ANATOMY

The elbow is a functional link for positioning the hand in space, a fulcrum for the forearm lever, and a load-carrying joint. As such, it requires a combination of mobility and stability. The three articulations of the elbow provide flexion and extension, as well as forearm rotation (Figure 15-1). Control and stability of flexion and extension are provided primarily through the ulnohumeral (trochlea and olecranon) articulation and secondarily through the radiohumeral (capitellum and radial head) articulation. The trochlea is shaped like a spool and fits in the wrench-shaped trochlear notch. This anatomic configuration, in conjunction with the collateral ligaments, provides a stable hinge joint that can lift heavy objects. Rotation of the forearm occurs through the proximal and distal radioulnar articulations.

Distal to the radial head, the bone tapers to form the radial neck, then flares at the radial tuberosity—the insertion site of the biceps tendon. Between the radius and the ulna is the interosseous membrane—a thickened, ligamentous structure that connects the two bones.

Figure 15-1: Bones of Right Elbow Joint
bones in a manner that provides stability while allowing forearm rotation.

Muscles that cross the elbow anteriorly include the elbow flexors and the flexor-pronator forearm muscles that originate from the medial epicondyle (Figure 15-2). In the forearm, the volar muscles are arranged in three layers. The superficial group includes the pronator teres, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris. The middle layer is the flexor digitorum superficialis. The deep layer comprises the supinator, flexor digitorum profundus, flexor pollicis longus, and pronator quadratus. The flexor-pronator muscle group primarily provides wrist flexion and forearm pronation. The biceps is a secondary flexor of the elbow and a strong supinator. Immediately deep to the biceps lies the brachialis muscle—the major flexor of the elbow.

Posterior elbow muscles include elbow extensors, wrist and finger extensors, and the supinator. Posterior forearm muscles are arranged in two layers. The superficial group originates from a common tendon at the lateral epicondyle and includes a lateral component (brachioradialis, extensor carpi radialis longus, and extensor carpi radialis brevis) and a medial subgroup (extensor digitorum, extensor digiti minimi, extensor carpi ulnaris, and anconeus). The deep posterior forearm muscles are the supinator