test is a provocative test for cubital tunnel syndrome. It is performed by having the patient fully flex and supinate the elbow. The pressure of a digit over the cubital tunnel can be added to increase sensitivity. A positive result is reproduction of paresthesias to the ulnar digits within 30 seconds.9,10

Diagnostic injections of anesthetic can help validate a diagnosis from intraarticular pathology to tendinosis to nerve compression syndromes. Injections to specific pathoanatomic locations with pain relief often is confirmatory.9

References


This article evaluates the ligamentous contribution to elbow joint stability throughout the range of motion. The anterior portion of the MCL was the strongest and stiffest.

Description of posterolateral rotatory instability of the elbow, its cause, and its physical examination.

The stability of the elbow is independent of the MCL at less than 20 degrees and greater than 120 degrees flexion. Maximum instability occurred between 60 and 70 degrees flexion.

Part one of three review articles. A review of appropriate history taking to help guide the physical examination in evaluating elbow complaints.

Part three of three review articles. A review of provocative tests used to help distinguish the cause of most common elbow disorders.

Textbook of physical diagnosis as pertaining to orthopedics.

Review article of elbow injuries, especially as pertaining to the athlete.

Textbook with a thorough description of the anatomy, pathology, diagnosis, and treatment of elbow disorders.

A thorough history and physical examination combined with a firm understanding of biomechanics helps the physician make the proper diagnosis and initiate successful treatment.

Review article describing how to recognize and treat acute and chronic instability of the elbow. Both osseous and soft tissue reconstructive options are described.

Part two of three review articles. Describes the physical examination of the elbow with respect to palpation and instability testing.

The anterior MCL is a major stabilizer. Fractures of the medial epicondyle must be anatomically reduced and fixed because lengthening may result in chronic elbow instability.

Review of the diagnosis and treatment of medial tennis elbow, that is, “golfer’s elbow.”

The histology of tennis elbow demonstrates noninflammatory tissue, named angiofibroblastic hyperplasia. Nonoperative treatment consists of rehabilitative exercise. Surgical treatment involves excision of the pathologic tissue with repair of the tendon.

Review of tennis elbow, including anatomy, pathology, diagnosis, and treatment.

Discusses nerve entrapment and compression syndromes in the upper extremity. Anatomy and clinical signs and symptoms are described.

Review of the evaluation of thrower’s elbow.
Tendon Injuries and Tendinopathies About the Elbow

Jeffrey E. Budoff

Tennis Elbow

- Tendinopathies usually are the result of overuse from repetitive tensile overload. Overuse injuries occur when the stress applied to a tissue exceeds its stress tolerance, which is a function of strength, flexibility, and endurance. When the tissue's stress tolerance is exceeded, tissue damage may occur. When repetitive tissue damage occurs at a rate exceeding the body's ability to heal it, tissue degeneration and subsequent symptoms of pain and disability may occur.

- Approximately 50% of tennis players may get tennis elbow at some point, but the term tennis elbow probably is a misnomer because 95% of cases occur in non-tennis players. The condition now is more commonly an industrial injury. Specific predisposing tasks involve repetitive forearm rotation, overuse of the wrist or finger extensors, lifting with the forearm pronated, and athletic activities including racket sports, throwing, and swimming. Throwing athletes tend to develop medial epicondylitis tennis elbow because of the valgus stresses experienced. Golfers tend to develop medial tennis elbow of the dominant arm and lateral tennis elbow of the nondominant arm. Posterior tennis elbow is seen with repetitive sudden elbow extension, as occurs during pitching, football line play, shot put, javelin throw, bowling, and heavy weight lifting. Lateral tennis elbow is three to seven times as frequent as medial tennis elbow. Posterior tennis elbow is uncommon, accounting for only approximately 2% of cases, and usually occurs in combination with other pathology, such as posterior impingement.

- The term tendinitis has been used to describe the theoretical chronic inflammatory changes in the overused tendon. However, histologic examination has found that acute inflammatory cells are invariably absent. Chronic inflammatory cells, if present, are those of traumatic repair, such as the cells found in granulation tissue and scar. Therefore, the term tendinitis also is a misnomer and should be replaced by the term tendinosis. Tendinosis more accurately defines the histopathology of the degenerative process. The characteristic appearance of this tissue consists of invasion of immature fibroblasts and disorganized, nonfunctional vascular elements. This granulation-like tissue has been termed angiofibroblastic hyperplasia by Nirschl.

- Angiofibroblastic hyperplasia is theorized to result from an aborted healing response to microtears. Healing may fail because of disruption of the repair response by continuing injury, the poor vascularity of the tendon origin, or the possibility that the degenerative tendinosis itself deters the process of repair. The angiofibroblastic hyperplasia/tendinosis tissue appears to be the primary...
source of pain, and its amount appears to correlate with the duration of symptoms and the intensity of the pain. However, what makes this tissue intrinsically painful is not fully clear. The pain may result from tissue ischemia, as electron microscopy has demonstrated that the vascular elements do not possess lumen and therefore have no oxygen transporting capability.\(^7\)

### History and Physical Examination

- The onset of symptoms usually is gradual, often appearing after vigorous activity. Less commonly, acute onset is associated with an extreme effort or direct trauma.\(^3\) In many instances no predisposing activity can be determined.\(^2\)

- Lateral tennis elbow is degenerative tendinosis of the origin of the extensor carpi radialis brevis (ECRB). In addition, the anterior origin of the extensor digitorum communis (EDC) is involved in 30% of cases. Both of these tendons take origin from the lateral epicondyle. The extensor carpi radialis longus (ECRL) and the extensor carpi ulnaris are rarely involved.\(^3\) Lateral tennis elbow presents with pain over the origin of the ECRB, and often the EDC. It often is associated with weakness of the wrist extensors. The pain often is described as “burning,” and may radiate down the forearm, occasionally to the dorsal hand. Radiating pain does not necessarily imply a neurogenic origin.\(^1\) As noted by Coonrad,\(^2\) pain at the origin of the ECRB while picking up a full cup of coffee (or any other fluid) is almost pathognomonic for lateral tennis elbow.

- Medial tennis elbow is degenerative tendinosis of the conjoined tendon interface of the pronator teres (PT) and the flexor carpi radialis (FCR), but it also has been noted in the origin of the flexor carpi ulnaris and rarely on the underside of the flexor digitorum superficialis origin.\(^3,5,8\) All of these tendons originate from the medial epicondyle. Medial tennis elbow typically presents with pain over the flexor-pronator mass. Ulnar nerve irritation, medial collateral ligament injury, and olecranon osteophytes may be associated with medial tennis elbow because they also are induced by repetitive valgus stress and overuse.\(^5\)

- Posterior tennis elbow is degenerative tendinosis of the triceps insertion and presents with pain there.

### Point of Maximum Tenderness

- Lateral tennis elbow causes tenderness over the origin of the ECRB, just anterior and slightly distal to the tip of the lateral epicondyle. If the EDC also is involved, it will be tender just posterior and distal to the tip of the lateral epicondyle. Associated bony exostosis of the lateral epicondyle can result in tenderness over the lateral epicondyle itself.

- **Pearl:** The point of maximum tenderness is invariably within 1 to 2 cm of the lateral epicondyle. If the point of maximum tenderness is distal to the level of the radial head, other diagnoses, such as radial tunnel syndrome, should be suspected.\(^1\)

- The point of maximum tenderness for radial tunnel syndrome is on the lateral side of the proximal forearm, in the soft spot just posterior to the mobile wad of Henry, approximately 4 to 5 cm distal to the lateral epicondyle. The lateral epicondyle, the radial head, and the radial tunnel lie in a line equidistant from each other.\(^1,4\) Tenderness here should be compared to the other side because this region often is a little tender to deep pressure.

- **The differential diagnosis** of lateral elbow pain includes radial tunnel syndrome, radiocapitellar disorder, (arthritis, fracture, avascular necrosis, osteochondral lesion) and cervical radiculopathy. Pain also may radiate from the shoulder, especially from the rotator cuff, to the lateral elbow.

- Medial tennis elbow causes tenderness over the origin of the flexor-pronator mass, just distal to the medial epicondyle. In addition, the PT has an origin proximal to the medial epicondyle, which may also be tender.

- **Pearl:** In medial tennis elbow, the point of maximum tenderness should be within 1 to 2 cm of the medial epicondyle. If the tenderness is more distal, other diagnoses should be considered.\(^2\)

- **The differential diagnosis** of medial elbow pain includes injury to the medial collateral ligament (MCL), ulnar neuritis/cubital tunnel syndrome, ulnotrochlear arthritis or fracture, and a snapping medial triceps tendon.

- Posterior tennis elbow leads to tenderness at the insertion of the triceps tendon.

- **The differential diagnosis** of posterior elbow pain includes posterior impingement (from chronic hyperextension or valgus extension overload), olecranon stress fracture, olecranon periostitis, olecranon bursitis, or ulnotrochlear arthritis.

### Provocative Tests for Lateral Tennis Elbow

- **Loading the injured musculotendinous unit(s) should reproduce the patient's symptoms.** The ECRB (a wrist extensor) is tested by having the patient hold the elbow extended and the forearm pronated while he/she makes a fist and extends the wrist. The patient should hold this position while the examiner applies resistance, i.e., attempts to forcibly flex the wrist. Pain at the origin of the ECRB is diagnostic of lateral tennis elbow. The test should be repeated with the elbow flexed 90 degrees. As the ECRB crosses the elbow anterior to its axis of rotation, it is tensioned by elbow extension and relaxed by elbow flexion. Provoked pain often is increased by elbow extension and lessened by elbow flexion. Pain that is not lessened by elbow flexion implies a greater extent...
of tendon degeneration and a poorer prognosis for successful nonoperative management.

- The EDC should also be tested. With the wrist in neutral, the forearm pronated, and the elbow extended, all of the fingers should be extended. The patient attempts to maintain this position as the examiner applies a downward (flexing) force to the metacarpophalangeal joint of the long digit or of all digits simultaneously. Pain at the origin of the EDC (as opposed to over the radial tunnel) is suggestive of EDC tendinosis. The finger extension test previously has been described as provocative for radial tunnel syndrome, where it is theorized to provoke pain by driving the medial edge of the ECRB, or its facial extension, against the posterior interosseous nerve (PIN). However, pain with resisted long digit extension probably more commonly represents degenerative tendinosis of the EDC origin. It is important to note the location of the provoked pain. Provocative testing in cases of PIN entrapment should refer pain to the radial tunnel, not the lateral epicondyle. Pain referred to or about the lateral epicondyle is consistent with lateral tennis elbow. The finger extension test may not reliably distinguish between these two pathologic entities.

### Provocative Tests for Medial and Posterior Tennis Elbow

- Symptoms of medial tennis elbow may be reproduced by resisted wrist flexion and pronation. With the elbow slightly flexed and the forearm supinated, the patient makes a fist and flexes the wrist. The patient maintains that position as the examiner attempts to forcibly extend the wrist. If resisted wrist flexion elicits pain at the flexor-pronator origin, the FCR tendon is involved. With the elbow extended and the forearm in neutral rotation, the patient should “shake hands” with the examiner. The patient should then try to forcefully pronate the forearm, which the examiner resists. If resisted pronation causes pain at the flexor-pronator origin, the PT is involved.

- **Pearl:** Symptoms caused by entrapment of the median nerve between the two heads of the PT (the pronator syndrome) may be reproduced by resisted forearm pronation with the elbow extended. However, in the pronator syndrome, resisted pronation leads to paresthesias of the radial digits, not medial elbow pain. In addition, resisted pronation with the elbow flexed should not reproduce symptoms caused by the pronator syndrome because only the ulnar head of the PT is tense in this position, and therefore the median nerve should not be compressed.

- Symptoms of posterior tennis elbow may be reproduced by resisted elbow extension.

### Radiography

- Standard radiographs should be evaluated for the presence of fracture, dislocation, subluxation, avascular necrosis, and degenerative changes. Radiographic exostosis of the lateral epicondyle occurs in 7% to 20% of patients with lateral tennis elbow. Although of questionable prognostic significance, consideration can be given to exostosis removal at the time of surgery, especially if they are tender. Medial tennis elbow is usually not associated with radiographic changes.

- Magnetic resonance imaging (MRI) of the elbow is not routinely necessary in patients with tennis elbow. Physical examination is the gold standard for diagnosis of the condition, with advanced radiologic studies adding little with regard to staging, prognosis, or the determination of treatment.

### Diagnostic Injection

- In cases of diagnostic dilemma, a diagnostic injection often can be helpful in determining the cause of the patient’s symptoms. Lidocaine injected deep to the origin of the ECRB over the anterior aspect of the lateral epicondyle should relieve pain caused by lateral tennis elbow. Injections just deep to the flexor-pronator mass for medial tennis elbow achieve the same result.

- Intraarticular injections should be avoided because they may further damage an already injured tendon.

- Subdermal injection of steroid superficial to the tendon may lead to subcutaneous fat atrophy, leaving a permanent dimple, thinner skin, and a poorly padded, tender epicondyle.

- Injection of lidocaine into the radial tunnel should relieve the pain of radial tunnel syndrome. The ECRB should be injected first because forceful wrist extension will not be possible after the injection.

- **Author’s technique:** Use a 22-gauge, 1.5-inch needle and 10 ml lidocaine (and 1 ml steroid if desired). The elbow should be flexed and pronated. Penetrate the skin over the radial tunnel, aiming somewhat posteriorly, for the radial neck. After contacting the radial neck, pull back 1 to 2 mm and inject all 10 ml. A PIN palsy should occur within a few minutes, confirming appropriate placement of the injection.

- An intraarticular injection of lidocaine, most often through the anconeus soft spot, should relieve pain resulting from intraarticular pathology.

### Treatment

- The aim of nonoperative management of tendinopathies is twofold: decreasing the stress applied to the injured tendon and increasing the tendon’s stress tolerance (i.e., strength). Approximately 75% to 95% of patients improve with nonoperative management.

- **Pearl:** It is critical to distinguish between comfort and cure. Therapeutic modalities (rest, nonsteroidal antiinflammatory drugs, and steroid injections) may temporarily relieve pain, but the pain relief does not necessarily imply healing or improvement of tissue quality. These interventions have no long-term curative
efficacy, and reliance upon them may result in further deconditioning and delay of the rehabilitative process. Therefore, these measures must be used only in the perspective of a larger treatment plan.

- If pain prevents the patient from performing the prescribed exercise program, an injection of corticosteroid is appropriate. However, the efficacy of steroid injections is questionable, as a randomized prospective trial found no difference in symptoms between patients injected with steroid and lidocaine and those injected with only saline at 3 and 12 months. Repetitive injections are inappropriate because they may cause cellular death, further tissue weakness, and actually slow the healing process.

- Rest should be relative. The patient should refrain from symptom-aggravating or abusive activities, not all activities. Work or play can be continued if the injured tissue can be protected through a reduction in stress. Faulty athletic or workplace techniques that place unnecessarily high stresses on the tendon origins should be identified and corrected. The patient's tennis swing, throwing motion, or other sport-specific task should be evaluated by an athletic trainer, coach, or professional. In cases of work-induced lateral tennis elbow, grasping or lifting with the forearm pronated (palm down) should be avoided, and the patient should be instructed to lift with the forearm supinated.

- Counterforce bracing reduces the transmission of externally applied forces to the tendon origins and decreases symptoms of tennis elbow. This brace should be worn during rehabilitative exercise, stressful daily activities, and upon return to work or sport. The brace usually is not necessary at rest or during light activities of daily living. Counterforce bracing also may function by preventing full muscular expansion, thereby not allowing maximal contraction, which further decreases force at the muscle's tendinous origin. In addition, the brace probably reminds the patient to exercise due caution. Wrist splints can be used to decrease stress during a specific activity. Continuous splint use or casting may relieve pain but at the price of atrophy, stiffness, and further deconditioning, and is not recommended.

- Although stress minimization is important, the mainstay of treatment is improvement of tissue quality through rehabilitative exercise, to allow the myotendinous unit to safely absorb the imposed forces. Activity modification to eliminate the motions causing pain may be necessary for three months. The term, “no pain, no gain,” does not apply to elbow tendinosis. The six key forearm exercises are wrist extension, wrist flexion, forearm pronation, forearm supination, finger extension, and the ball squeeze (Figures 35–1, 35–2, and 35–3). The patient should be instructed not to work through pain. If pain occurs, the resistance, number of repetitions, or arc of motion should be decreased.
The final stage involves performing the exercises with the elbow extended and the forearm unsupported. Depending upon symptoms, the resistance should be decreased and reprogressed. It is important to continue the strengthening program as return to work or sport occurs; otherwise the patient risks reinjury or the return of symptoms.\(^1\)

The ECRB is stretched by wrist flexion with the forearm pronated and the elbow extended. This maneuver may be best performed in a hot shower.

Nonoperative management may require 2 to 3 months to decrease symptoms. Work-related tendinopathies often are more resistant to nonoperative management, probably because athletes can often reduce participation in the aggravating activity, whereas those with work-related tendinosis often do not have that option.\(^4\)

The efficacy of extracorporeal shock wave therapy for treatment of lateral tennis elbow is controversial.\(^13-16\)

Operative Management

Following at least 3 months of appropriate nonoperative management with no improvement (not necessarily complete symptom resolution), the patient has the choice of either accepting the pain and disability, lowering his/her activity level to the point where the pain is tolerable, or seeking a surgical solution.

The key to successful tendinopathy surgery is identifying and excising the pathologic tendinosis while minimizing iatrogenic injury to normal tissue. This option is preferable to tendon releases or slides, which fail to remove the pathology and weaken the force generators, leading to less predictable results with a greater incidence of persistent pain and weakness.\(^3\)

Lateral Tennis Elbow

The Nirschl technique of lateral tennis elbow excision has reported consistently good results: 85% of patients reported complete pain relief, full strength, and full return to all prior activities without pain. Twelve percent reported significant but not complete pain relief and return of strength. Only 3% failed to improve. No patient had increased symptoms postoperatively. Complications have been minimal: 1% superficial infection and 1% mild (<5 degrees) loss of extension.\(^3,5\)

Modified Nirschl Technique\(^17\)

- **Pearl:** The key to this surgery is realizing that the ECRB is hidden under the ECRL, which merges with the EDC at a thickening called the *extensor aponeurosis*. The ECRL must be mobilized and retracted to expose the ECRB.
  1. A longitudinal incision is made just anterior to the tip of the lateral epicondyle, centered over it proximodistally (Figure 35–4). The tendinous layer is exposed (Figure 35–5).
  2. The ECRL muscle is red. It merges posteriorly with the EDC at a palpably firm white structure called the *extensor aponeurosis*. This aponeurosis is incised 3 mm posterior to the ECRL, paralleling it, to leave a tendinous cuff for firm repair (Figure 35–6).
  3. This layer is incised to a depth of only 2 to 3 mm.
  - **Pitfall:** Incising too deeply distorts the origin of the ECRB, which lies beneath the ECRL.
  4. The ECRL (red) is sharply dissected off the underlying ECRB tendon origin (white-gray). The ECRL is dissected medially until the entire triangular origin of the ECRB is exposed (Figure 35–7).
  5. The entire ECRB proximal origin is excised down to bone. Often it is easiest to cut down to bone proximally on two sides of the triangle and then lift the origin off the bone from proximally to distally to the level of the radiocapitellar joint (Figure 35–8). Only rarely is tendinosis found distal to the radiocapitellar joint. The ECRB origin is excised to this level. The lateral joint capsule is just deep to the ECRB and is optimally spared. However, it often is inadvertently incised, which leads to no negative consequences, even if it is not repaired. The

![Figure 35–3: Finger extension and ball squeeze.](image1)

![Figure 35–4: Lateral tennis elbow excision: incision.](image2)
elbow joint can be inspected if intraarticular pathology is suspected, but this is not routinely performed.

6. Tendinosis tissue appears grayer than the normal white tendon and more edematous. The more steroid injections a patient has had, the more pronounced the tendinosis. In mild to moderate cases the superficial tendon may be relatively normal, with most of the pathology in the deep tendon. The Nirschl scratch test is used to remove all tendinosis while leaving normal tendon behind. Using a fresh blade in a scraping fashion (as opposed to a cutting or stabbing fashion) will not injure normal tendon. Tendinosis is more friable and will be scraped off. In 30% of cases the anterior EDC also is involved (Figure 35–9).

Figure 35–5:
Lateral tennis elbow excision: fascial exposure. ECRL, Extensor carpi radialis longus; EDC, extensor digitorum communis.

Figure 35–6:
Lateral tennis elbow excision: fascial incision. ECRL, Extensor carpi radialis longus.

Figure 35–7:
Lateral tennis elbow excision: exposure of extensor carpi radialis brevis (ECRB) tendinosis. ECRL, Extensor carpi radialis longus.

Figure 35–8:
Lateral tennis elbow excision: extensor carpi radialis brevis (ECRB) origin excision. ECRL, Extensor carpi radialis longus; EDC, extensor digitorum communis.

Figure 35–9:
Lateral tennis elbow excision: extensor carpi radialis brevis (ECRB) origin excision. ECRL, Extensor carpi radialis longus; EDC, extensor digitorum communis.
7. **Pearl:** No bone is removed, drilled, or altered. Tendon excrescences present on the tip of the lateral epicondyle may be removed, but any bony work significantly increases postoperative pain and morbidity and delays return to full activity.

8. The ECRL muscle and tendinous cuff are repaired back to the EDC with a running no. 1 Vicryl stitch (Figure 35–10). The knot is anchored in the middle (proximodistally), where the tendon is strongest. It is run proximally and then distally, where it is tied buried deep to the fascia. The fascia becomes weaker proximally and may not provide as secure a closure if tied there. A firm closure of this layer is important to prevent synovial cyst formation secondary to fluid leakage from the elbow. The skin is closed in subcuticular fashion.

- **Postoperative:** Early motion is started within a few days. Strengthening is started as tolerated by the patient, usually within 3 to 4 weeks. Soreness may persist for 3 to 6 months, but relief from the most severe pain often is fairly rapid.\(^1,17,18\)

- **Pearl:** Because of the extensive origin of the ECRB from the annular ligament, the undersurface of the extensor aponeurosis, the undersurface of the ECRL, and the lateral epicondyle, the ECRB tendon does not retract even when the majority of its origin is excised. Therefore, it is not necessary to reattach the tendon to bone. Doing so only risks creating a flexion contracture.\(^17\)

**Revision Surgery**

- The three most common reasons for failure of lateral tennis elbow surgery are (1) failure to identify and completely remove all tendinosis (most common), (2) iatrogenic trauma to the lateral collateral ligament or other structures, and (3) misdiagnosis.

- Tendinosis excision works well following failed lateral tennis elbow surgery, leading to 83% good or excellent results at average 64-month follow-up, and is my preferred revision procedure.\(^19\)

- Postoperative synovial cysts are caused by an iatrogenic defect in the extensor layer. Failing nonoperative management, an anconeus flap can be used to cover this defect or to provide more padding over the lateral epicondyle in cases of severe fat atrophy from multiple steroid injections.\(^20\) Normal tendon should not be transected or debrided in order to rotate this flap.

**Medial Tennis Elbow**

- The results of surgery for medial tennis elbow excision are less predictable than those for lateral tennis elbow. In a study of 50 cases, all patients reported partial or complete pain relief, with increased strength. However, 26% were not able to return to their same level of sporting activity. No major complications occurred.\(^3,8\)

**Modified Nirschl Technique**\(^1,8\)

1. A curvilinear incision is made over the cubital tunnel. Dissection is carried down to the ulnar nerve, taking care to dissect out and preserve branches of the medial antebrachial cutaneous nerve (Figure 35–11).

2. An in situ release of the ulnar nerve is performed from the level of the epicondyyle distally to prevent postoperative swelling from inducing an iatrogenic...
neuropathy. To prevent subluxation, the nerve is not released proximal to the epicondyle. If symptomatic cubital tunnel syndrome is present, the nerve may be transposed subcutaneously.

3. The conjoined tendon of the PT and FCR can be exposed by raising a medially based semicircular fascial flap, as for a subcutaneous transposition (Figure 35–12). This procedure exposes the white conjoined tendon, which is excised (Figures 35–13 and 35–14). Care is taken to avoid disrupting the MCL, which is deep to this tendon. The ligament is part of the joint capsule and appears smooth compared to the rougher tendon fibers. The Nirschl scratch test is used to excise all tendinosis while leaving normal tendon, as for lateral tennis elbow (Figure 35–15).

- **Pearl:** Please note that the bone is not altered. No epicondylectomy, drilling, or abrasion is performed.

4. The fascial sling is repaired and the skin routinely closed (Figure 35–16).

- **Postoperative:** As for lateral tennis elbow.
Posterior Tennis Elbow

- This procedure is essentially the same as that used to treat Achilles tendinosis or patellar tendinosis.

1. The triceps tendon is exposed through a posterior incision (Figure 35–17). The tendon is incised in the line of its fibers (Figure 35–18).

2. The Nirschl scratch test is used to remove pathologic tendinosis, while leaving normal tendon behind (Figure 35–19). Consideration should be given to not excising more than 50% of the triceps insertion, although the amount removed is usually significantly less.

3. The remaining tendon is closed side to side (Figure 35–20). The skin is routinely closed.

Postoperative: As for lateral tennis elbow.
**Distal Biceps Rupture**

**History and Physical Examination**

- Tendon degeneration in the hypovascular zone close to its radial tuberosity insertion predisposes to distal biceps rupture. Smoking leads to a 7.5 times greater risk of rupture, probably by further decreasing tendon oxygenation in this hypovascular zone. Use of anabolic steroids is a risk factor. Mechanical irritation has been theorized to play a role because of a 50% decrease in the interosseous space during pronation.

- Rupture occurs most commonly in the dominant arm of men 40 to 60 years old who engage in manual labor, athletics, or weight lifting. Rupture usually is associated with a painful pop following an episode of eccentric tensile overload, when the arm is forced from a flexed position, as occurs when lifting or moving heavy objects.

- Physical examination often reveals antecubital tenderness, swelling, and ecchymosis. The biceps muscle is retracted proximally, and the normal proximal-distal tracking of the biceps muscle belly with passive forearm rotation is lost. Flexion power is mildly reduced, supination power is markedly reduced, and resisted flexion and supination is painful.

- **Pitfall:** Do not mistake the intact lacertus fibrosus (bicipital aponeurosis) for the ruptured biceps tendon. Compare the affected elbow to the contralateral side, and note that the bicipital aponeurosis does not move significantly with forearm rotation.

- MRI is not routinely necessary to diagnose a complete tear but can be helpful in unclear cases or in the workup of a partial tear.

**Treatment**

- Nonoperative management leads to a 30% loss of flexion strength and a 40% decrease in supination strength and endurance.

- Surgical reattachment to the radial tuberosity is indicated for active individuals with complete ruptures. This procedure is best done within the first 2 to 3 weeks, before scarring and retraction make dissection difficult and obliterate the tunnel the tendon follows to the tuberosity.

- Either a single-incision technique using two to three suture anchors or a two-incision technique using a bone trough may be used. Both techniques lead to excellent results in acute injuries, with good return of supination and flexion power and endurance in most cases and predictably excellent functional results and patient satisfaction. However, in one comparison, the two-incision technique showed fewer complications and more rapid recovery of flexion strength. Repair of the nondominant arm does not lead to as good results as repair of the dominant arm, with less than full recovery of strength and endurance.

- For chronic tears, the biceps tendon may not easily reach the tuberosity because of retraction and scarring. An autograft or allograft may be necessary to prolong the tendon. It may first be attached to the radial tuberosity as for an acute tear, and then secured to the remaining distal biceps tendon at the appropriate length and tension using a Pulvertaft weave. Results of chronic tear repair are not as good as those following acute repair. Although strength...
is improved, it does not return to the preinjury level, and the biceps muscle contour frequently is only partially corrected.22,26

- Partial-thickness tears often present with atraumatic onset of pain at the insertion of the distal biceps tendon. These tears initially may be treated nonoperatively with splinting and decreased activity level. Failing this, operative intervention involves completion of the tear, debridement of the symptomatic tendinosis, and reinsertion.

**Two-Incision Technique**

1. A transverse incision is made in the antecubital crease (Figure 35–21). Dissection is carried down to the distal biceps tendon, which is milked into the wound. Care is taken to avoid injuring the lateral antebrachial cutaneous nerve. Degenerative tendinosis is debrided off the tendon end sharply and/or using the Nirschl scratch test. The tendon end is rounded off. Two no. 2 fiber-wire stitches of different colors are woven into the tendon in either Bunnell or running locked fashion (Figure 35–22).
- **Pearl:** The biceps tendon sheath may still be intact, giving the false impression of continuity to the radial tuberosity. This sheath is opened to identify the free tendon end.

2. With the forearm supinated (to avoid the PIN), a tonsil forceps is placed through the biceps tendon tunnel, hugging the radial tuberosity (staying away from the ulna), and is punched through the interosseous space to tent the skin posteriorly (Figure 35–23). The interosseus tunnel is bluntly enlarged to allow easy passage of the biceps tendon.

3. A longitudinal posterior incision is centered over the tonsil’s tip (see Figure 35–23). The common extensor and supinator muscles are split, staying away from the ulna, until the radial tuberosity is visualized. Pronation improves visualization of the tuberosity and protects the PIN. The entire tuberosity is cleaned of residual soft tissue with a
rongeur, curette, and/or elevator, and its limits are defined. A 5-mm burr is used to make a trough as medial as possible (toward the free end of the tuberosity) while leaving the cortical wall intact. The trough is approximately 6 mm wide and 12 mm long (Figure 35–24).

4. A 3-mm drill is used to make a hole from the radial shaft into the trough, one proximal and one distal, with a large bone bridge between. All bone dust is thoroughly irrigated out of the wound.

5. The biceps tendon’s lead sutures are passed through the interosseous space into the posterior wound. One free end of each stitch is passed through each of the two drill holes using a Hewson suture passer.

6. The forearm is rotated to neutral and the sutures are tensioned to pull the tendon into the bone trough. A freer elevator is used to help “shoe-horn” it into position. Each suture is firmly tied (Figure 35–25).

7. To determine postoperative restrictions, supinate the forearm and note the amount of elbow extension that occurs before the tendon repair becomes tensioned. Routine closure is performed.

● Postoperative: The elbow is splinted at 90 degrees flexion and full supination for 1 week before noncomposite elbow motion is begun. After 1 week, supervised elbow extension is allowed with the forearm supinated to the degree determined intraoperatively. No active flexion is allowed. Full forearm rotation is allowed with the elbow flexed 90 degrees. Full active and gentle passive motion is allowed after 4 weeks. Progressive strengthening is allowed at 3 months, heavy lifting at 4 months, and contact sports at 6 months.

Triceps Tendon Ruptures

● Rupture of the triceps tendon is the rarest of all tendon ruptures. Predisposing factors include renal insufficiency with secondary hyperparathyroidism, use of systemic steroids, and steroid injections. Triceps rupture occurs by a similar mechanism to olecranon fractures: either a sudden forceful flexion of the extended elbow, as occurs during a fall on the outstretched hand, or a direct blow to the olecranon area.

● The most common site of rupture is the tendo-osseous junction. Avulsion often occurs with a small fleck of bone, which may be visible on radiography. Examination usually reveals swelling and a palpable gap in the tendon proximal to the olecranon.

● A modified Thompson test for the triceps has been described: The upper arm is supported, allowing the elbow to flex 90 degrees with the elbow relaxed, such as a prone position with the forearm hanging over the end of the table. The triceps muscle belly is squeezed. If elbow extension is produced, the triceps is not completely ruptured. Absence of elbow extension suggests a complete rupture.

● A complete tear results in the inability to extend the elbow against even slight resistance. Operative reattachment is recommended.

● A partial tear allows some active elbow extension. It can be treated nonoperatively in a splint at 30 degrees flexion for 4 weeks. However, some active elbow extension may be present even in cases of near-complete
tears from the lateral triceps expansion onto the forearm fascia. In this case, elbow extension can be maintained with the elbow straight but not attained from greater than 90 degrees flexion. Whether nonoperative treatment of both large and small partial tears will produce a good functional outcome is unknown. Therefore, if a large tear of greater than 50% of the triceps is noted on MRI and is associated with a significant loss of triceps power, operative repair should be considered, especially in athletic individuals.\(^2\)

- MRI can assist in differentiating partial from complete ruptures.
- As for distal biceps ruptures, surgical repair is easiest performed within the first 2 to 3 weeks. Results of surgical repair generally are excellent, with no pain, normal strength, and full motion.\(^2\)

**Technique of Triceps Repair**

1. Make a longitudinal posterior incision, just medial to the olecranon (Figure 35–26). The triceps tendon is retrieved and its end debrided of tendinosis (Figure 35–27). Two no. 2 or no. 5 fiber wire sutures of different colors are placed in Bunnell or running locked fashion (Figure 35–28).

2. Identify and protect the ulnar nerve. Clean soft tissue off the superficial olecranon. Use a 5- to 6-mm burr to make a unicortical hole in the superficial/posterior portion of the proximal olecranon, where the triceps naturally inserts. Do not violate the posterior cortex. When this trough has been partially drilled, place a freer inside of it and move the elbow to ensure the hole is extraarticular. Place two distal 3-mm drill holes through posterior cortex into the trough, with a large bone bridge between (see Figure 35–28).

3. Bring one of each suture’s free end through each drill hole with a Hewson tendon passer. Extend the elbow and firmly tie these stitches (Figure 35–29). A tendon turndown flap can be used as needed to reinforce the repair or to prolong a retracted tendon.\(^1\)

- **Postoperative:** The elbow is immobilized at 30 degrees flexion for 4 weeks, followed by progressive motion. Full use is restricted for 4 months.
References


Reports 83% success for resection of lateral tennis elbow on patients who did not respond to prior surgical intervention.

Reported 94% patient satisfaction at a mean of 48 months following anconeus muscle transfer for lateral tennis elbow.

Reports that smoking is associated with a 7.5x greater risk of distal biceps tendon rupture.

The common biceps and triceps injuries about the elbow are reviewed. The relevant anatomy, presenting signs, symptoms, and treatment of these injuries are discussed.

Ten patients showed a return to normal elbow flexion and supination strength and endurance following surgical repair of a distal biceps rupture.

Nonoperative management of distal biceps ruptures led to a mean loss of 40% of supination strength and a mean loss of 30% of elbow flexion strength.

This comparison of outcomes for distal biceps repair through either one or two incisions showed minor differences between these techniques, with the two-incision technique showing a slightly more rapid recovery of flexion strength and fewer complications.

Notes that repair of the biceps tendon in the nondominant arm does not lead to results as good as repair in the dominant arm, with less than full recovery of strength and endurance.
Elbow Instability and Arthroscopy

David S. Ruch* and Anastasios Papadonikolakis†

Introduction

- Elbow instability following ligamentous and bony trauma remains complex.
- Outcome studies demonstrate that injuries resulting in significant ligamentous disruption have worse results than fractures in isolation.1,2
- Key determinants of stability are the coronoid process, medial collateral ligament (MCL) complex, and the lateral/posterolateral ligament complex.

Anatomy

Medial Collateral Ligament Complex

- The MCL originates posterior to the axis of rotation and inserts onto the medial aspect of the coronoid process (Figure 36–1).3
- The MCL complex is composed of the anterior bundle, posterior bundle, and transverse ligament. Some authors refer to the MCL as the ulnar collateral ligament complex (Box 36–1).

Lateral Collateral Ligament

- Originates at the lateral humeral epicondyle and inserts into the supinator crest of the ulna (Figure 36–2).
- This broad, flat ligament remains taut throughout the range of elbow flexion and extension, with little change throughout the range of motion in the distance between its origin and insertion points.5
- It can be divided into lateral, medial, and anterior bundles.7 The relative contribution of each bundle to stabilizing the elbow remains controversial; however, it is accepted that disruption of the posterior lateral ligamentous complex results in loss of the “sling” effect on the radial head, which suspends the radial head to the capitellum, maintaining articular congruity.
- Without this effect, the radial head rotates away from the capitellum, resulting in subluxation or dislocation of the radiocapitellar joint, and subsequently the ulnohumeral articulation.7

Secondary Stabilizers

Bony Structures

- The articulation between the capitellum and radial head is an important secondary stabilizer to valgus stress. Cadaveric studies indicate that following division of the anterior bundle of the MCL, the radial head is the primary stabilizer preventing valgus instability.8
- The coronoid process also is key and acts as a direct buttress and an insertion point for critical ligaments.9 Cadaveric studies indicate that if more than 50% of the coronoid height is lost, a statistically significant increase in posterior translation in the elbow may occur in response to axial load.9

Muscular Structures

- Cadaveric studies indicate that the common extensor origin with the interdigitating fascial bands and
intramuscular septate stabilize the lateral aspect of the elbow.\textsuperscript{10}

- On the medial aspect of the elbow, the flexor carpi ulnaris muscle, positioned directly over the MCL, works with the common digital flexors to provide medial support in the case of ligamentous laxity.\textsuperscript{11} Despite anatomic positioning, electromyographic studies do not demonstrate increased electrical activity in flexor carpi ulnaris and common digital flexors when assessing a group of baseball pitchers with MCL insufficiency. This finding suggests that the muscles on the medial side of the elbow do not augment the role of the MCL during a baseball pitch.\textsuperscript{12}

- The brachialis, brachioradialis, and triceps brachii function as direct buttresses to prevent anteroposterior subluxation and may also dynamically stabilize the elbow. The brachialis muscle with its broad insertion across the coronoid provides a direct buttress to posterior subluxation. In addition, the compressive loads by biceps and triceps during forced coupling may compress the articular surface, thus maximizing joint surface contact and subsequently diminishing instability (Box 36–2).

### Acute Injury

#### Presentation and Diagnosis

- Acute instability is commonly seen following dislocation of the elbow.
- Avulsion of the flexor pronator origin from the medial side of the elbow is frequently seen.
- The diagnosis of valgus instability may be readily apparent. Examination reveals hemorrhage along the medial epicondyle and gross instability to valgus stress (Boxes 36–3 and 36–4).

### Chronic Instability

- Chronic instability commonly results from repetitive microtrauma caused by chronic overload during overhead throwing (Box 36–5).

### Imaging

- Plain radiographs should be made with the elbow in flexion and under significant valgus stress.\textsuperscript{17} These dynamic radiographs may reveal widening of the joint space in up to 80\% of patients, but many patients do not “open up” until they are under anesthesia.

### Anatomy of the MCL Complex

1. The anterior bundle is divided into anterior and posterior segments. The anterior segment provides the majority of stability.\textsuperscript{4}
2. The anterior bundle has an isometric point where some fibers are taut in extension and others are taut in elbow flexion.\textsuperscript{3}
3. The transverse ligament originates at the central two thirds of the anteroinferior undersurface of the medial epicondyle.\textsuperscript{5} It does not have a defined function; however, it deepens the greater sigmoid notch.
4. The posterior bundle has fibers that become taut during both maximum elbow extension and maximum elbow flexion.\textsuperscript{4} It lies posterior to the axis of rotation. Because of the cam effect of the MCL, the posterior bundle may require partial release to achieve full elbow flexion in patients with long-standing stiffness.

### Patterns of Valgus Instability

- Valgus instability may be seen either acutely following trauma or chronically following attenuation of repetitive injury. The primary stabilizer to valgus load is the anterior bundle of the MCL. Cadaveric studies indicate that 100\% of the anterior bundle of the MCL must be sectioned before demonstrating significant valgus or intrarotatory elbow instability.\textsuperscript{13,14}
Computerized tomography with arthrography and magnetic resonance imaging (MRI) with or without arthrography are of higher sensitivity than ultrasound, and are best at demonstrating abnormalities of the MCL.\(^\text{18}\) A computerized tomography arthrogram allows best visualization of partial undersurface tears of the MCL.\(^\text{19}\) Arthroscopy can confirm the diagnosis, but visualization of the MCL is incomplete and the diagnosis more likely is made by excessive laxity when the arthroscope is passed through the ulnohumeral articulation. Arthroscopy is more useful for assessing secondary changes. Cadaveric studies indicate that 100% of the anterior bundle of the MCL must be cut before 1 to 2 mm of joint space opening is present and visible arthroscopically (Figure 36–3 and Box 36–6).\(^\text{14}\)

### Box 36–3 Treatment of Acute Injuries
- A reduction should be performed and an assessment of range of motion initiated.
- With loss of stability in elbow extension, the elbow should be placed in pronation and flexed to 90 degrees.
- Range of motion should be initiated with an extension block at the point at which the elbow becomes unstable.
- The elbow should be extended approximately 30% per week such that the elbow is in full extension by the end of 3 weeks.
- Surgical exploration is indicated if the patient is unable to maintain reduction in pronation at 45 to 60 degrees flexion.
- Possible causes:
  1. Entrapment of the medial epicondyle
  2. Loose body
  3. Unrecognized coronoid/radial head/capitellum trauma

### Box 36–4 Acute Instability Operative Treatment
- Acute instability can be treated with direct repair of the avulsed MCL using drill holes or suture anchors. MCL almost always fails at its humeral origin. Suture anchors usually are not strong enough for repair. In such cases, drill holes through the medial epicondyle should be used.
- Care should be taken to reattach the ligament to the undersurface of the medial epicondyle at the anatomic origin.
- Following repair, tension in the anterior bundle of the ligament should be demonstrated in both flexion and extension. Only the middle bundle of the anterior portion of the ligament demonstrates isometry.
- If the elbow subluxes or dislocates as the elbow is brought down into extension, the forearm should be placed in pronation at 90 degrees elbow flexion.
- If stability is restored, then a hinge brace or cast brace can be applied.
- The elbow should be brought down out of flexion over a 3-week period such that, at the end of 3 weeks, full arc of motion is permitted.

### Box 36–5 Critical Points in the Evaluation of MCL Insufficiency
- Patients complain of increasing pain after repetitive throwing, particularly during the early and middle phases of the throwing motion. Approximately 25% present with ulnar sensory symptoms.
- Typically patients demonstrate pain and tenderness posteroinferior to the medial epicondyle at the ulnar attachment of the ligament.
- Insufficiency is most evident with the elbow flexed from 70 to 90 degrees.\(^\text{15}\)
- During the cocking phase of throwing, the elbow is subjected to tremendous valgus stress. As the laxity progresses, increased loading of the capitellum leads to cartilage wear. Abutment of the olecranon against the posterior medial aspect of the humerus also occurs, resulting in osteophyte formation.\(^\text{16}\) Intraarticular trauma and increased capitellar loading can occur, leading to cartilage wear and loose body formation. Traction on the ulnar nerve may result as instability increases, leading to neuritis in 30% of cases.

### Box 36–6 Critical Points in the Evaluation of MCL Insufficiency
- Patients complain of increasing pain after repetitive throwing, particularly during the early and middle phases of the throwing motion. Approximately 25% present with ulnar sensory symptoms.
- Typically patients demonstrate pain and tenderness posteroinferior to the medial epicondyle at the ulnar attachment of the ligament.
- Insufficiency is most evident with the elbow flexed from 70 to 90 degrees.\(^\text{15}\)
- During the cocking phase of throwing, the elbow is subjected to tremendous valgus stress. As the laxity progresses, increased loading of the capitellum leads to cartilage wear. Abutment of the olecranon against the posterior medial aspect of the humerus also occurs, resulting in osteophyte formation.\(^\text{16}\) Intraarticular trauma and increased capitellar loading can occur, leading to cartilage wear and loose body formation. Traction on the ulnar nerve may result as instability increases, leading to neuritis in 30% of cases.

### Treatment of Chronic Injuries
- Nonoperative treatment involves rest and physical therapy. Pain-free motion is necessary prior to gradual resumption of competition level play.
- Forty-two percent of athletes treated nonoperatively can return to their previous level of competition at an average of 24.5 weeks following diagnosis.

**Figure 36–3:**
Avulsion of the proximal portion of the medial collateral ligament with fluid extravasation medially.
No particular findings demonstrate whether or not a patient will be successful with nonoperative management. If nonoperative management is unsuccessful, ligament reconstruction is indicated. Attempts at direct ligament repair are less reliable than reconstruction using tendon graft (Figure 36–4, Boxes 36–7 and 36–8).20

Postoperative Management

- The elbow is splinted at 40 degrees flexion for 10 to 14 days. Active motion in a hinged elbow brace with a 20-degree extension stop is performed for 4 more weeks. The elbow brace can be unlocked at 6 weeks. Light activity should be resumed at 3 months. Full restoration of activity is expected at 1 year.

In a series of 72 baseball pitchers who underwent arthroscopic or open elbow surgery, postmedial olecranon osteophytes occurred in 65%, ulnar collateral ligament (MCL) injuries in 25%, and ulnar nerve neuritis in 15%. The authors noted that in the presence of posterior medial olecranon osteophytes, attenuation of the medial collateral ligament can be considered the cause of the osteophyte formation.6

Additional Findings Associated with MCL Insufficiency

- If nonoperative management is unsuccessful, ligament reconstruction is indicated. Attempts at direct ligament repair are less reliable than reconstruction using tendon graft (Figure 36–4, Boxes 36–7 and 36–8).20

Postoperative Management

- The elbow is splinted at 40 degrees flexion for 10 to 14 days. Active motion in a hinged elbow brace with a 20-degree extension stop is performed for 4 more weeks. The elbow brace can be unlocked at 6 weeks. Light activity should be resumed at 3 months. Full restoration of activity is expected at 1 year.

In a series of 72 baseball pitchers who underwent arthroscopic or open elbow surgery, postmedial olecranon osteophytes occurred in 65%, ulnar collateral ligament (MCL) injuries in 25%, and ulnar nerve neuritis in 15%. The authors noted that in the presence of posterior medial olecranon osteophytes, attenuation of the medial collateral ligament can be considered the cause of the osteophyte formation.6

Additional Findings Associated with MCL Insufficiency

- If nonoperative management is unsuccessful, ligament reconstruction is indicated. Attempts at direct ligament repair are less reliable than reconstruction using tendon graft (Figure 36–4, Boxes 36–7 and 36–8).20

Postoperative Management

- The elbow is splinted at 40 degrees flexion for 10 to 14 days. Active motion in a hinged elbow brace with a 20-degree extension stop is performed for 4 more weeks. The elbow brace can be unlocked at 6 weeks. Light activity should be resumed at 3 months. Full restoration of activity is expected at 1 year.

In a series of 72 baseball pitchers who underwent arthroscopic or open elbow surgery, postmedial olecranon osteophytes occurred in 65%, ulnar collateral ligament (MCL) injuries in 25%, and ulnar nerve neuritis in 15%. The authors noted that in the presence of posterior medial olecranon osteophytes, attenuation of the medial collateral ligament can be considered the cause of the osteophyte formation.6

Additional Findings Associated with MCL Insufficiency

- If nonoperative management is unsuccessful, ligament reconstruction is indicated. Attempts at direct ligament repair are less reliable than reconstruction using tendon graft (Figure 36–4, Boxes 36–7 and 36–8).20

Postoperative Management

- The elbow is splinted at 40 degrees flexion for 10 to 14 days. Active motion in a hinged elbow brace with a 20-degree extension stop is performed for 4 more weeks. The elbow brace can be unlocked at 6 weeks. Light activity should be resumed at 3 months. Full restoration of activity is expected at 1 year.
Patterns of Instability

Posterolateral Instability

- Chronic subluxation or dislocation of the radial head in a posterolateral direction has been associated with attenuation of the posterior lateral corner of the lateral collateral ligament. O’Drcoll referred to the posterior region of the lateral collateral ligament complex as the lateral ulnar collateral ligament (LUCL). The significance of the LUCL is reflected in its role in securing the ulna to the humerus and preventing posterolateral rotatory instability. They documented the kinematics of elbow subluxation and dislocation in which the forearm rotates away from the humerus in valgus and external rotation during flexion from the extended position. Despite an intact MCL, the radial head can rotate away from the capitellum, and the ulna essentially “pivots” on the MCL and rotates off the lateral trochlea (Boxes 36–9 and 36–10).

Imaging

- Confirming a chronic tear of the lateral ulnar collateral ligament with MRI can be difficult, but it may demonstrate thinning.

Treatment of Posterolateral Instability

- Treatment of acute posterolateral rotatory instability may require repair or reconstruction of the radial head so that the intact ligament has an osseous structure to support.
- The ligament may be disrupted either at its origin or (rarely) at its insertion.
- Acute injuries may be treated with immediate repair of the ligament back to bone.

Box 36–8 Authors’ Preferred Technique for MCL Reconstruction

- The procedure is performed with the patient in supine position under tourniquet control. Prior to starting the procedure, I prefer to document insufficiency with fluoroscopic images performed with the elbow flexed to approximately 45 degrees compared to the contralateral side. After documentation of insufficiency, I make a longitudinal incision slightly posterior to the medial epicondyle in line with the ulnar nerve. The ulnar nerve is identified proximally and dissected from proximal to distal, with release of the arcade of Struthers, excision of the intermuscular septum and release of Osborne’s fascia. Once the nerve has been decompressed, a muscle-splitting approach is used and the flexor pronator muscle mass is gently retracted. The origin of the MCL on the epicondyle is identified. The ligament is isolated. The insertion on the olecranon is identified through the muscle-splitting approach and retractors are placed. At this point, the anterior bundle of the MCL can be identified. There usually is an elliptical region of insufficient tissue in this area that may or may not be frankly disrupted but permits significant gaping of the humeral ulnar articulation with valgus stress. If there is a frank tear, it may be incorporated into the approach. If there is no tear, then a longitudinal incision is made in the MCL in line with its fibers through the most attenuated portion of the ligament. Again, tension is placed on the origin of the MCL at the inner two thirds of the epicondyle. A drill bit (3.2-mm in females, 4.5-mm in males) is used to create divergent drill holes in the medial epicondyle. A single hole is used to create one tunnel going cephalad and one tunnel going medial. The tunnels are connected again using the drill.
- Convergent drill holes are created in the ulna at the level of the tubercle on the medial aspect of the coronoid process. The sublime tubercle can be palpated; it usually is the hardest bone on the medial aspect of the coronoid. Care should be taken to avoid penetrating the articular surface.
- At this point, the palmaris graft is harvested from the ipsilateral upper extremity. If this is unavailable, either the contralateral palmaris or a toe extensor is used, harvested from a skin incision at the wrist crease and a separate incision at the muscular tendonous junction. The median nerve is often transposed. I prefer to make a Z-plasty in the flexor pronator fascia and suture the limbs loosely over the transposed nerve.
- The remaining limbs of the MCL can be used to reinforce the graft with a 3-0 Vicryl suture.
- The ulnar nerve is often transposed. I prefer to make a Z-plasty in the flexor pronator fascia and suture the limbs loosely over the transposed nerve.
- In patients with no evidence of preoperative ulnar nerve palsy, the nerve can be left in situ. A formal transposition is not performed.
- Postoperatively, the patient is placed in a long arm splint with the elbow flexed 90 degrees and the forearm in neutral rotation. At 10 days to 2 weeks, range of motion of the shoulder, wrist, and elbow in neutral forearm rotation is performed. Supination is started at 4 weeks, and strengthening is added at 6 weeks.

Box 36–9 Presentation and Diagnosis of Posterolateral Rotatory Instability

- Diagnosis can be made historically based upon presentation of painful, recurrent clicking, snapping, or locking of elbow with pain located posterior to the proximal radio-ulnar joint as the elbow moves into supination and extension.
- Lateral pivot-shift test: Radial head is subluxed with a combination of full supination, axial compression, and valgus load as the elbow is placed in 40 degrees flexion. Because of patient apprehension and pain, this test is best done under anesthesia.
Dislocations

Instability Associated with Fracture-Dislocations

- Successful restoration of elbow stability following fracture-dislocation is dependent on the following factors:
- Restoration of the anatomy of the ulna, including the coronoid
- Chronic injuries require reconstruction of the ligament using a free tendon graft.
- In a cadaveric study, reconstruction of the LUCL restored elbow stability to that of the intact state (Box 36–11).

Box 36–10 Which Ligamentous Structures Are Responsible for Stability?

- Cohen and Hastings10 and Imatani et al.24 documented that the LUCL itself is a relatively slender structure and may not contribute significantly to stability. Subsequent sequential sectioning studies documented that both the ulnar bundle of the LUCL and either the anterior bundle or the annular ligament must be disrupted in order to result in reproducible subluxation of the ulnar humeral joint.25 It appears critical for the radial head to have a posterior lateral sling, which allows rotation of the radial head without permitting it to sublux away from the distal humerus.

- Restoration of the radial buttress, either by repair or by reconstruction of the radial head
- Direct or indirect repair of the medial and lateral ulnar collateral ligaments, either by direct repair to bone or by maintaining the elbow in the reduced position and allowing these ligaments to heal in an anatomic position.

Treatment

- In a retrospective series of 56 patients with fracture-dislocations of the elbow, 13 patients had a posterior dislocation of the elbow associated with both a fracture of the radial head and the coronoid process. Ten of the 13 elbows remained unstable following operative treatment, with early arthritis seen in all 10 patients. The authors found that recurrent instability was noted in type 2 and 3 coronoid fractures. In addition, 90% of the patients who had removal of a fractured radial head had an unsatisfactory outcome, whereas only one third of patients in whom the radial head was fixed had an unsatisfactory result.26
- The injury of a posterior dislocation of the elbow with associated fracture of the radial head and a greater than 50% fracture (type 2 or 3) of the coronoid process of the elbow has been referred to as a terrible triad. Based on these results, the surgeons recommend the following27:

Box 36–11 Authors’ Preferred Technique: Lateral Collateral Ligament Reconstruction

- Under general anesthesia, a posterior lateral rotatory instability assessment is performed with the patient supine. The elbow is supinated, and a valgus load is applied. The elbow subluxates in full extension and then reduces as the elbow is brought back into flexion. This situation can be confirmed with simultaneous fluoroscopy, which demonstrates that the radial head subluxates off the capitellum. We prefer that with additional stress and valgus load, the ulnohumeral articulation also truly dislocate.
- Reconstruction is performed under tourniquet control. The preferred graft is the palmaris longus from the ipsilateral upper extremity; however, if none is available, a toe extensor can be taken.
- A 10-cm Kocher incision is made over the extensor carpi ulnaris–anconeus interval. The common wrist extensors are peeled off the humerus anteriorly, and the lateral epicondyle and supinator crest of the ulna are visualized.
- Typically, in acute trauma, this procedure reveals an avulsion of the majority of the soft tissue off the lateral epicondyle in one soft tissue sleeve. In chronic situations, the avulsion may have already healed back to the epicondyle and require dissection. Two connecting drill holes are made in the ulna. The most proximal drill hole is made on the supinator crest at the level of the middle-distal annular ligament insertion; the other is placed 10 to 12 mm distally.
- The most distal wall of the humeral tunnel should be at the 3:00 o’clock position on the lateral epicondyle. After placing the drill holes, it often is useful to place a suture through the drill holes in the same path that the graft will take and use this suture to determine the isometric point on the distal humerus. Although, based on cadaver studies there is no true isometric point for this ligament because of multiple bundles, there is an obvious point at which the graft must originate in order to prevent posterolateral subluxation with elbow extension. A graft that is placed too posteriorly on the lateral aspect of the humerus may permit too much posterolateral subluxation with elbow extension; therefore care must be taken to ensure that the graft is sufficiently anterior to prevent recurrent instability. After determining the isometric point, two additional converging holes are made in the distal humerus.
- The palmaris graft can be woven through the holes in the humerus and ulna and then pulled taut prior to being sutured to itself. While the graft is pulled taut, the elbow is brought down into supination and extension with a valgus stress. Make note that there is no further subluxation of the radial head posterolaterally. The graft is then tensioned and sutured with the forearm fully pronated and the elbow flexed 40 degrees.
- The graft can be sutured into position. If the graft appears to be insufficient, it can be augmented using a large (no. 2 or 5) Ethibond suture.
- Postoperatively, the patient is placed in a cast in full pronation for approximately 3 weeks. I then permit full range of motion, with the elbow maintained in neutral rotation and prevented from terminal extension for an additional 3 weeks. At 3 weeks, full range of motion from 0 to 150 degrees is permitted, with restoration of full supination with the elbow maintained at 90 degrees. Patients then can be started on gentle strengthening, with emphasis on avoiding simultaneous full supination and full extension.
1. Operative stabilization of type 2 and 3 coronoid fractures
2. Repair and reconstruction of the radial head with either stable internal fixation or an implant
3. Repair of the lateral ulnar-collateral ligament

- Even with operative treatment in a review of 11 patients at a minimum 2-year follow up, 3 of the 11 patients were considered failures. In the remaining 8 patients the results were rated as “excellent” in 2, “good” in 2, “fair” in 3, and “poor” in 1. Overall, the results were rated as unsatisfactory for 7 of 11 patients (Box 36–12).

Longitudinal Instability

Anatomy

- Longitudinal stability of the forearm is provided by three major anatomic constraints:
  1. Palmar and dorsal radioulnar ligaments
  2. Central band of the interosseous membrane (IOM)
  3. Radial head
- The individual contribution of the distal radioulnar joint (DRUJ) ligaments and the central band of the IOM remains somewhat controversial.
- The central band of ligamentous IOM tissue, approximately twice the thickness of the membrane on either side, is responsible for the majority of longitudinal stiffness of the IOM after radial head excision. This central band has properties similar to those of the patellar tendon. The ligament has a modulus of elasticity of 120% of the patellar tendon and an ultimate tensile strength of 84% of the patellar tendon.30
- Disruption of the longitudinal stiffness of the forearm permits shortening of the radius relative to the intact ulna. Resection of the radial head results in late proximal migration of the radius, which leads to distal ulnar impaction syndrome and DRUJ incongruity.
- When axial loading of the distal radius results in sufficient displacement of the radius relative to the ulna, disruption of the IOM and triangular fibrocartilage complex (TFCC) may occur. Resection of the fractured radial head alone without repair or reconstruction may result in DRUJ incongruity with ulnar impaction syndrome and pain (Essex-Lopresti fracture-dislocation).
- One author documented a fibrous tract from the distal dorsal corner of the sigmoid notch, which extends to the IOM of the forearm.31 These fibers may contribute to dorsal stability of the DRUJ and to longitudinal stability.
- Complications are more common and prognosis is worse for displaced fractures such as the Essex-Lopresti fracture-dislocation.

Imaging

- Results of late reconstruction of the IOM continue to be problematic. To avoid resection of the radial head in the face of IOM injury, several cadaveric studies examined the role of imaging modalities.
- MRI using axial T2-weighted fast-spin echo images with fat suppression in the middle third of the forearm may provide accurate information.32
- Dynamic ultrasound, which permits visualization of the IOM over the length from its radial and ulnar insertions, may be useful.33

Diagnosis

- MRI or ultrasound for diagnosis of IOM rupture?
- No statistically significant difference in accuracy between MRI and ultrasound has been observed.34
- Diagnosis can be made intraoperatively prior to replacing the radial head. Longitudinal traction on the radial neck can be combined with fluoroscopic evaluation of the DRUJ. If proximal migration greater than 6 mm occurs, gross longitudinal instability is present with disruption of both the IOM and the DRUJ ligaments. In this case, reconstruction or direct repair of the ligament may be indicated.35

Treatment

Acute

- If the IOM injury is recognized acutely, one article has documented the feasibility of a direct primary repair of the torn IOM through an open approach.36 In this article, successful repair of an acute IOM disruption with evidence of healing at follow-up was documented. This technique can be combined with repair or reconstruction of the radial head.

Chronic

- Following proximal migration, ulnar shortening osteotomy can be combined with reconstruction of the IOM and possibly TFCC.
- Reconstruction of the IOM can may performed with patellar tendon graft, allograft, or pronator teres rerouting.37
- Reconstruction of the radial head with either prostheses or allograft can be performed.31,38
- When forearm rotation is severely limited and pain relief is the primary operative indication, creation of a one-bone forearm has been performed. The results were rated as excellent and good in 37% and 32%, respectively.38
No comparative studies have been performed on reconstructive options, but poor outcome has been associated with infection, severe nerve injury, and multiple previous surgical procedures.

Other Causes of Mechanical Elbow Pain Treatable by Arthroscopy

- In a review of 414 cases of elbow arthroscopy, the most common final diagnoses were osteoarthritis in 150 cases, loose bodies in 112 cases, and rheumatoid disease in 75 cases. The most common procedures include synovectomy (134), debridement of joint surfaces (180), excision of osteophytes (164), diagnostic arthroscopy (154), and loose body removal (144).

Plicae

- Antuna and O’Driscoll described the snapping plica syndrome in which a band of tissue snaps over the radial head between 90 and 110 degrees elbow flexion and pronation.
- Subsequent snapping may mimic either loose body formation or instability in some cases.
- Subsequent histologic studies demonstrated that this tissue is highly vascularized and innervated.
- Treatment: Arthroscopic excision of this band of tissue relieves symptoms.

Osteoarthritis

- With the exception of throwing athletes, patients tend to be older men. Classic findings include osteophytes from the coronoid and olecranon, loose bodies, and bony hypertrophy of the distal humerus. A flexion contracture is a common finding secondary to posterior mechanical impingement. Bony changes produce mechanical symptoms.
- Retrospective reviews of the treatment of osteoarthritis of the elbow indicate that the degree of improvement is dependent upon intrinsic degenerative changes in the elbow. In a series of 70 patients, 73% benefitted in some way from arthroscopic procedures to the elbow. Overall, diagnostic arthroscopy was beneficial in 64% of elbows, whereas operative arthroscopy was of therapeutic value in 70% of elbows. However, the degree to which the procedure was deemed beneficial was in diagnosing discrete articular lesions or loose bodies.
- In another series of 22 patients treated arthroscopically for loose bodies and osteochondrotic lesions, 12 rated the results as good or excellent, four had slight improvement, and six were not satisfied. The patients who remained dissatisfied with the procedures were those in whom marked degenerative changes were encountered during arthroscopy.

Rheumatoid Arthritis

- Arthroscopic synovectomy appears to be an excellent option. In a series of 29 elbows with rheumatoid arthritis followed for a minimum of 42 months, short-term results appear to be good, with clinical recurrence of synovitis in five of 21 elbows. Overall, only patients with early or moderate (Larsen grade I or II arthritis) appeared to have favorable long-term results (Box 36–13).

Osteochondritis Dissecans

- Presentation: The condition is most commonly seen in patients between 10 and 17 years old. The patients usually participate in sport activities in which the elbow functions as a weight-bearing joint.
- Diagnosis: Symptoms are pain with activity, dull aching at rest, catching, and locking. Swelling, tenderness over the

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal conditions</td>
</tr>
<tr>
<td>I</td>
<td>Abnormalities not related to arthritis, such as marginal bone deposition, may be present</td>
</tr>
<tr>
<td>II</td>
<td>Slight abnormality</td>
</tr>
<tr>
<td>III</td>
<td>Periarticular soft tissue swelling, or osteoporosis and slight joint space narrowing</td>
</tr>
<tr>
<td>IV</td>
<td>Definite early abnormality</td>
</tr>
<tr>
<td>V</td>
<td>Erosion and joint space narrowing corresponding to the standards</td>
</tr>
<tr>
<td>VI</td>
<td>Medium destructive abnormality</td>
</tr>
<tr>
<td>VII</td>
<td>Erosion and joint space narrowing corresponding to the standards</td>
</tr>
<tr>
<td>VIII</td>
<td>Severe destructive abnormality</td>
</tr>
<tr>
<td>IX</td>
<td>Erosion and joint space narrowing corresponding to the standards</td>
</tr>
<tr>
<td>X</td>
<td>Mutilating abnormality</td>
</tr>
<tr>
<td>XI</td>
<td>Original articular surfaces have disappeared</td>
</tr>
<tr>
<td>XII</td>
<td>Dislocation and bony ankylosis, which are late and secondary, should not be considered in the grading; if present, the grading should be made according to the concomitant bone destruction or deformation</td>
</tr>
</tbody>
</table>

Larsen Classification

- Grade 0: Normal conditions
- Grade I: Abnormalities not related to arthritis, such as marginal bone deposition, may be present
- Grade II: Slight abnormality
- Grade III: Periarticular soft tissue swelling, or osteoporosis and slight joint space narrowing
- Grade IV: Definite early abnormality
- Grade V: Erosion and joint space narrowing corresponding to the standards
- Grade VI: Medium destructive abnormality
- Grade VII: Erosion and joint space narrowing corresponding to the standards
- Grade VIII: Severe destructive abnormality
- Grade IX: Erosion and joint space narrowing corresponding to the standards
- Grade X: Mutilating abnormality
- Grade XI: Original articular surfaces have disappeared
- Grade XII: Dislocation and bony ankylosis, which are late and secondary, should not be considered in the grading; if present, the grading should be made according to the concomitant bone destruction or deformation
radiocapitellar joint, and limitations in elbow motion (flexion-extension) usually are the objective findings.

- **Treatment:** Arthroscopic management of osteochondritis dissecans of the humeral capitellum has been successful.
- The goal of surgery is resection of the osteochondritic lesion and removal of loose bodies with limited synovectomy.
- Success rates at 2- to 5-year follow-up are approximately 90%.45–48
- The more advanced the lesion and the older the patient, the worse the result.
- **Postoperative management:** A postoperative course of continuous passive motion and early active range of motion using a bivalve extension cast helps prevent flexion contraction.

**Arthrofibrosis**

- **Presentation and diagnosis:** The resulting loss of motion may cause significant morbidity. Flexion contracture, that is, loss of elbow extension, can have several causes, such as fractures, dislocations, osteoarthritis, burns, or increased spasticity.
- **Treatment:** When arthrofibrosis is associated with lesions of the radial head and capitellum, debridement may yield excellent results. However, when degenerative changes are noted in the trochlea or olecranon, patients appear to have a more protracted recovery, according to the degree of articular cartilage degeneration.
- **Arthroscopic capsulectomy** is a procedure that requires the highest level of experience. Among nonexperienced surgeons, the risk of causing injury to a major nerve is very high. However, capsular release does not appear to be as effective as capsulectomy or capsulotomy (Box 36–14).49–51
- **Postoperative management:** Passive motion is started in the recovery room. Active therapy should be initiated the day after surgery. The goal is to achieve full active motion. Splinting can be used at night for at least 3 weeks after surgery.

**Lateral Epicondylitis**

- **Presentation and diagnosis:** Presents as pain on the lateral epicondyle or 1 to 2 cm forward of it on the tendon. It usually is worse with strong gripping with the elbow in an extended position. It usually is seen in tennis players, but this disease can occur in those who participate in golf and other sports or after repetitive use of tools.
- **Treatment:** Before surgery is considered, a trial of appropriate non-operative management is indicated, with a maximum of three cortisone injections in 1 year.
- **Arthroscopic management of lateral epicondylitis** may have some clinical utility. The degenerative changes in the common extensor origin are debrided from inside the joint from the anterolateral portal and the cortex may be abraded. Tendon repair is not performed.54
- In one series of 42 releases with follow-up of 2.8 years, patients demonstrated a high satisfaction rate and returned to work at an average of 2.2 weeks.54

---

**Box 36–14 Pearls and Pitfalls**

- **Pitfall:** Possibility of iatrogenic radial nerve injury is a concern during arthroscopic anterior capsule release.
- In a stiff elbow, capsular tissue expansion capacity is approximately 6 to 7 mm compared to a normal of 14 mm. Consequently, the safe zone is decreased, and tethering of the radial nerve and direct injury from shaving may result.52

**Figure 36–5:** Characteristic osteophyte on olecranon process in a baseball player with chronic medial collateral insufficiency.
• Arthroscopic evaluation also allows identification of intraarticular pathology, which has been noted in approximately 20% of cases, including synovitis, osteophytes, plicae, and loose bodies.55
• Arthroscopy allows adequate debridement of the common extensor origin without instability, provided care is taken to avoid resection posterior to the midaxis of the radial head. Arthroscopy also facilitates identification of intraarticular pathology.55
• Postoperative management: Some patients are relatively pain-free with simple movements at the initial follow-up visit. Resistance exercises usually are not permitted for 3 to 4 weeks after surgery. Unrestricted use of the elbow usually is allowed at 12 weeks.

References

   Discussion of elbow dislocations with a fracture of the coronoid process and radial head.
   Discusses use of the fixator in the management of recurrent complex elbow instability after failure of conventional treatment.
   Discusses the anatomy of the lateral and medial collateral ligaments based on 10 cadaveric dissections.
   This study defines the anterior band as the primary constraint to valgus forces.
   The anterior medial collateral ligament originates exclusively from the anteroinferior surface of medial epicondyle, and only 20% of the width of the medial epicondyle in the coronal plane can be removed without violating a portion of its origin.
   This study demonstrates that both single- and double-strand lateral ulnar collateral ligament reconstructions restore varus and posterolateral elbow stability.
   Classification of the spectrum of elbow instability, from subluxation to dislocation, is presented.

This study defines the MCL as the primary constraint of the elbow joint to valgus stress and the radial head as a secondary constraint. Communitied radial head fracture uncomplicated by MCL insufficiency can be treated by excision without replacement.

   Elbows with a fracture involving more than 50% of the coronoid process displace more readily than elbows with a fracture involving 50% or less.
    Forty fresh cadavers were studied to define the ligamentous anatomy of the lateral aspect of the elbow as it relates to rotatory instability.

    The flexor carpi ulnaris and the flexor digitorum superficialis muscles are the muscles best positioned to support the MCL.
    This study suggests that the muscles on the medial side of the elbow cannot supplant the role of the medial collateral ligament during the fastball pitch.
    This retrospective review found that professional football players with medial collateral ligament injuries and valgus instability were able to function without operative reconstruction, and no evidence of valgus instability remained at average 3.4-year follow-up. This is in contrast to baseball players, in whom the mechanics and demands may differ.
    The authors found that the entire anterior bundle must be sectioned before measurable and reproducible arthroscopic evidence of valgus instability is seen.
    This study indicates that valgus instability should be evaluated at 70 to 90 degrees of flexion. Detection of partial ruptures in the anterior bundle of the medial collateral ligament based on medial joint opening and increased valgus movement is impossible.
    Reconstruction of the ulnar collateral ligament was effective in correcting valgus elbow instability and allowed most athletes to return to sport in less than 1 year.


20. Conway JE, Jobe FW, Glousman RE, Pink M: Medial instability of the elbow in throwing athletes. Treatment by repair or reconstruction of the ulnar collateral ligament. *J Bone Joint Surg* 74A:67-83, 1992. Good or excellent results are reported in 10 of 14 patients following MCL repair (seven returned to sport) and in 45 of 56 (80%) following reconstruction; 38 (68%) returned to sport. Follow-up averaged 6.3 years.


24. Imatani J, Ogura T, Morito Y et al: Anatomic and histologic studies of lateral collateral ligament complex of the elbow joint. *J Shoulder Elbow Surg* 8:625-627, 1999. This cadaveric study suggests that the lateral ulnar collateral ligament contributes to posterolateral rotatory stability as part of the lateral collateral ligament complex but is not the major constraint.


37. Ruch DS, Chang DS, Koman LA: Reconstruction of longitudinal stability of the forearm after disruption of interosseous
Technique for reconstruction of the central band of the interosseous membrane in conjunction with surgical repair of the DRUJ and radial head prosthesis is presented.
45. Jackson DW, Silvino N, Reiman P: Osteochondritis in the female gymnast’s elbow. Arthroscopy 5:129-136, 1989. Once bony changes are detected from capitellar osteochondritis dissecans in high-performance teenage female gymnasts, symptoms may be improved by surgery, but persistent pain makes return to high-level competitive gymnastics unlikely.
47. Ruch DS, Cory JW, Poehling GG: The arthroscopic management of osteochondritis dissecans of the adolescent elbow. Arthroscopy 14:797-803, 1998. Reports that 11 of 12 pediatric patients were highly satisfied following arthroscopic debridement for capitellar avascular necrosis at a mean 3.2 years of follow-up.
Fractures of the Elbow

Ajay K. Seth* and Mark E. Baratz†

Introduction

- Elbow fractures can be subdivided into distal humerus fractures, radial head fractures, and olecranon fractures.
- Types of elbow fractures depend primarily on the position of the elbow and the axis of the force from the trauma.

Distal Humerus Fractures

- Treatment depends on anatomic reduction of fracture fragments, rigid fixation, preservation of the soft tissue envelope, and early motion.

Anatomy

- The distal humerus consists of two columns: medial and lateral (Figure 37–1).
- The medial column consists of the medial flare of the metaphysis, the medial epicondyle, and the medial condyle including the trochlea.
- The lateral column consists of the lateral metaphyseal flare, the lateral epicondyle, and the lateral condyle including the capitellum.
- Between the two columns is the coronoid fossa anteriorly and the olecranon fossa posteriorly.

Mechanism of Injury

- Supracondylar fractures generally result from a fall from a standing height.
- Intraarticular fractures result from high-energy injuries in young individuals and lower-energy injuries to osteopenic bone in elderly individuals.

Evaluation

- Assess the elbow for skin lacerations, nerve function, and pulses in the upper extremity. Note the potential for ulnar nerve compromise in T-condylar distal humerus fractures and radial nerve and anterior interosseous nerve palsy in pediatric supracondylar fractures.
- Anterior interosseous nerve palsy causes deficit in the flexor pollicis longus, the flexor digitorum profundus to the index finger, and the pronator quadratus.
- Radial nerve palsy presents with deficits in extension of the wrist, thumb and fingers.
- Check the arm, forearm, and hand for compartment syndrome. Signs of compartment syndrome are
  - Pain with passive range of motion
  - Pain out of proportion to the injury
  - Paresthesias
  - Poikilothermia (cooleness of extremity)
  - Loss of pulse (often the last sign)
- Examine the shoulder and wrist for associated injuries.
- Radiographic examination should include anteroposterior (AP) and lateral radiographs of the elbow. (Radiographs should also include the shoulder and wrist.)
- Oblique views should be ordered to diagnose subtle fractures. For example, the radial head oblique view is
shot 30 degrees cephalad to a true lateral view to diagnose occult radial head fractures.

- Radiographs should be inspected for dislocations, positive posterior or anterior fat pad signs, fractures, and subluxations.
- Computed tomography (CT) can be used for finer bony detail of intraarticular fractures.

**Classification**

- Divided into supracondylar, transcondylar, and intercondylar fractures.
  - Supracondylar fracture: above the olecranon fossa
  - Transcondylar fracture: through the olecranon fossa
  - Intercondylar fracture: between the condyles of the distal humerus
- AO classification (Figure 37–2) divides fractures into
  - Type A: extraarticular
  - Type B: extension into the articular surface
  - Type C: complete separation of the articular surface from the shaft
  - Numerical attachments are used, depending on the degree of comminution (1–3, with 3 being highly comminuted)
- Intercondylar fractures divided by the Riseborough and Radin types (all types include a supracondylar component)
  - Type I: nondisplaced fracture between the capitellum and trochlea
  - Type II: displaced, nonrotated fracture between the condyles
  - Type III: displaced and rotated fracture between the condyles
  - Type IV: severe comminution of the articular surface of one or both condyles (Figure 37–3)

**Treatment**

**Nonoperative**

- Limited role for nonoperative treatment of distal humerus fractures.
- Goal of treatment is early motion to prevent stiffness.
- Elderly patients with multiple medical problems can be treated with the “bag of bones” method: splint in 60 degrees flexion for 2 to 3 weeks, followed by gentle motion.
Operative

- Goals of treatment are a pain-free joint with functional motion (30 degrees extension, 130 degrees flexion, 50 degrees supination and pronation).
- Stable fixation allows elbow motion as soon as the skin is sealed.
- Plate fixation consists of double plating the distal humerus: medial and posterolateral, or medial and lateral.

Surgical Procedure

- Patient placed in the lateral decubitus position with the affected arm over a padded post.
- Identify and mobilize the ulnar nerve.
- Extensile posterior approach: olecranon osteotomy or triceps retraction
- Olecranon osteotomy: excellent exposure, particularly when the articular surface is comminuted. However, nonunions may occur at the osteotomy site. Note nonunion rates are decreased with use of a chevron osteotomy and secure tension band wiring or plate fixation.
- Retraction of the triceps can be used when there are three major fragments and no articular comminution.
- The view of the trochlea can be improved by removing approximately 1 cm of the tip of the olecranon process.
- Studies have shown that plates can be aligned in orthogonal planes or parallel. Allow the fracture pattern to dictate the placement of plates.
- The articular surface is assembled and then attached to the shaft.
- Provisional fixation with pins can be used first, then a 3.5-mm DC plate can be contoured to the posterior surface of the lateral column and a 3.5-mm reconstruction plate contoured to fit the medial column (new precontoured plates may simplify this process) (Figure 37–6).
- Take care not to compress the articular segment from medial to lateral, by using a fully threaded, cortical screw.
- Metaphyseal–diaphyseal contact is important to avoid nonunions.
- Use a structural graft. Use corticocancellous iliac crest graft when there is a break in cortical continuity of the triangle: medial column, joint surface, lateral column. Use cancellous graft when the triangle is intact and there is loss of metaphyseal bone.
- Key points to remember in fixation:
  - Place as many screws as possible into the distal fragments.
  - Screws from the medial and lateral plates should be placed into as many comminuted fragments as possible.
  - Plates can be placed on the medial and lateral surfaces.

Figure 37–4:
Type 1 capitellar fracture.

Figure 37–5:
Classification of capitellar fracture.
Alternative Treatment: Total Elbow Arthroplasty

- Considered for patients with severe comminution and osteoporosis.
- In low-demand patients, total elbow arthroplasty (TEA) can restore motion and hand function.
- Technique similar to TEA for degenerative conditions.
  1. Long-stemmed components should be available in case of proximal fracture extension.
  2. Operative Pearls:
     - Use a posterior approach. Similar steps taken to open reduction internal fixation (ORIF) humerus.
     - Transpose the ulnar nerve anteriorly.
     - Work on both sides of the triceps to remove condylar pieces. (Key: Do not take down/off the triceps from the olecranon during approach.)
     - You can remove the entire distal humerus to the olecranon fossa without a problem because it is replaced by the prosthesis. Removal of an additional 1 to 2 cm does not lead to any significant sequelae.
     - After removing the condyles, use the triceps muscle to gauge proper tension of the humeral prosthesis.
     - Remove the proximal tip of the olecranon to allow better access for implanting the ulnar component (Figure 37–7).

Postoperative Care

- The elbow is immobilized in a posterior splint for 3 to 5 days.
- The splint is removed, and the patient is started on active-assisted motion as long as the skin is sealed. Wait longer after a TEA to ensure the skin has healed. (May leave elbow in an extension splint for 2 weeks to help obtain better extension.
- A removable splint is fashioned to protect the limb while allowing frequent removal for range of motion exercises.
- Active motion is started when healing is eminent, usually at 6 to 8 weeks.
- Passive stretch is started when the fracture is fully healed.

Articular Shear Fractures of the Distal Humerus

- Fractures of the capitellum and trochlea often result from shear forces.
- Oblique views or CT scans may be needed to identify fracture fragments.
Nondisplaced fracture fragments are treated with a brief period of immobilization.
X-ray films of the fracture are needed weekly for 2 to 3 weeks to check the maintenance of reduction.

Displaced Fractures
- Type I: capitellar fractures
  - Treat with ORIF
  - Lateral approach allows best access to the fracture fragment.
  - Headless compression screws are placed anterior to posterior.
  - Short threaded malleolar screws are placed posterior to anterior (Figure 37–8).
- Types II and III
  - Fixation is difficult.
  - Best to perform excision of the fracture fragments.
  - Check valgus stability to rule out associated medial collateral ligament injury.
  - Begin early motion.
- An isolated displaced trochlea fracture is addressed with ORIF
  - An olecranon osteotomy or extended lateral approach is required to inspect and reduce articular fragments.10

Complications of Distal Humerus Fractures
- Complications of distal humerus fractures include loss of motion, nonunion, malunion, heterotopic ossification, infection, nerve injury, extensor tendon dysfunction, and symptomatic hardware.

Fractures of the Radial Head
- Result from axial load applied through a flexed elbow.
- Radial head fractures that occur with elbow dislocation often have associated disruptions of the medial and lateral collateral ligaments, anterior joint capsule, and coronoid process.
- High-energy axial load to the forearm can lead to an Essex-Lopresti lesion, which consists of:
  - A comminuted fracture of the radial head
  - Rupture of the interosseous membrane
  - Injury to the triangular fibrocartilage complex (TFCC)

Classification of Radial Head Fractures
- Hotchkiss modification of Mason-Johnston:
  - Type I: nondisplaced or minimally displaced fracture of the head or neck; no block to pronation or supination
  - Type II: displaced (>2 mm) fractures of the head or neck; may have incongruity at the neck or fracture site causing a block to motion
  - Type III: comminuted fracture (Figure 37–9)
Evaluation

- Appropriate treatment of radial head fractures is guided by the following four factors:
  1. Forearm rotation
  2. Elbow stability
  3. Wrist pain
  4. Imaging

- The patient with a suspected fracture has tenderness over the radial head and an elbow effusion.
- May have limited forearm pronation or supination.
- The limitations in rotation should improve with aspiration of the elbow and injection of anesthetic.
- The limitation may improve with 1 week of rest and gentle immobilization.
- A block to forearm rotation is an indication for operative intervention.
- T enderness over the medial collateral ligament with elbow laxity during a valgus stress confirms associated elbow instability.
- Wrist pain and tenderness in the region of the distal radioulnar joint may indicate a concurrent rupture of the TFCC and interosseous membrane.

Radiographs

- AP and lateral projections of the elbow.
- Oblique projection: 30 degrees anterior to a true lateral; may help identify impacted fractures.
- Wrist radiographs of both the injured and uninjured arms should be obtained when a patient has a radial head fracture and wrist pain suggesting the possibility of an Essex-Lopresti lesion.

Treatment

- The most common problem is elbow stiffness.
- The goal should be to design a treatment option that permits early motion.

Type I

- Rarely associated with injury to the elbow’s collateral ligaments or interosseous membrane.
- If the elbow is stable and the wrist is not tender, place in a sling for comfort and have the patient work on elbow motion and forearm rotation.

Type II

- May be associated with an elbow dislocation and have associated medial or lateral collateral ligament injuries.
- The marginal fracture of the radial head may create a block to forearm rotation.
- The medial fracture fragment may impinge on the sigmoid notch of the proximal ulna, limiting rotation. This is best visualized on an oblique radiograph.
- Operative treatment is highly successful for type II fractures. If a block to motion exists, surgical intervention is the treatment of choice.
- A lateral approach to the elbow is used.
- Large fragments of the radial head are treated with ORIF.
- The safe zone for screw placement is formed by a 110-degree arc from a line perpendicular to the radial styloid and one perpendicular to Lister’s tubercle. The safe zone is centered laterally with the forearm in neutral rotation, and extends 65 degrees anteriorly and 45 degrees posteriorly. This is the portion of the radial head that does not articulate with the proximal radioulnar joint.
- Fixation is accomplished with headless screws, lag screws, or plates.

Type III

- Highly comminuted fractures reflect a high-energy injury with the possibility of associated damage to the collateral ligaments, coronoid process, and interosseous membrane.
- During the lateral approach, care must be taken to inspect for injury to the lateral complex.
- If the ligament complex has been stripped from the lateral epicondyle, it should be repaired using sutures passed through bone tunnels at the completion of surgery. (Suture anchors are often not adequate for this repair.)
- Three or fewer head fragments may allow an internal fixation to be performed.\(^9,10\)
- More than three fragments may necessitate either radial head replacement or excision of the radial head.\(^10-12\)
- If the radial head cannot be repaired, the surgeon must assess the status of the:
  - Medial collateral ligament with valgus stress testing using intraoperative imaging
  - Integrity of the interosseous membrane with the “pull test”
    - A posteroanterior image of the wrist is obtained before and after applying traction to the fractured end of the proximal radius.
    - Translation of 6 mm or more suggests disruption of the interosseous membrane and the TFCC.
- If there is no valgus laxity or longitudinal instability (distal migration of the radius), the radial head can be excised, which is the exception. However, if there is any other ligamentous or osseous injury to the elbow, a radial head prosthesis should be used.
- The remaining metaphyseal bone should be trimmed distal to the sigmoid notch to avoid neck-notch impingement.
- If there is evidence of valgus or axial laxity, then a metallic radial head prosthesis is inserted.
- The head diameter is estimated by assembling the fractured head fragments.
• Images should be obtained intraoperatively to evaluate for (Figure 37–10):
  ● Match of the radial head with the capitellum
  ● Match of the radial head with the sigmoid notch
  ● Alignment of the prosthesis in the shaft
  ● The medial joint space
  ● If the elbow remains stable at 30 degrees of flexion, the wounds are closed.
  ● If the elbow dislocates at 30 degrees, consideration is given to repairing the medial collateral ligament through a separate incision.

Postoperative Care
• Patients are placed in a posterior splint for approximately 5 days to allow the swelling to subside and the incision to heal.
• Patients then begin active-assisted motion.

Olecranon Fractures
• Fractures result from a direct blow to the dorsal surface of the proximal ulna.
• The humeral articular surface often functions as a wedge to fracture the proximal ulna.

Evaluation
• Evaluate the soft tissues for disruption, including the presence of an open fracture.
• Nerve dysfunction and vascular status must be evaluated (particularly the ulnar nerve).
• Palpate and check range of motion of the shoulder and wrist to identify any associated injuries.
• AP and lateral x-ray films should be obtained. The lateral radiograph of the elbow helps determine fracture displacement, comminution, and joint congruity.

• Oblique views of the AP projection help assess medial and lateral wall reduction and comminution.
• CT can help define the size and location of articular fragments.

Classification
• Fractures are divided into three types using the Mayo classification system (Figure 37–11):
  ● Type I: nondisplaced fractures
  ● Type II: displaced fractures but the elbow is stable
  ● Type III: fractures are displaced and the elbow is unstable (either from rupture of the medial collateral ligament or fracture comminution that extends to and disrupts the insertion of the medial collateral ligament) (Figure 37–12)

Figure 37–10:
Intraoperative image of a radial head implant performed for a type III fracture of the radial head.

Figure 37–11:
Mayo classification for olecranon fractures.
Treatment

- Management depends on displacement, comminution, and elbow stability.

Nondisplaced Fractures
- Nondisplaced fractures can be immobilized in a long arm cast or splint in 30 degrees of flexion.
- Repeat radiographs are obtained in 1 week to evaluate fracture displacement.
- Immobilization is discontinued within 2 weeks, and active motion without resistance is initiated (use a similar protocol for comminuted fractures in elderly, debilitated patients).

Displaced Fractures
- Displaced fractures are treated according to fracture pattern.
- The patient is placed in the lateral decubitus position.
- Use a posterior approach with the incision curving medial to the olecranon.
- Options for treatment include tension band wiring, plate fixation, and primary excision.

Tension Band Wiring
- Recommended for transverse fractures with minimal comminution.
- A large bone tenaculum is used to help reduce and compress the fracture fragments.
- Two 0.062-inch Kirschner wires are inserted into the tip of the olecranon and advanced across the fracture and into the anterior cortex of the ulna. (We do not use screws, because they are not as forgiving when trying to compress the fracture with a tension band wire.)
- Using an angiocatheter placed anterior to the triceps tendon, an 18-gauge wire is passed so that it rests on the olecranon. The angiocatheter is placed from medial to lateral to avoid injuring the ulnar nerve.
- A 2.0-mm drill hole is created in the posterior cortex approximately 2 cm distal to the fracture site.
- The wire is passed through the tunnel to create a figure-eight pattern. The wire is pulled and twisted taut.
- The pins are bent and cut at 180 degrees and impacted into the olecranon tip.
- Check to ensure that full motion has been preserved (Figure 37–13).

Plate Fixation
- Plate fixation is indicated in comminuted fractures, fractures distal to the coronoid process, oblique fractures distal to the midpoint of the trochlear notch, and Monteggia fracture-dislocations of the elbow.
- Plates can be placed posteriorly or medially. There is no difference except that the posterior position minimizes malreduction in the sagittal plane (Figure 37–14).
- Can use a posterior plate to help with fracture reduction. Place screws peripherally to allow placement of an intramedullary screw.
- Severely comminuted fractures often require dual plating to achieve stability.

Resection of the Proximal Fragment
- Option for managing severely comminuted olecranon fractures.
- Often used for elderly patients in whom the fracture fragments constitute less than 70% of the articular surface and are too comminuted for fixation.
- Extent of the resection is dictated by the insertion of the medial collateral ligament.
- The triceps tendon is reattached using nonabsorbable suture passed through drill holes toward the proximal edge of the articular surface. This method creates a sling.

Figure 37–12: Displaced olecranon fracture with instability.

Figure 37–13: Fracture treated with tension band wiring.
and a smooth surface for articulation with the distal humerus; however, it may decrease extensor strength secondary to a shortened triceps’s moment arm (Figure 37–15).

- The remaining olecranon should be cut transversely.

Postoperative Care for Resection or Plate Fixation

- The elbow is splinted in approximately 60 degrees of flexion.
- Reevaluate the patient in 5 to 7 days. If the skin is sealed, initiate active-assisted motion.
- Between exercises, the elbow is protected in a posterior splint.
- The splint is discontinued at 2 weeks and active motion is started.
- Passive and resisted exercises are started when the fracture has healed, usually around 8 weeks. If the fracture fragment was excised with triceps advancement, resistive exercises begin after week 12.

Complications

- Complications of tension band wire include loss of fixation, nonunion, skin breakdown, infection, and prominent hardware.
- Complications of plate fixation include metal prominence, loss of reduction, malreduction, and nonunion (<10%).

References

   A good or excellent result was obtained in 56% of patients, including all patients younger than 40 years but only two of 10 patients older than 50 years. Stiffness was seen more frequently in men, those immobilized for more than 3 weeks, and with the triceps-splitting approach.

   An excellent review of the technique of operative fixation of comminuted distal humerus fractures.

   Reported 93% satisfactory results in 23 patients at mean 45-month follow-up but significantly poorer results in those with high levels of articular comminution.

   DASH and SF-36 scores revealed minor but significant impairment consistent with the loss of motion and weakness noted in these patients.

This study evaluated 21 patients with capitellar or trochlear fractures fixed with implants buried beneath the articular cartilage. Motion averaged 96 degrees.


9. Ring D, Quintero J, Jupiter JB: Open reduction and internal fixation of fractures of the radial head. *J Bone Joint Surg Am* 84:1811-1815, 2002. Comminuted Mason type 3 fractures with more than three articular fragments have a high percentage of unsatisfactory results following ORIF whereas those split into two to three fragments have a better prognosis.

10. Caputo AE, Mazzocca AD, Santoro VM: The nonarticulating portion of the radial head: anatomic and clinical correlations for internal fixation. *J Hand Surg [Am]* 23:1082-1090, 1998. The nonarticulating portion of the radial head subnets an average arc of 113 degrees and is the “safe zone” for hardware placement. It can be localized as the arc between the radial styloid and Lister’s tubercle.


14. Karlsson MK, Hasserius R, Besjakov J, et al: Comparison of tension-band and figure-of-eight wiring techniques for treatment of olecranon fractures. *J Shoulder Elbow Surg* 11:377-382, 2002. No differences were found when the two techniques were compared, except for an 81% rate of hardware removal with tension band wiring compared to 43% with figure-of-eight wiring.


17. Gartsman GM, Sculco TP, Otis JC: Operative treatment of olecranon fracture. Excision or open reduction with internal fixation. *J Bone Joint Surg* 63:718-721, 1981. No difference was noted with regard to pain, functional range of motion, elbow stability, degenerative changes, or biomechanical testing. The open reduction group had 13 local complications, and the excision group had only two.
Elbow Arthritis

Steven H. Goldberg*, Mark S. Cohen†, and Leonid I. Katolik‡

Introduction

- Three primary patterns of arthritis affect the elbow: rheumatoid (inflammatory), posttraumatic, and primary osteoarthritis. Each occurs in different patient populations and with different presentations.
- The elbow has two main functions:
  1. Position the hand in space
  2. Stabilize the upper extremity for power and fine motor activities
- Clinical consequences of progressive arthritis (Box 38–1):
  - Pain that can result in further morbidity from disuse, exacerbating stiffness
  - Functional difficulty using the hand for activities of daily living. A 100-degree flexion/extension arc of motion from 30 to 130 degrees typically is quoted for normal activities. However, flexion is much more important than extension, as loss of extension can be compensated for by moving closer to an object.
  - Functional forearm rotation is quoted as 100 degrees, with 50 degrees pronation and 50 degrees supination. However, supination is more important than pronation, which can be compensated for by shoulder abduction.¹

Rheumatoid Arthritis (Figure 38–1)

- Most frequent type
- Majority of cases are bilateral
- Immunologically mediated inflammatory disorder of synovial joints
- Elbow arthritis affects 20% to 50% patients with rheumatoid disease
- Women are affected three times more commonly than men
- Prolonged inflammation and synovitis can lead to secondary changes
  - Fixed joint contracture
  - Ligamentous attenuation
    - Ulnar collateral ligament incompetence can lead to valgus ulnohumeral instability and ulnar nerve dysfunction
    - Lateral collateral ligament incompetence can lead to posterolateral rotatory instability

Box 38–1 Symptoms of Elbow Arthritis

- Pain with range of motion (flexion-extension or rotation)
- Stiffness with loss of flexion-extension and/or rotation
- Swelling or effusion, more common with inflammatory arthritis
- Neurologic symptoms or deficits, most commonly involving ulnar nerve
- Instability, more common with end-stage inflammatory arthritis
CHAPTER 38  Elbow Arthritis  533

Annular ligament incompetence can lead to radial head subluxation
Combined ligamentous injury with bone loss leads to greater instability
Cyst formation
Results from proliferation of synovium (pannus)
Predisposes to subarticular fracture
Can cause compression of the ulnar and/or radial nerves

Posttraumatic Arthritis
- The second most prevalent type of arthritis
- May affect any age group but more common in young and middle-aged individuals
- The elbow is one of the joints in the body most intolerant to trauma, with a high propensity for stiffness and arthritis following injury
- Prolonged immobilization following trauma may predispose to stiffness
- The primary complaint often is restricted motion

Primary Osteoarthritis
- Least common and represents only 1% to 2% of patients presenting with degenerative arthritis
- Most commonly seen in middle-aged and older patients
- Predilection for males
- More common in individuals exposed to repetitive manual labor
- Osteophyte formation at the tip of coronoid and the olecranon tip
- Radiocapitellar narrowing common and may be the “wear generator”
- Typically presents with pain at the end range of motion, mechanical block to flexion and extension, pain carrying an object with the arm in extension, often with mechanical symptoms of clicking and catching from loose bodies

Physical Examination
- It is important to perform a thorough evaluation of the cervical spine, shoulder, elbow, and wrist to determine if

Figure 38–1:
A, Anteroposterior radiograph of an elbow with rheumatoid arthritis. Note the symmetric ulnolhumeral and radiocapitellar complete loss of joint space, a large subchondral cyst in the lateral epicondyle, periarticular osteopenia, and absence of osteophytes. B, Lateral radiograph showing loss of ulnolhumeral and radiocapitellar joint spaces with intussusception of the distal humerus into the greater sigmoid notch of the ulna because of bone loss of the coronoid and greater sigmoid notch. Note the olecranon osteopenia, normal radial head-capitellar alignment, and absence of osteophytes.
the patient’s complaints are limited to the elbow or are more diffuse in nature. For example, isolated elbow involvement in rheumatoid arthritis is rare.\textsuperscript{3} Associated wrist (distal radioulnar joint) pathology can contribute to loss of forearm rotation and affect axial radial stability if radial head excision is being considered. Limited shoulder abduction can prevent the ability to compensate for loss of pronation.

- Inspect the elbow for evidence of prior incisions, ecchymosis, or gross deformity.
- Effusion can be best appreciated by palpation of a “soft spot” at the center of an equilateral triangle formed by the olecranon, radial head, and lateral epicondyle.
- Radial head identification is facilitated by palpation during forearm rotation.
- Synovial thickening can be palpated medially and laterally as a boggy fullness along the joint line.
- Test active and passive range of motion with a goniometer. Normal elbow motion is 0 to 140 degrees, with 0 degrees defined as full elbow extension. Pronation and supination are measured with the arm at the side at 90 degrees elbow flexion. Normal is approximately 75 degrees pronation and 85 degrees supination. Some rotation can take place through the wrist. Placement of pens in the hand can help measure rotation. All values must be compared to the normal, uninvolved side.
- Careful neurologic assessment of sensory (normal static two-point discrimination is 5 mm or less) and motor function of the radial, posterior interosseous, ulnar, median, and anterior interosseous nerves should be performed.
- Provocative testing can elicit symptoms of ulnar neuropathy (Tinel percussion along the ulnar nerve at the elbow, the elbow flexion test with simultaneous manual ulnar nerve compression), radial tunnel syndrome (manual pressure directly over the mobile wad to compress the posterior interosseous nerve), carpal tunnel syndrome (median nerve compression test, Tinel percussion over the median nerve in the volar palm, Phalen maneuver), and tests for medial collateral and lateral collateral instability.

### Radiographic Assessment

- Anteroposterior, lateral, and oblique radiographs should be obtained at the initial evaluation. When full extension is not possible, the beam should not be centered on the antecubital crease. For distal humerus pathology, the beam is centered perpendicular to the distal humerus. For proximal forearm pathology, the beam is centered perpendicular to the radial head. The lateral view should be shot in 90 degrees flexion with the forearm in neutral rotation. A medial oblique view improves visualization of the trochlea, olecranon fossa, and coronoid tip. A lateral oblique view provides visualization of the radiocapitellar joint, medial epicondyle, radioulnar joint, and coronoid tubercle.
- Common radiographic findings are given in Box 38–2.
- Rheumatoid arthritis has a specific radiographic classification system (Table 38–1 and see Figure 38–1).
- Ultrasound and magnetic resonance imaging typically are unnecessary in the diagnosis and treatment of elbow arthritis.
- Computed tomography occasionally is needed in preoperative planning.

### Box 38–2 Common Radiographic Findings

1. Soft tissue swelling
   - Can indicate inflammation and subcutaneous rheumatoid nodules.
2. Visualization of fat pad
   - Signifies an effusion causing the fat pad to lift away from the bone. An anterior fat pad can be normally seen, but the presence of a posterior fat pad is abnormal because it normally sits deep in olecranon fossa.
3. Osteophytes
   - Often present on the coronoid and olecranon (best seen on lateral views) or the radial head.
4. Loose bodies
   - Often best seen on lateral view. Opacification of the fossa above the trochlea on anteroposterior view can suggest bony overgrowth or loose bodies.
5. Joint line narrowing
   - Assess the ulnohumeral and radiocapitellar joints. Asymmetry or gapping at the medial ulnohumeral joint can suggest medial collateral ligament incompetence.
6. Radial head position
   - Ensure the center of the radial head lines up with the capitellum on all views. Disruption of this relationship indicates radial head subluxation or, more commonly, posterolateral joint subluxation.
7. Bone quality
   - Note the presence of periarticular osteopenia, which is more common in rheumatoid arthritis.
CHAPTER 38  Elbow Arthritis  535

Table 38–1: mayo Clinic Classification of Disease Severity

<table>
<thead>
<tr>
<th>GRADE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Periarticular osteopenia and soft tissue swelling associated with mild synovitis</td>
</tr>
<tr>
<td>II</td>
<td>Mild-to-moderate joint space narrowing without architectural distortion, usually associated with synovitis refractory to isolated NSAIDs</td>
</tr>
<tr>
<td>III</td>
<td>More advanced joint space narrowing with or without cyst formation, associated with architectural changes such as olecranon thinning or trochlear destruction. Synovitis may be present or burnt out</td>
</tr>
<tr>
<td>IV</td>
<td>Extensive articular damage with loss of subchondral bone and subluxation or ankylosis of joint</td>
</tr>
</tbody>
</table>

Nonsurgical Treatment (Box 38–3)

- Activity modification: Limit activities that exacerbate symptoms
- Nonsteroidal antiinflammatory drugs (NSAIDs)
  - Decrease synovial reactivity and alleviate pain and swelling in milder cases
  - Represents first-line treatment of all types of arthritis
- Immunosuppressive agents, such as gold salts, methotrexate, and antimalarial agents, are used for recalcitrant inflammatory arthritis. Serious side effects, including thrombocytopenia, hepatic or renal insufficiency, and pulmonary toxicity, complicate their use. Newer immunosuppressive agents, such as leflunomide and infliximab, are effective but may impair the patient’s ability to mount a response to infection.
- Oral and intraarticular corticosteroid injections can be effective for acute episodes of painful synovitis and “flares” about the elbow. Elbow arthrocentesis or injection should be performed through the lateral soft spot described in the physical examination section.

Surgical Treatment

- Indications: Failed response to appropriate nonsurgical management with functional limitations because of pain or loss of motion and patients who will be compliant with postoperative rehabilitation.
- The following surgical procedures represent a spectrum, from joint debridement and soft tissue release to elbow replacement (see Box 38–3).

Ulnohumeral Debridement

- Indications: Most commonly used for osteoarthritis and posttraumatic arthritis with soft tissue contracture, impingement in flexion and/or extension, and mechanical symptoms. A normal central ulnohumeral joint is required. The goal is to remove any soft tissue or bony constraints to flexion, extension, or rotation (Figures 38–2 and 38–3).

Open Technique

- Open options include either lateral and/or medial column approaches.
- Anesthesia with axillary block is preferred.
- Positioning supine with arm table.
- Midline posterior incision allows access to both medial and lateral arthrotenomies and exposure of ulnar nerve if transposition is necessary.
- Alternatively, medial and lateral approaches can be used.

Lateral Column Procedure (Lateral Collateral Ligament Complex Preserved)

- Can use midline posterior or lateral incision.
- Fasciocutaneous flaps are elevated.
- Starting proximally, the lateral supracondylar ridge is palpated.
The triceps and anconeus are elevated and reflected posteriorly, exposing the posterior ulnohumeral joint (see Figure 38–2, A).

Triceps tenolysis is performed, the olecranon fossa cleaned, and spurs and loose bodies removed (see Figure 38–2, B).

The anterior joint is exposed by first sliding along the lateral humeral supracondylar ridge above the epicondyle and splitting distally between the extensor carpi radialis longus (ECRL) muscle anteriorly and the remaining extensor origin covered by fascia posteriorly. The deep dissection is between the ECRL and the extensor carpi radialis brevis, which is tendinous and lies deep to the ECRL (see Figure 38–2, C).

The joint capsule is exposed by elevating the brachialis (blunt Metzenbaum scissors are helpful to avoid entering the joint prior to isolating the entire capsule).

The capsule is excised, the anterior coronoid and radial fossae cleaned, and spurs and loose bodies removed (see Figures 38–2, D and 38–3, A).

The Y-shaped split in the lateral fascia is repaired with no violation of the lateral ligament complex.

**Medial Column Approach (Medial Collateral Ligament Preserved)**

- Find and protect the medial anterbrachial cutaneous nerves.
Mobilize the ulnar nerve and free it proximally and distally.

Expose the medial intermuscular septum and origin of the flexor-pronator muscle mass.

The intermuscular septum is used to help reflect the triceps posteriorly.

The posterior ulnohumeral joint is debrided of soft tissue and any olecranon tip and fossa osteophytes are removed.

From the intramuscular septum, slide along the anterior humerus, reflecting the brachialis anteriorly. Distally, the flexor-pronator is split and elevated anteriorly, exposing the anterior joint capsule. The medial collateral ligament is protected beneath the posterior flexor-pronator muscle.

The brachialis is retracted anteriorly and the joint capsule excised.

Soft tissue is debrided from the coronoid and radial head fossae and osteophytes are removed.

Reattach the flexor-pronator tendinous origin.

The ulnar nerve is transposed anteriorly into a subcutaneous position.

Figure 38-3: Ulnohumeral debridement. Loss of motion can occur secondary to soft tissue contracture or bony impingement. A, Improved extension is obtained by anterior capsulectomy, brachialis tenolysis, removal of soft tissue and bony overgrowth in the olecranon fossa, and excision of olecranon tip osteophytes. B, Improved flexion is obtained by posterior capsular release, triceps tenolysis, removal of soft tissue and bony overgrowth within the coronoid and radial head fossae, and debridement of coronoid or radial head osteophytes.
Open Outcome

- Good to excellent pain relief up to 36 months after open procedures
- Range of motion averages 8 to 137 degrees after open release

Arthroscopic Technique

- Much more challenging
- Usually indicated in less severe contractures because risk of neural injury is increased secondary to decreased capsular volume
- Patient position can be:
  - Supine: requires overhead traction, which can limit elbow manipulation, or an assistant to hold the arm; has limited access to the posterior joint.
  - Prone: improved access to the posterior joint, easier to manipulate elbow, no traction needed.
  - Lateral decubitus: easier to position, improved airway access for anesthesia (Figure 38–4).
- Equipment:
  - 4-mm, 30-degree arthroscope (2.7-mm arthroscope may be needed in small contracted joints)
  - Coban to wrap hand and forearm to limit fluid extravasation and swelling
  - 18-gauge spinal needle to insufflate joint with 15 to 25 ml saline, cannulas with no side fenestrations to prevent soft tissue extravasation, mechanical shaver and radiofrequency ablation device for soft tissue debridement, power burr for bony debridement, retractors to improve visualization, switching sticks to facilitate changing portals
- Portals (Figure 38–5):
  - Scalpel used to incise through skin only, followed by blunt dissection with a hemostat to the capsule, then blunt trocars used to enter the joint
  - Proximal medial
    - 2 cm proximal to the medial epicondyle just anterior to the medial intermuscular septum; ulnar nerve located posterior to septum
    - Can visualize the entire anterior joint
    - Contraindication to this portal is prior anterior transposition of ulnar nerve
    - Posterior branch of the medial antebrachial cutaneous nerve is at highest risk for injury
  - Proximal lateral (proximal anterolateral)
    - 2 cm proximal and 1 cm anterior to the lateral epicondyle
    - Can visualize the entire anterior joint
    - Posterior branch of the lateral antebrachial cutaneous nerve is at highest risk for injury
  - Anterolateral
    - Several locations described
    - Preferred location is between the radial head and capitellum 1 cm anterior and 1 cm distal to the lateral epicondyle
    - Radial nerve at risk
  - Direct lateral
    - “Soft spot” at center of triangle formed by olecranon, lateral epicondyle, and radial head
    - Can visualize the inferior radial head, capitellum, and radioulnar joint
    - At the beginning of the procedure, insufflate the joint with saline through this portal and remove the needle. If this portal is needed for visualization or work, use it at the end of the procedure because of an increased incidence of fluid extravasation.
  - Anteromedial
    - 2 cm distal and 2 cm anterior to the medial epicondyle
    - Medial antebrachial cutaneous nerve at risk
    - Consider using inside-out technique to create portal
  - Posterolateral
    - 3 cm proximal to olecranon tip and lateral to the edge of the triceps tendon
    - Make portal with elbow in 45 degrees flexion to relax posterior capsule and triceps
    - Can visualize the tip of the olecranon, olecranon fossa, and medial and lateral gutters

![Arthroscopy positioning with patient in the lateral decubitus position.](image)
- Straight posterior
  - 3 cm proximal to the olecranon tip through the triceps in center of tendon
- Radial nerve at risk during anterior capsulectomy near anterolateral portal
- Ulnar nerve at risk during posteromedial debridement
- Methods to decrease injury:
  - Flex elbow to 90 degrees during anterior portal placement to release tension on the anterior capsule and nerves.

- Distend joint with 15 to 25 ml saline injected through lateral soft spot to displace the capsule and nerves during portal placement.
- Using retractors during debridement can maintain capsule and nerve displacement.
- Debride synovium, osteophytes, and loose bodies first and remove capsule last to decrease risk of fluid extravasation and swelling.
- Arthroscopic outcome (Figure 38–6):

Figure 38–5:
● 80% regain functional arc of motion; 10% are within 5 to 10 degrees of full motion.10
● The ulnar nerve must be evaluated prior to open or arthroscopic procedures. In the presence of limited flexion (extension contracture), ulnar nerve symptoms, or sensitivity to percussion, decompression and transposition are recommended.

Rehabilitation
● Restoration of motion typically is excellent but requires an extensive rehabilitation program, including continuous passive motion starting immediately postoperatively in the recovery room and continued at home for several weeks. Formal therapy begins on postoperative day 1 and includes edema control, weighted wrist stretches, and patient-adjusted, static progressive bracing.

Complications
● Wounds (hematoma, seroma, ischemia)
● Infection
● Neuritis is minimized if the ulnar nerve is decompressed and/or transposed in patients with less than approximately 90 to 115 degrees flexion or with any nerve tension signs preoperatively.
● Arthroscopy is associated with a higher incidence of multiple nerve injuries during portal placement.
● Heterotopic ossification:
  ● Increased risk with open surgery, history of heterotopic bone, or multiple surgical insults.
  ● Consider several weeks of oral indomethacin (Indocin) sustained release or a single dose of radiation on postoperative day 1 if heterotopic bone formation is of concern.

Synovectomy
Indications
● As a palliative procedure to reduce pain in inflammatory arthritis in early disease (Mayo I or II) with preservation of articular surfaces and subchondral bone.
● Some studies suggest efficacy in more radiographically advanced stages.11,12

Open
● The open technique is the gold standard for synovectomy.
● Can approach joint through medial or lateral column approaches described in the ulnohumeral debridement section.
● Possible disadvantage: increased potential for wound problems.
● Outcomes:
  ● Up to 90% excellent pain relief in the first 2 to 5 years after surgery.
  ● Late results demonstrate deterioration over time, with success rates falling to 60% at 5 to 10 years.11–13
  ● No significant change in range of motion.
● Largest study reviewed 171 rheumatoid elbows with synovectomy and radial head excision.11 Failure was defined by the need for revision surgery or significant pain. The study reported a 1-year survival rate of 81%, 6.5-year survival rate of 45%, and deterioration rate of
3% per year. The strongest predictor of success was greater than 50% limitation of forearm rotation preoperatively. There was no association between radiographic severity and outcome. Failure correlated with recurrent synovitis (43%), instability, limitation of flexion-extension less than 60 degrees, prolonged preoperative symptoms, ulnar neuritis, and poor upper extremity function.

Arthroscopic Synovectomy
- Equipment, positioning, portals as described in the section on ulnohumeral debridement.
- Offers potential for decreased morbidity and faster rehabilitation.6
- Disadvantages: With disease progression, alteration of bony and soft tissue landmarks makes spatial orientation during arthroscopy difficult. Capsular contracture leads to decreased working space and more limited visualization. Increased risk to neurovascular structures.²

Outcomes: Greater than 76% to 90% good and excellent pain relief for 3 to 4 years, after which pain and recurrent synovitis can recur with no improvement in range of motion.¹⁴,¹⁵

Concomitant Radial Head Excision
- Can be performed open or arthroscopically but is controversial, with trend toward radial head preservation unless pain with forearm rotation is a major symptom.
- Advantages: Elimination of a painful contact area between the head and humeral capitellum. May improve forearm rotation.
- Disadvantages: The radial head is an important secondary stabilizer to valgus load.¹⁶ Resection can lead to valgus instability of the elbow and accelerate ulnohumeral arthritis if the medial collateral ligament is attenuated.¹⁷
- Rehabilitation: Typically less intensive therapy is required than after complete ulnohumeral debridement, but all modalities described in the section on ulnohumeral

Figure 38–6:
A, Anteroposterior radiograph showing osteoarthritis with mild ulnohumeral joint space narrowing and presence of loose bodies (asterisk) in either the coronoid or olecranon fossa. B, Lateral radiograph showing radiocapitellar joint space narrowing and presence of loose bodies (asterisks) in both the coronoid and olecranon fossae.
debridement can be used as necessary. Begin early active and passive motion and edema control. Continuous passive motion typically is not necessary.

**Interposition Arthroplasty**

- **Indications:**
  - Ideal candidate is a young, active patient with severe posttraumatic arthritis associated with severe pain and limited motion.
  - Patient is too young or active for total joint arthroplasty.
- **Contraindications:**
  - Significant joint destruction with gross loss of architecture
  - Active infection
  - Gross joint instability
  - Need for elbow to assist in transfers/weight bearing, because excessive loading leads to destabilization
  - Inflammatory arthritis resulting from progressive disease
  - Resurfacing materials include autologous fascia lata from the thigh, autologous skin, and more commonly allograft soft tissue. Preferred allograft is the Achilles tendon because of its availability, size, and the ability to use part of it for concomitant ligament reconstruction.
  - Surgical technique:
    - Supine position.
    - Posterior midline skin incision to expose the ulnar nerve.
    - Lateral extensile Kocher approach through the anconeus–extensor carpi ulnaris interval.
    - Release the lateral collateral ligament.
    - Excise the anterior and posterior capsule.
    - Preserve the radial head if possible.
    - Remove a small amount of bone from the greater sigmoid notch, trochlea, and capitellum to accommodate the tendon graft and create concentric, fluid joint motion.
    - Place drill holes from posterior to anterior in the distal humerus to pass sutures that will secure the graft to bone.
    - The Achilles tendon graft is contoured to the size of the distal humerus and then draped over the trochlea and capitellum, and sutures placed through the bone to secure the graft.
    - Excess graft can be used to reconstruct lateral collateral and ulnar collateral ligaments through bone tunnels.
    - The tourniquet is released and hemostasis achieved.
    - A hinged external fixator is applied.
    - The triceps is reattached through drill holes in the olecranon.
    - Kocher’s interval is closed.
- **Rehabilitation:** Motion is started early, with possible use of continuous passive motion. The fixator is removed under anesthesia with examination to determine motion and stability. Gentle manipulation is performed as needed. Progressive static splinting is applied for residual stiffness.
- **Outcome:** 35 rheumatoid elbows with an average follow-up of 6 years. Outcome was rated fair for joint mobility and joint stability but good for pain relief. Radiographic destruction progressed in half of all elbows, with bone loss making reoperation difficult or impossible. The authors recommend total elbow replacement as the first choice in the surgical treatment of advanced rheumatoid arthritis.
- **Complications:**
  - Bone resorption
  - Continued pain, stiffness, instability
  - Heterotopic bone formation
  - Triceps rupture
  - Infection
  - Deterioration in results over time

**Total Elbow Arthroplasty**

- **Indications:** rheumatoid, posttraumatic, or primary arthritis with advanced symptoms and radiographic destruction after failed medical or less aggressive surgical treatment. The patient must agree to postoperative limitations of no lifting more than approximately 5 to 10 lb and no repetitive lifting of any object more than 2 to 3 lb to limit the risk of early failure.
- **Contraindications:**
  - Sepsis
  - Need for soft tissue coverage
  - Severe muscle weakness or paralysis
  - Noncompliant patient
- **Types:**
  - Constrained (historical)
  - Linked prosthesis with high incidence of loosening of 24% at 4 years because of excessive load transfer to the bone–cement interface
  - Semiconstrained (Figure 38–7)
  - “Sloppy” hinged prosthesis with metal and polyethylene articulation that allows limited rotational and varus/valgus motion between humeral and ulnar components to decrease the bone–cement interface loading. However, stress concentration at the hinge can lead to polyethylene wear, debris, osteolysis, and component loosening. Newer designs have been developed in an effort to decrease stress transfer at the joint articulation and diminish these problems. Clinical results are pending.
- **Outcome:**
  - Variable because of different indications, multiple different prostheses, and multiple generations within individual prostheses.
  - Significant pain relief reported in 76% to 92%.
  - Improved final arc of flexion-extension of 29 to 131 degrees.
Results of total elbow replacement in 45 elbows of 38 patients with rheumatoid arthritis compared with results of radial head excision with synovectomy in 45 age-matched patients showed better pain reduction and higher complications after replacement, with no differences in motion.

Complications:
- Radiographic loosening up to 8\%\(^3\)
- Revision for loosening 3\% to 15\%\(^{20,21}\)
- Postoperative neuropathy 14\%\(^20\)
- Overall minor and major complication rate up to 55\%\(^20\)

Unconstrained (Figure 38–8)
- No linkage between the humeral and ulnar components with a metal on polyethylene articulation. Relies on ligaments and muscles for joint stability. Theoretically decreases loosening at the bone–cement interface with greater longevity (not proven). Carries a greater risk for instability, especially in the rheumatoid population. Newer designs have the ability to be inserted semi-constrained or unlinked. Clinical data are pending.

Outcome:
- Variability because of different indications, multiple different prostheses, and multiple modifications within individual prostheses
- Significant pain relief reported in 79\% to 94\%\(^{22,23}\)
- Improved final arc of flexion-extension of 32 to 136 degrees\(^24\)

Complications:
- Radiographic loosening 0\% to 70\%\(^{25,26}\)
- Instability 2\% to 29\%\(^{23,26,27}\)
- Revision for loosening or instability 0\% to 11\%\(^{25,26}\)
- Complication rate up to 80\%\(^3\)
- Surgical technique:
  - Lateral decubitus position with body supported by bean bag and bony prominences padded
  - Posterior midline incision
  - Ulnar nerve mobilized and transposed and protected throughout procedure
  - Triceps reflecting approach from medial to lateral most commonly used to expose the joint
  - Alternatives are the triceps midline split and the triceps preserving approach, which involves release of the entire flexor-pronator and extensor origins, allowing the humerus to be delivered medial and lateral to the triceps insertion on the ulna
  - The tip of the olecranon is resected and the elbow is hyperflexed to expose the trochlea
  - The radial head is resected if required
  - The humeral and ulnar canals are entered with a burr and enlarged with rasps
  - Trial prostheses are placed and motion and stability checked, then the trials are removed
  - The canals are irrigated with pulsatile lavage and then dried to remove marrow contents
  - Cement plugs are placed in the humeral and ulnar canals to limit cement within the canal, allow pressurization, and improve the cement mantle
  - The polymethylmethacrylate is often mixed with antibiotics and the canals are filled in retrograde fashion with long, flexible tubing attached to the injection gun
  - The components are placed and the cement allowed to harden
  - The triceps is meticulously repaired

- Rehabilitation:
  - Short-term immobilization in a posterior long arm splint to protect the skin closure
  - No lifting over 10 lb as a single event or 2 lb repeatedly
  - Usually minimal formal therapy needed
  - A night elbow extension splint in maximum extension can be helpful in limiting flexion contracture
References


13. Maenpaa HM, Kuusela PP, Kaarela K, et al: Reoperation rate after elbow synovectomy in rheumatoid arthritis. J Shoulder Elbow Surg 12:480-483, 2003. Reports complete pain relief in 44%, with excellent or good outcomes in 72% following synovectomy for juvenile rheumatoid arthritis. The cumulative survival rate was 84% at 5 years. There was no significant improvement in functional ability or range of motion.


19. Ljung P, Jonsson K, Larsson K, Rydhholm U: Interposition arthroplasty of the elbow with rheumatoid arthritis. J Shoulder Elbow Surg 5:81-85, 1996. At 6-year follow-up, pain relief was good, but joint mobility and stability were only fair. Radiographic elbow destruction progressed in half. The authors recommend TEA instead.

Pronation improved. Revisions were performed in 24 percent, mainly because of loosening or deep infection.


At 3.8-year follow-up, there was little or no pain in 53 of 58. Motion was improved. They noted no loosening, but a 22% rate of complications was reported.


Although pain relief was initially achieved in all patients, at 5-year follow-up six prostheses had radiographic loosening and two patients had symptomatic loosening.


Pronation, supination, and flexion improved considerably, but improvement in extension was limited. Malarticulation or dislocation occurred in 25%. 25% had asymptomatic radiolucent lines.


Reported pain relief in 34 of 35 at 5.6-year follow-up. Range of motion increased in all planes except extension. There was a 57% complication rate but no unstable elbows.


Report improved pain and range of motion for 30 capitellocondylar arthroplasties at 39.9-month follow-up. Deep wound infections occurred in 6.6%. Subluxation, which responded to treatment with long-arm casting, occurred in 13.2%.


Report 29 good, 1 fair, and 7 poor results at 9.5-year follow-up. Poor results most commonly were caused by posterior displacement of the humeral component, which subsided in 70%. Ulnar component loosening occurred in 5%. A humeral component with an intramedullary stem was recommended.


Twelve-year survivorship was 87% with revision as the endpoint. If the endpoint was revision or a 1-mm circumferential lucency, survivorship fell to 80%.
Introduction

- Humeral shaft fractures compose approximately 3% to 5% of all fractures.
- Humeral shaft fractures can be isolated injuries or one of many fractures in a polytraumatized patient.
- Most humeral shaft fractures do not require operative intervention.

Anatomy

- The humeral diaphysis is the segment of the humerus extending from the proximal aspect of the pectoralis major insertion to the suprACLavicular ridge.
- Functionally there are two compartments in the arm: anterior and posterior. The biceps, coracobrachialis, brachioradialis, and brachialis are the muscles of the anterior compartment. The triceps is the sole muscle of the posterior compartment. It is composed of a long head, lateral head, and medial head. The lateral and medial heads take origin from the posterior humeral shaft proximal and distal to the spiral groove, respectively.
- The median, ulnar, and musculocutaneous nerves are located in the anterior compartment. Unlike the radial nerve, they are rarely injured by nonpenetrating trauma.
- The radial nerve is located in the posterior compartment and courses immediately adjacent to the posterior aspect of the humerus in the spiral groove. As it travels diagonally across the humerus, it courses 20 cm proximal to the medial epicondyle and 14 cm proximal to the lateral epicondyle. The nerve remains along the posterior humerus and pierces the intermuscular septum approximately 10 cm proximal to the distal humeral articular surface.
- The incidence of radial nerve palsy associated with humeral shaft fractures reportedly is 15% to 20%, with midshaft fractures accounting for the majority.
- The brachial artery provides the predominant arterial supply for the arm. The first major branch is the profunda brachii artery. Distally the brachial artery splits to form the radial and ulnar arteries. The anterior humeral circumflex artery is a branch of the axillary artery and provides the majority of the blood supply to the humeral head. The posterior humeral circumflex artery travels with the axillary nerve under the deltoid through the quadrangular space.
- Fracture displacement is partly dependent upon the location of the fracture relative to the origin and insertion of the major muscle groups about the humeral shaft. The pectoralis major and deltoid muscles are the major deforming forces that involve the proximal half of the humerus. The pull of the biceps and triceps may result in additional angulation and fracture shortening.

Physical Examination

- Circumferential inspection of the skin identifies abrasions, contusions, and open wounds.
Detailed neurologic examination of the arm is essential. Motor and sensory evaluation of the median, ulnar, axillary, and radial nerves should be performed and documented. Particular care should be directed toward identifying and documenting any injury to the radial nerve, given the frequent coexistence of radial nerve injuries and humeral shaft fractures.

Arterial injuries are not common but they do occur. Pulses must be palpated. Excessive swelling must be critically assessed for occult arterial injury.

**Radiographic Examination**

- Orthogonal radiographs (anteroposterior and lateral) are obtained. Both the shoulder and elbow joints should be imaged to rule out associated fractures.
- Occasionally traction views are useful, particularly for evaluating comminuted fractures in the supracondylar region.
- Angiography may be indicated if vascular injury is suspected.
- Computed tomographic scanning or magnetic resonance imaging are rarely indicated in the initial evaluation of these injuries.

**Classification**

- No universally accepted classification system is used to describe humeral shaft fractures. In the AO classification scheme, type A fractures are simple fractures with spiral, oblique, or transverse characteristics; type B fractures have an associated “wedge” fragment; and type C fractures are significantly comminuted/segmental (Figure 39–1).
- More commonly, however, humeral shaft fractures are classified in descriptive terms, such as fracture location and characteristics.
- Holstein and Lewis identified a unique spiral fracture pattern of the distal third of the humerus, commonly referred to as a Holstein-Lewis fracture. In their case series, the authors demonstrated a high incidence of radial nerve palsy associated with these fractures. However, others have demonstrated that the most common region associated with radial nerve palsy remains the mid-diaphysis.

**Treatment**

- The vast majority of isolated humeral shaft fractures are amenable to nonoperative management (Figure 39–2).

**Nonoperative Treatment**

- Initially, patients are placed in a coaptation splint and collar-and-cuff immobilization. Oddly enough, the most challenging patients can be the ones with a simple transverse fracture with distraction. A high percentage of these patients go into delayed union or nonunion without internal fixation. To improve alignment, the patient can be placed in a semi-sitting or full upright position, using gravity to improve alignment. The coaptation splint is placed from the axilla medially, around the elbow distally, and ends about the superior aspect of the acromioclavicular joint. Prior to plaster setting, the splint can be gently molded to reduce the major displacements. Anteroposterior and lateral radiographs are obtained to assess fracture position. The neurologic examination, particularly of the radial nerve, is then repeated. Patients should understand that they will be transitioned into several splints/braces while awaiting union.
- Patients are placed into a prefabricated functional brace (Sarmiento brace) within 1 to 2 weeks after injury. The patient is instructed on how to tighten the straps to
maintain a snug fit, as fracture reduction is obtained and maintained by the hydrostatic pressure within the soft tissue envelope created by the brace. After brace application, immediate orthogonal radiographs are obtained. Adjustments can be made to neutralize specific deformities. For example, a small abduction pillow at the patient’s waist can be used to eliminate a varus deformity, and pads can be placed in the axilla to eliminate a valgus deformity.10–13

Patients are encouraged to begin active range of motion exercises of the fingers, wrist, elbow, and shoulder as tolerated.

Radiographs are obtained weekly for the first 3 to 4 weeks to ensure satisfactory maintenance of reduction and initiation of range of motion exercises. Radiographic and clinical healing usually becomes apparent at the 6- to 8-week mark. Weaning of the brace can begin at this time.

Shoulder and elbow stretching and strengthening exercises are subsequently encouraged.

Hanging casts, rather than coaptation splints, occasionally are used acutely, provided the top of the cast ends at least 2 cm above the fracture. They are mainly indicated in oblique or spiral fractures with shortening. Patients are transitioned into a functional brace. The main concern with hanging casts is the potential for overdistraction of the fracture and subsequent nonunion.

With all of these techniques, significant hand and forearm edema may develop. The edema usually is a benign occurrence secondary to dependency. Encouraging active finger, wrist, and elbow range of motion and ensuring there are no constrictions in the region of the antecubital fossa often improve the situation.

Acceptable alignment:
- 20 degrees anterior or posterior angulation
- 30 degrees varus or valgus angulation
- Up to 2 cm of shortening

Operative Treatment

Indications

Most of the indications for operative management of humeral shaft fractures are relative.

Failure of nonoperative management is an indication for operative fixation. Inability to maintain acceptable alignment is a relative indication for surgical stabilization. Patients with a large body habitus are more prone to unacceptable reductions with varus deformities.

The presence of multiple injuries is a relative indication for operative management. The rationale is to facilitate mobilization, nursing care, personal hygiene, and early weight bearing on the arm.14

Associated vascular injuries requiring repair invariably require fracture stabilization to maintain the integrity of the vascular supply.

Associated brachial plexus injuries often result in flaccid paralysis of the musculature of the upper extremity. Fracture distraction is particularly difficult to manage with closed methods and frequently leads to delayed or nonunion.15

Pathologic fractures should be treated operatively. In these cases, humeral nails have superior biomechanical properties compared to plates, and are the usual implant of choice.16
● Open fractures requiring surgical debridement and irrigation often are stabilized to promote soft tissue healing, minimize dead space, and facilitate wound care. Injuries without significant soft tissue injury and with favorable fracture patterns can, however, be managed with functional bracing after operative debridement.

● Associated ipsilateral upper extremity fractures, such as the “floating elbow,” are relative indications for operative fixation.

● Segmental humeral fractures are a relative indication for surgical management because they may be difficult to manage with functional bracing. However, successful treatment can be obtained with nonoperative means.

● Intraarticular extension, either proximal or distal, is a relative indication for shaft fixation.

● Radial nerve palsy following closed reduction is a relative indication for operative intervention. Although controversial, evidence supports observation, provided alignment of the humeral shaft remains satisfactory and no other relative indications for surgical treatment are present.7,17–19

Plate Osteosynthesis

● Plate stabilization has demonstrated satisfactory union rates with low complications and remains the gold standard for the majority of humeral shaft fractures20–24 (Figure 39–3).

● The choice of surgical approach is dependent upon associated injuries and fracture location, among other factors.

Surgical Approaches

Posterior: Triceps Splitting

● The patient is positioned in the lateral or prone position.

● A longitudinal posterior skin incision is made. Distally, the incision is curved around the tip of the olecranon. The deep investing muscular fascia is incised. The interval between the long head and lateral heads of the triceps is identified and developed.

● The radial nerve (with the accompanying profund brachii artery) is located, mobilized, and protected as it crosses from medial to lateral along the posterior aspect of

Figure 39–3:
A 25-year-old man with multiple injuries, including tibial shaft and pelvic ring fractures. A, B, Injury radiographs.
the humerus in the spiral groove. The medial head of the triceps originates from the posterior aspect of the humerus distal to the spiral groove. The medial head is incised and elevated in a subperiosteal manner (Figure 39–4). This approach allows access to the posterior aspect of the humerus for plating. With mobilization of the radial nerve, this approach allows for exposure of approximately 75% of the humeral shaft.1

**Posterior: Modified Extensile**

- The patient is positioned in the lateral or prone position.
- A midline longitudinal posterior skin incision is performed.

---

**Figure 39–3: cont’d**

C, D, The patient was treated with open reduction internal fixation via the modified extensile posterior approach.

---

**Figure 39–4:**

Triceps splitting posterior approach.

- The lower lateral brachial cutaneous branch of the radial nerve is identified on the posterior aspect of the lateral intermuscular septum and followed proximally to identify the radial nerve proper along the posterior aspect of the humerus (Figure 39–5).
- At the lateral border of the humerus, the radial nerve trifurcates into three branches: the lower lateral brachial cutaneous nerve, a branch to the medial head of the triceps, and the continuation of the radial nerve into the distal aspect of the upper arm and forearm. Once the
radial nerve is identified, it is followed distally to the lateral intermuscular septum. The lateral intermuscular septum is incised proximally and distally, allowing for mobilization of the radial nerve.

- The triceps is elevated from lateral to medial (see Figure 39–5). This exposure is more extensile than the triceps splitting approach with visualization of approximately 94% of the humeral diaphysis. It is limited proximally by the course of the axillary nerve and the posterior humeral circumflex artery.

### Lateral

- The patient is positioned in the supine position.
- The incision is made on the lateral aspect of the arm from the deltoid insertion to the lateral epicondyle.
- Identification of the radial nerve is performed as described in the extensile posterior approach.
- This approach should be considered for surgical stabilization of humeral shaft fractures in the multiply injured patient.

### Anterior

- The patient is positioned in the supine position. Proximally, this exposure is extensile via the deltopectoral interval.
- The incision is made along the lateral border of biceps and ends proximal to elbow crease. Proximally, the interval is between the deltoid (lateral) and the pectoralis major (medial) muscles.
- The biceps muscle is retracted medially, exposing the brachialis muscle, which covers the anterior aspect of the humerus. The musculocutaneous nerve is identified between the biceps and the brachialis.
- The brachialis muscle is incised longitudinally, exposing the anterior aspect of the humerus (Figure 39–6).
- Distally the radial nerve lies between the brachialis (medial) and the brachioradialis (lateral). Controversy exists regarding the need to expose the radial nerve in this approach. Although it is not necessary to expose the radial nerve, it is important to be certain of the intervals used and the lack of the radial nerve in the wound or under the plate.
- This exposure should be considered when managing fractures involving the proximal third of the humeral diaphysis.

### Fixation Strategies

- Most humeral shaft fractures can be managed using 4.5-mm limited contact dynamic compression plates. Traditional teaching advocated the use of broad 4.5-mm implants for fractures of the humeral shaft; however, current practice suggests most fractures can be adequately managed with narrow 4.5-mm implants. This later finding likely results from improved handling of comminuted fracture fragments and their soft tissue attachments and understanding the superior mechanical benefits afforded with longer plates and fewer screws.
- Lag screws applied through the plate substantially improve the construct strength and should be used whenever possible. Compression plating techniques are advocated for transverse or short oblique fractures.
- Highly comminuted fractures usually require bridging rather than compressing techniques.
- Double plating, with plates placed orthogonal to each other, may be needed for fixation of distal fractures.
- Acute bone grafting is rarely necessary, provided good soft tissue technique is used during reduction and stabilization.
- At the conclusion of posterior plate applications, the location where the nerve crosses the plate should be noted and included in the operative report, in case future surgery is required.

### Intramedullary Fixation

- Intramedullary nailing of humeral shaft fractures has not been as successful as in the lower extremity and remains controversial.
- The main concerns with humeral nailing are
  - Shoulder pain and decreased range of motion (thought to be secondary to rotator cuff injury at the time of antegrade nailing)
  - Radial nerve injury (during closed nailings)
  - Nonunion (particularly if the fracture is left distracted)
  - Iatrogenic fracture in the supracondylar region (retrograde nailing)
- Two randomized trials failed to demonstrate any superiority of humeral nailing over compression plate techniques.4,14
- Despite this finding, intramedullary nailing of humeral shaft fractures remains an important device in the armamentarium of the orthopaedic trauma surgeon and should be used in the appropriate situation.26,27
The majority of humeral nailings performed in North America use an antegrade statically locked nail with a minimally reamed technique. Multiple nail designs are available. Standard antegrade nails are placed just medial to the greater tuberosity and require the rotator cuff to be incised and retracted to allow nail passage. Newer nails are available that allow antegrade nailing yet do not require violation of the rotator cuff (Figure 39–7). Hopefully these devices can decrease the shoulder morbidity identified with standard antegrade nailing technique, but data supporting this hypothesis are lacking. Other devices allow multiple screws to be placed within the humeral head and are useful for humeral shaft fractures with associated fractures in the region of the surgical neck. Retrograde nailing avoids breaching the rotator cuff but requires the creation of an entrance hole in the supracondylar region of the humerus that is associated with iatrogenic fracture. Unlocked flexible nails, such as elastic nails or Enders nails, are infrequently used for management of these fractures. Despite reports of their successful use, they have poor rotational control and are suboptimal for comminuted fractures. Although their use is acceptable, other treatments are commonly preferred.

Radial Nerve Management During Intramedullary Nailing of the Humerus

Radial nerve injury during closed humeral nailing is the biggest detractor from the technique. Two established techniques to prevent this complication are as follows:

1. Direct operative visualization of the fracture ends during reduction and nail passage to ensure that the nerve is not trapped within the fracture. Using this technique, the nerve does not need to be explored, but it must be verified to be out of harm’s way.
2. Utilization of somatosensory evoked potentials during closed nailings.

Fractures can be nailed without using the aforementioned techniques in the following situations:

- Fractures that are well proximal or distal to the region of the spiral groove
- Near anatomic fracture reduction that can be obtained without undue manipulation or force
- Patients who can be examined preoperatively and postoperatively

We have a low threshold for proceeding with open visualization of the radial nerve during humeral nailing.

Antegrade Technique

The patient is placed supine or in the beach chair position. This position allows the injured extremity to be elevated and rotated “away” from the surgeon. Fluoroscopy equipment is located on the contralateral side of the operating table. Combined with the rotation of the patient, the C-arm can traverse a near 90-degree arc without the patient’s torso obscuring the image. A small longitudinal incision is made from the lateral aspect of the acromion distally. Blunt dissection is performed down to the rotator cuff. The rotator cuff is incised in line with its fibers and retracted. The starting point is confirmed radiographically.
Neurovascular structures, including the radial, median, and musculocutaneous nerves and the brachial artery, are at risk with distal interlocking.

**Retrograde Technique**
- The patient is placed in the lateral or prone position.
- Fluoroscopy equipment is generally located at the patient’s head.
- The distal portion of a triceps splitting approach is performed.
- The staring point is in the midline approximately 2.5 cm proximal to the proximal extent of the olecranon fossa.
- When placing the proximally locking screws, the axillary nerve is at risk, so blunt dissection to bone is important.
- Great care must be taken when creating the entry portal, because the most common complication of retrograde nailing is fracture in this region.

**External Fixation**
- Rarely indicated.
- When used, the pins should be placed with direct visualization of bone when neurovascular structures are at risk.
- Consider this technique for high-energy open injuries.
- Successful outcomes in properly selected cases have been demonstrated.

**Rehabilitation**
- Immediate active finger, wrist, elbow, and shoulder range of motion is encouraged.
- Early weight bearing should be considered, particularly in the polytraumatized patient if the extremity is needed for mobilization.
- Strengthening is emphasized at approximately 6 to 8 weeks.
- Radiographs typically are obtained at 6, 12, and 24 weeks.

**Complications**

**Nerve Injury**
- The radial nerve is the nerve injury most frequently associated with humeral shaft fractures. The majority of these injuries (90%) are neuropraxias, and spontaneously recovery is the rule.
- Open humeral shaft fractures have a higher incidence of radial nerve lacerations. These injuries should be explored initially and repaired (or grafted) at a secondary surgery, once the wound is stable and clean and the level of nerve injury is clearly demarcated.
- Closed humeral shaft fractures with radial nerve injuries are managed with observation, as the prognosis for nerve recovery is excellent. During the time of paralysis, passive range of motion of the fingers and wrist is imperative. Use of a “cock-up” wrist brace facilitates function.
- Use of electromyography for monitoring nerve recovery is controversial. Changes in electromyographic (EMG) recordings typically occur only 1 month prior to clinical signs of recovery and limit their usefulness. Some patients may not demonstrate spontaneous recovery for up to 6 months after injury, but the majority begin recovery within 4 months.
- Nerve regeneration typically occurs at the rate of 1 mm/day and follows a reproducible pattern of muscle reinnervation.
- A progressive clinical sequence of recovery begins with radially deviated wrist extension (extensor carpi radialis longus), followed rapidly by wrist extension in a neutral plane (extensor carpi radialis brevis). Finger extension (extensor digitorum communis) occurs subsequently, with extension of the thumb interphalangeal joint (extensor pollicis longus) recovering later. The extensor indicis proprius is the last muscle to recover.
- The two treatment strategies for management of a nonrecovering radial nerve palsy are exploration and nerve grafting versus tendon transfers. Nerve grafting is a long, uncertain process that offers the chance at independent finger extension. Tendon transfers are more predictable but are limited in that the patient will not have fine independent finger extension.
- Iatrogenic nerve injuries are not uncommon. The radial nerve is at risk with most open reduction internal fixation procedures. With humeral nailing, the axillary nerve is vulnerable with proximal interlocking, whereas the radial, median, and musculocutaneous nerves all are at risk with distal locking. Injuries to the brachial artery have been described.

**Nonunion**
- Nonunion rates are slightly higher in series of patients treated operatively for humeral shaft fractures compared to nonoperatively managed groups. Up to 29% nonunion rates have been reported. More commonly, nonunion rates of 5% to 10% are presented. Overall, union rates may be higher in patients treated with plate osteosynthesis compared to humeral nailing.
- Compression plating with or without bone grafting has been the treatment of choice for humeral nonunions. Several small series have supported humeral nailing for treatment of nonunion.

**Shoulder Pain**
- Shoulder pain more commonly is experienced following antegrade humeral nailing. Theoretically it is less of a problem with antegrade humeral nails with entry sites distal to the rotator cuff. The reported rates of shoulder dysfunction or pain range from nearly none to nearly all patients. Some patients treated by all methods, even closed management, report shoulder pain and functional loss.
Elbow Pain

- Elbow pain has been described following retrograde nailing of the humerus and following open reduction internal fixation and antegrade humeral nailing.
- Measurable elbow stiffness has been identified with plating fractures of the distal third of the humeral shaft.\(^\text{20}\)

References


2. Uhl RL, Larosa JM, Sibeni T, Martino LJ: Posterior approaches to the humerus: when should you worry about the radial nerve. *J Orthop Trauma* 10:338-340, 1996. Describes the path of the radial nerve, particularly where it pierces the intramuscular septum and travels in the spiral groove.


Ninety-five percent had full or near-full recovery. EMG studies are recommended at 4 to 6 months, with tendon transfers deferred for at least 6 months and preferably for 1 year.


21. McCormack RG, Brien D, Buckley RE et al: Fixation of fractures of the shaft of the humerus by dynamic compression plate or intramedullary nail. A prospective, randomized trial. J Bone Joint Surg 82B:336-339, 2000. The authors advocate the use of plate osteosynthesis for humeral shaft fractures requiring fixation, reserving nail stabilization for special situations. They noted no significant differences in shoulder or elbow function for plates or nails, but the overall complication rate was higher in the nailed group.


23. McKee MD, Pedlow FX, Cheney PJ, Schemitsch EH: Fractures below the end of locking humeral nails: A report of three cases. J Orthop Trauma 10:500-504, 1996. Three cases of fracture following antegrade humeral nailing at the distal interlocking site are described. All patients were treated with secondary surgeries.


30. Rommens PM, Verbruggen J, Broos PL: Retrograde locked nailing of humeral shaft fractures. A review of 39 patients. J Bone Joint Surg 77B:84-89, 1995. Reports a 7% nonunion rate and a 4% radial nerve palsy rate with complete recovery in all cases. Entry site fractures occurred in 4%. Shoulder and elbow function was excellent in almost 90%.


33. Farragos AF, Schemitsch EH, McKee MD: Complications of intramedullary nailing for fractures of the humeral shaft: a review. J Orthop Trauma 13:258-267, 1999. Complications following nailing of humeral shaft fractures are described and compared to studies of plate fixation, for which lower complication rates are seen.


CHAPTER 40

Examination of the Shoulder

Jeffrey E. Budoff

MD, Assistant Professor, Hand and Upper Extremity Institute, Department of Orthopaedic Surgery, Baylor College of Medicine; Houston Veterans Affairs Medical Center, Houston, TX

Introduction

• The majority of shoulder disorders can be diagnosed based on a thorough history and physical examination. Overreliance on diagnostic imaging is discouraged because the sensitivity of magnetic resonance imaging (MRI) and other studies used to detect common shoulder disorders still is suboptimal. Conversely, imaging studies may detect many asymptomatic abnormalities that do not require intervention.

• Physical examination can be relatively straightforward. The physician determines the location of the patient’s pain by history, localizes the area(s) of tenderness and then applies his/her knowledge of anatomy to determine “what lives there.” This process generates a differential diagnosis of potentially injured structures. The physician then stresses those individual structures to determine which reproduces the patient’s pain. That structure most probably is the source of the patient’s symptoms. If an anesthetic agent can be reliably injected into a localized area, the clinical impression can be confirmed with diagnostic injections. Although no test is perfect, if an injection decreases the patient’s pain, the anesthetized structure probably is contributing to the patient’s symptoms.

Anatomy and Biomechanics

• The shoulder consists of three synovial joints (glenohumeral, acromioclavicular [AC], and sternoclavicular) and two articulations (scapulothoracic, and acromiohumeral). The glenohumeral joint is the most mobile joint in the body. Unlike the hip, the glenoid socket is not intrinsically stable; it relies on static and dynamic soft tissue stabilizers to remain centered. Because of its lack of osseous stabilizers, it is the most commonly dislocated large joint in the body (Figure 40–1).

Static Stabilizers: Glenohumeral Joint Capsule

• The joint capsule originates on the glenoid neck and inserts along the proximal humerus (Figure 40–2). Important capsular thickenings include the superior glenohumeral ligament (SGHL), the middle glenohumeral ligament (MGHL) and the inferior glenohumeral ligament (IGHL). The IGHL is a complex structure composed of an anterior bundle (aIGHL) and a posterior bundle (pIGHL), with the axillary pouch spanning the interval between them (Figure 40–3). This setup has been compared to a hammock that supports the humeral head during arm elevation. Although clinically, individual ligaments are not tightened in isolation, they are differentially tensioned according to the degree of elevation.

• With the shoulder adducted at rest, the SGHL and negative intraarticular pressure stabilize against inferior subluxation.

• At 45 degrees elevation, all capsuloligamentous components are at their loosest, with the MGHL, aIGHL, and subscapularis being the main restraint to anteroinferior translation.
The IGHL complex is the prime stabilizer preventing anterior instability at higher degrees of abduction.\textsuperscript{2,3} The capsuloligamentous restraints function as checkreins, maintaining stability at the end range of motion when they tighten. The anterior ligaments oppose anterior humeral translation in external rotation, and the posterior ligaments oppose posterior humeral translation in internal rotation. In the midrange of motion, where most activities of daily living occur, the capsuloligamentous structures are lax; therefore, their contribution to stability is limited. Stability is maintained by dynamic means.

**Dynamic Stabilizers**

- The dynamic stabilizers include all musculature around the shoulder, with the rotator cuff playing a major role (Figures 40–4 and 40–5). The rotator cuff is composed of four tendons: the supraspinatus, infraspinatus, teres minor, and subscapularis. All rotator cuff muscles originate from the scapula and insert onto the greater tuberosity (supraspinatus, infraspinatus, teres minor) or lesser tuberosity (subscapularis). The subscapularis functions as an internal rotator; the infraspinatus and teres minor function as external rotators of the glenohumeral joint.

**Mechanisms of Dynamic Stabilization\textsuperscript{3}**

- **Concavity–Compression**
  - In the absence of rotator cuff function, deltoid activation approximates its insertion on the humerus to its origin on the acromion, leading to superior humeral migration and ineffective elevation. To prevent this occurrence, the rotator cuff compresses the convexity of the humeral head into the concavity of the glenoid, like a golf ball into a tee (Figures 40–6 and 40–7, A). With the humeral head stabilized within the glenoid, deltoid...
activation then can effectively elevate the arm. Lippitt et al.\textsuperscript{5} showed that this mechanism resists the superior shearing moment of the deltoid with a high efficiency approaching 60%.

- The long head of the biceps originates from the superior glenoid labrum and the supraglenoid tubercle and exits the shoulder in the intertubercular/bicipital groove. In abduction-external rotation, the biceps tendon runs almost perpendicular to the glenoid surface and may help increase compression of the humeral head into the glenoid, especially in cases of rotator cuff deficiency or shoulder instability.\textsuperscript{6,7}

- Muscle contraction actively centers the humeral head on the glenoid.

- Passive barrier effect: The subscapularis muscle is an important barrier resisting anteroinferior humeral head displacement. The supraspinatus, infraspinatus, and teres minor are important barriers to posterior subluxation.

**Scapulothoracic Motion**

- The scapula provides the stable base from which glenohumeral mobility occurs. The scapula is the origin for the rotator cuff and deltoid, so its stability is required for optimal function of these muscles. The scapulothoracic muscles position the glenoid in synchrony with glenohumeral motion in order to optimize concavity-compression. This synchronous motion has been likened to a “ball balanced on the tip of a seal’s nose” to illustrate the glenoid’s active response that keeps the humeral head centered during motion. This coordination of motion is especially important during midrange motion, where the capsuloligamentous constraints are lax. Important scapulothoracic stabilizers include the serratus anterior, the rhomboids, and the trapezius.\textsuperscript{8}

- Scapulothoracic weakness, fatigue, or dysfunction increases stresses on the rotator cuff and static stabilizers, especially during high-demand activities such as overhead athletics (see Figure 40–7, B).\textsuperscript{8} Conversely, the scapular stabilizers are inhibited by painful shoulder conditions, leading to scapulothoracic dysfunction in up to 68% of rotator cuff disorders and 100% of glenohumeral instabilities.\textsuperscript{9}

**Rotator Cuff Cable and Crescent\textsuperscript{10,11}**

(Figures 40–8 and 40–9)

- The rotator cuff has a cable-like thickening that runs from the anterior supraspinatus to the inferior infraspinatus. This cable is consistently located at the margin of the avascular zone. The cable itself rarely degenerates.

- The rotator cuff crescent consists of the insertions of the supraspinatus and infraspinatus tendons, lateral to the cable. The vast majority of tendon degeneration and tearing occurs within the rotator cuff crescent, where the blood supply is poor.\textsuperscript{12}

- The anatomic cable corresponds well to the functional “anteroposterior force couple” of the rotator cuff. This force couple consists of the subscapularis anteriorly, balanced against the inferior infraspinatus and teres minor posteriorly. Both sides of this force couple must be intact in order for the rotator cuff to function. Torn rotator cuffs can function biomechanically as long as the cable/force couple is intact. If a rotator cuff tear extends outside the cable and involves either the subscapularis or the most inferior infraspinatus and teres minor, the
shoulder becomes dysfunctional, and active elevation is compromised.

**History**

- Chief complaints include pain, stiffness, weakness, instability, and mechanical issues, such as painful snapping or catching.
- **History of present illness**: Note the pain’s location, symptom duration, exacerbating activities, the presence of nocturnal pain, any history of trauma, overuse, or neck disorders, whether symptoms are improving or worsening, and any treatments attempted (operative or otherwise) and their effectiveness.
- Pain of rotator cuff origin usually is located laterally, anterolaterally, or posterolaterally. Scapulothoracic pain is located posteromedially, or over the trapezius, medial to pain of rotator cuff origin. Biceps pain is universally anterior.
Rotator cuff symptoms often are exacerbated by arm elevation, internal rotation, lifting, sudden motions, overhead athletics, and other strenuous activities. Pain frequently worsens at night and may wake the patient from sleep. Pain of rotator cuff origin may radiate as far distally as the lateral elbow. This radiation need not imply neurogenic origin.

**Instability:** Note provocative positions, whether the initial onset was traumatic or atraumatic, whether frank dislocation or only subluxation has occurred, the number of instability events, and the direction of dislocation. Also note any residual symptoms between instability episodes, which often are referable to the rotator cuff, posttraumatic synovitis, and/or arthritis.

**Past medical history:** Note any history of rheumatoid or inflammatory arthritis, crystal deposition disease, diabetes mellitus, or hypothyroidism.

**Differential diagnosis:**
- Lateral pain (including anterolateral or posterolateral pain): rotator cuff injury
- Anterior pain: rotator cuff injury (including subscapularis injury), bicipital tendinosis, arthritis
- Superior pain: trapezial strain (usually secondary to rotator cuff dysfunction), AC joint pain, os acromiale (rare)
- Posterior pain: rotator cuff injury, strain of the scapulothoracic stabilizers, suprascapular nerve compression
- Generalized pain: Rotator cuff injury, arthritis
- Painful snapping: glenohumeral instability, biceps tendon instability, SLAP lesions, arthritis, scapulothoracic “bursitis”
- Feelings of instability: glenohumeral instability, biceps tendon instability, loose body, SLAP lesion
- Note that pain can radiate to the shoulder from the cervical region, intraabdominal and intrathoracic viscera, or Pancoast tumors. Although uncommon, one should always be aware of these potential sources of shoulder pain.
- Rotator cuff injury nearly always is in the differential diagnosis of shoulder disorders and is the most common source of symptoms referable to the shoulder. However, it is important to ensure that any rotator cuff involvement is not secondary to another primary disorder, such as instability or scapulothoracic dysfunction.

**Physical Examination**
- The single most important diagnostic procedure performed on the shoulder.
- **Observation at rest:** Note atrophy of the supraspinatus or infraspinatus and any scapular protraction (anterolateral migration of the scapula from the midline).
- **Observation with (attempted) elevation:**
  - Scapulothoracic asymmetry: Results from scapulothoracic weakness and often is more pronounced in descent. It commonly presents as a hitch or jump in the normally smooth motion of the scapula and in subtle cases may require a few repetitions to become evident.
  - Scapular shrug: The patient elevates the scapula to substitute trapezius function for that of a painful rotator cuff. This overuse may lead to trapezial pain.
• Uncontrolled anterosuperior instability: Inability to elevate the arm, associated with the fullness of the humeral head appearing under the anterior subcutaneous tissues, following surgical resection of the coracoacromial arch.

• Observation during wall push-ups: Winging of the scapula is a sign of significant serratus anterior dysfunction.

• Neck: Note tenderness of the paraspinals, sternocleidomastoid, or trapezius. Note range of motion and any radicular pain with motion or compression. C5 radiculopathy occasionally refers pain to the shoulder.

• Active and passive shoulder motion: External and internal rotation are most accurately measured with the arm abducted 90 degrees, not behind the back. With one hand on the acromion the humerus is rotated until scapular motion is noted. This defines true glenohumeral motion. As noted by Kibler et al.,13 measurements of shoulder rotation based upon the vertebrae to which the thumb reaches are less reliable because they are affected by factors other than pure glenohumeral motion. These factors include scapulothoracic motion, elbow motion, forearm rotation, wrist radioulnar deviation, thumb motion and alignment, and imprecise location of the spinous processes.13

• Loss of passive range of motion indicates adhesive capsulitis, guarding, arthritis, or a congenital or posttraumatic deformity.

• Loss of active motion with passive motion retained (an “elevation lag”) indicates dysfunction of the deltoid and/or rotator cuff caused by pain, neurologic injury, muscle weakness, or loss of tendon continuity.

• Palpation:

• The rotator cuff can be palpated just anterior to the acromion with the shoulder extended. Rotation of the arm may allow palpation of full-thickness rotator cuff tears. According to Wolf and Agrawal,14 in skilled hands palpation may be as accurate as MRI for assessment of full-thickness rotator cuff tears.

• The rhomboids, levator scapulae, and trapezius should be palpated. The coracoid may be tender at the pectoralis minor insertion. In addition, the long head of the biceps and the AC and sternoclavicular joints should be palpated.

Provocative Examinations

• Scapulothoracic stress test: The patient actively retracts the scapula. Burning pain that occurs in less than 15 to 20 seconds indicates scapulothoracic weakness and/or dysfunction.

• Lateral scapular slide test: Measure the distance between the thoracic spinal processes and the inferomedial angle of the scapulae in three positions: (1) with the arms adducted at the side, (2) with hands on hips (thumbs posterior), and (3) with the arms elevated in the scapular plane in internal rotation (thumbs down/empty can position). A distance 1.5 cm greater than the contralateral side in any position suggests scapulothoracic weakness with secondary scapulothoracic protraction (Figure 40–10).8

• Scapular assistance test: This test is performed if the patient has rotator cuff symptoms elicited by active forward flexion. Retract the scapula and stabilize it against the thorax by pulling back on the acromion and pushing
down on the inferomedial scapular angle. Have the patient repeat active shoulder flexion. Diminution of pain suggests that the rotator cuff is being impinged secondary to inappropriate scapular protraction, which allows the acromion to fall forward onto the rotator cuff during arm elevation. Decreasing their pain by this maneuver can motivate patients to perform scapulothoracic strengthening to be better able to control their scapula and reduce their symptoms (Figure 40–11).8

● Provocative tests: Rotator cuff
  ● Neer test: Stabilize the acromion and flex the internally rotated shoulder (Figure 40–12).15
  ● Hawkins test: Flex the shoulder 90 degrees and flex the elbow 90 degrees, then internally rotate the arm (Figure 40–13).16
  ● “Thumb down” or “empty can test”: Elevate the shoulder to 90 degrees in the scapular plane with the elbow straight and the shoulder internally rotated, while the patient resists a downward force (Figure 40–14).17
  ● “Thumb up” or “full can test”: This test is performed in similar fashion to the “thumb down” or “empty can test,” except that the arm is externally rotated (see Figure 40–14).17
  ● Whipple test: Elevate the arm to 90 degrees and adduct it so that the hand is in front of the opposite shoulder, with the elbow straight and the palm down. Have the patient resist a downward force. The Whipple test is sensitive for anterior supraspinatus pathology (Figure 40–15).18
  ● External rotation strength may be tested with the arm adducted against the side to assess infraspinatus function (Figure 40–16). Pain and/or weakness may indicate pathology of that tendon.10
  ● Napoleon test: Inability to bring the elbow anteriorly with the hand pressed against the belly is specific for subscapularis dysfunction (Figure 40–17).19
  ● Lift-off test: Inability to lift the hand off the lower lumbar region without extending the elbow is specific for subscapularis deficiency. This position may be difficult for patients to assume because of pain or restricted motion (Figure 40–18).11
  ● Speed test: Provokes the pain of bicipital tendinosis. It is performed by having the patient resist forward flexion of the shoulder with it flexed 90 degrees, the elbow extended, and the forearm supinated. A positive test reproduces pain at the bicipital groove. Pain reproduced
in other areas may be related to a variety of other shoulder pathologies (Figure 40–19).20

- **O’Brien active compression test:** The shoulder is flexed 90 degrees and adducted 10 to 15 degrees to the sagittal plane of the body. The elbow is fully extended and the shoulder internally rotated so that the thumb points down. The patient resists a downward force. The test is repeated with the forearm fully supinated so that the palm points upward (Figure 40–20). The test is considered positive if pain elicited in the first position is relieved in the second position. Pain localized “on top” of the shoulder suggests an AC joint abnormality, whereas pain located “inside” of the shoulder suggests a SLAP lesion.21

- **Biceps load test II:** The arm of the supine patient is elevated 120 degrees and maximally externally rotated with the elbow at 90 degrees flexion and the forearm supinated. The patient is asked to flex the elbow while it is resisted by the examiner. Reproduction of pain or an increase in pain with elbow flexion is a positive test. No pain or no change in preexisting pain with elbow flexion is a negative test (Figure 40–21).
  - Reported by Kim et al.22 to be 89.7% sensitive and 96.9% specific.

- **Instability testing:** Especially important in patients younger than 40 years. This testing may be difficult because of patient apprehension, and definitive examination may not be possible in the awake patient.
  - **Instability testing:** Especially important in patients younger than 40 years. This testing may be difficult because of patient apprehension, and definitive examination may not be possible in the awake patient.
  - **Glenohumeral translation versus glenohumeral instability:** Instability refers to excessive, pathologic, symptom-producing translation. Not all increased translation is pathologic. For example, throwers may develop increased asymptomatic anterior glenohumeral translation in their dominant shoulder.
  - Examine the contralateral, presumably normal, shoulder first to assess physiologic translation for the patient and to
reassure the patient that the examination will not hurt, possibly decreasing guarding.

- **Author's preferred technique for office examination of the awake patient:** This is similar to Andrews and Dugas’ “Lachman test” for instability and Cofield and Irving’s examination under anesthesia. Stand in the supine patient’s axilla. Grasp the superior shoulder with the hand closer to the patient. The ulnar digits secure the scapula, and the thumb and index finger grasp the humeral head so that any motion that is noted is glenohumeral in origin. The examiner’s other hand grasps the patient’s wrist. The shoulder is held in neutral rotation; abduction can be varied between 45 and 90 degrees. Anterior translation is produced by gently lowering the arm as the index finger pushes the humeral head anteriorly. Posterior translation is produced by gently raising the arm as the thumb pushes the humeral head posteriorly (Figure 40–22). After the amount of glenohumeral translation in neutral rotation is noted, the arm is externally rotated. At maximal external rotation, no anterior glenohumeral translation should be possible; there should be a firm endpoint because of capsuloligamentous tensioning. The presence of continued anterior translation is indicative of instability, similar to the Lachman test for the knee. Posterior instability is similarly evaluated by assessing posterior translation with the shoulder held in maximal internal rotation.

- **Glenohumeral translation:**
  - 1+: Increased translation compared to the contralateral, presumably normal side, without distinct subluxation of the humeral head over the glenoid rim. 1+ anterior translation can be normal in the dominant extremity, especially in overhead athletes.

---

**Figure 40–14:** Thumb up and thumb down tests.

**Figure 40–15:** Whipple test.

**Thumb Up-Thumb Down Tests**

**Whipple Test**

Lift-off test: A, Starting position with the shoulder internally rotated and the elbow flexed so that the back of the hand rests on the lower lumbar area. B, The patient actively lifts the hand away from the lower back without extending the elbow. (From Burkhart SS: *Orthop Clin North Am* 24:111-123, 1993.)

- 2+: Humeral head is subluxable to the rim of the glenoid but does not lock in frank dislocation.
- 2+ anterior translation is pathologic, whereas this degree of translation can be normal in the posterior direction.
- 3+: Humeral head can be dislocated and locked over the glenoid rim. 3+ translation always is abnormal.
- **Jobe anterior apprehension/posterior relocation test:** Abduct, extend, and maximally externally rotate the shoulder of the supine patient. Apprehension that the arm may dislocate, which is relieved by a posteriorly directed force applied to the proximal humerus, is highly sensitive and specific for instability (Figures 40–23 and 40–24). Pain alone is not a positive test, because pain can be caused by rotator cuff pathology in the absence of instability.26
- An alternative way to perform this test is the reverse posterior relocation test. A posteriorly directed force is placed against the patient’s proximal humerus before and during placement of the arm into abduction-external rotation. This often elicits less discomfort. After the patient has been placed in this position, the posterior force is slowly decreased. Apprehension concerning impending instability strongly suggests anterior glenohumeral instability.
- **Posterior stress test:** Flex the supine patient’s shoulder to 90 degrees, then internally rotate and adduct it. The elbow also is flexed 90 degrees. A posterior directed force is applied. Painful posterior subluxation or apprehension suggests posterior instability. Symptoms should diminish...
with abduction/extension. If scapular malpositioning is contributing to the instability, the patient’s assistance may be needed to recreate the symptoms (Figure 40–25).27

- **Sulcus sign:** Pull inferiorly on the relaxed patient’s adducted arm. Significantly increased space, especially more than 2 to 3 cm, observed/palpated beneath the lateral acromion suggests inferior glenohumeral hyperlaxity. Failure of the sulcus to diminish with external rotation suggests a tear of the rotator interval. As for the other instability tests, comparison should be made to the opposite shoulder (Figure 40–26).25

- **Diagnostic injections:** Helpful in determining the source of pain in closely related anatomic regions. For example, a decrease in superior shoulder pain and a cross-arm adduction test made negative by an AC joint injection are strongly suggestive of symptomatic pathology at this location. Steroid placed in the injection has the potential to provide at least temporary symptomatic relief.

- **Pearl:** Probably the least painful way of injecting the subacromial space is to insert a 22-gauge 1.5-inch needle through the Neviaser portal, medial to the acromion, anterior to the scapular spine, and posterior to the clavicle. Aim anterolaterally toward the greater tuberosity. Make sure to start medial enough that you do not hit the inferior acromion, which may cause significant pain (Figure 40–27).

- **Another common method of injection is to start just inferior to the posterior border of the acromion and aim anteriorly and slightly medially.**

- **Pearls:**
  - Most symptomatic rotator cuff pathology begins on the articular side. Therefore, although the subacromial injection may relieve the often considerable pain of secondary impingement, it may not completely eliminate the patient's pain.
  - Look at the patient's anteroposterior radiograph before injecting the AC joint to determine its slope, which varies. Following this slope often makes entering the AC joint easier. The AC joint often is easier to enter in its posterior half. The inside of the joint often feels gritty because of the intraarticular disc. Once the joint is full, there is often a back-pressure on the syringe's plunger. If you go through the AC joint, your needle will be in the subacromial space. For this reason, when trying to differentiate between sources of pain, it is often preferable to inject the subacromial space before injecting the AC joint.

---

**Diagnostic Imaging**

- **Plain radiographs:** Shoulder radiographs should include an anteroposterior radiograph in the plane of the scapula with the humerus externally rotated, a transscapular lateral (“Y”) view, and an axillary lateral.
- **The axillary radiograph most clearly demonstrates glenohumeral dislocation or subtle arthritis.**

- **Emergency Room Pearls:**
  - Always get an axillary radiograph.
  - In cases of acute trauma precluding comfortable shoulder abduction, a Velpeau axillary view may easily be substituted. In this view, the arm remains in a sling and the standing patient leans backwards into the XR beam, which is positioned vertically. Alternatively, the patient may be supine (Figure 40–28).28
  - Never accept suboptimal radiographs. Many emergency room technicians are not highly experienced in taking good shoulder radiographs. Decisions often are made, and diagnoses ruled out, based on those radiographs. If you are unsure, repeat the radiographs. You may have to assist with patient
positioning in order to obtain the radiographs you require.

- **Ultrasound:** Although isolated reports show efficacy in diagnosing full-thickness rotator cuff tears, results are operator dependent, and ultrasound currently is not commonly used.

- **Magnetic resonance imaging:** Provides excellent soft tissue detail. Especially good at diagnosing avascular necrosis, tumors, cysts, osteomyelitis, and rotator cuff muscle atrophy.

---

**Figure 40–20:**
O’Brien test.

**Figure 40–21:**
Biceps load II test.

**Figure 40–22:**
Instability test.
Figure 40–23: Anterior apprehension test.

Figure 40–24: Posterior relocation test.

Figure 40–25: Posterior stress test.

Figure 40–26: Sulcus test.
Figure 40–27:
Subacromial injection via Neviser portal.

Figure 40–28:
CHAPTER 40 Examination of the Shoulder

References


3. Itoi E, Hsu HS, An KN: Biomechanical investigation of the inferior glenohumeral ligament complex and compares it to a hammock that supports the humeral head during arm elevation.


20. Bennett WF: Specificity of the Speed’s test: arthroscopic technique for evaluating the biceps tendon at the level of the bicipital groove. *Arthroscopy* 14:789-796, 1998. Reports Speed’s test to be 90% sensitive and 13.8% specific. The test was positive with a variety of shoulder pathologies other than bicipital tendinosis.

Reports the O’Brien active compression test for SLAP lesions and acromioclavicular joint abnormalities.

22. Kim SH, Ha KI, Ahn JH et al: Biceps load test II: A clinical test for SLAP lesions of the shoulder. *Arthroscopy* 17:160-164, 2001. The biceps load test II is described and is reported as 89.7% sensitive and 96.9% specific.


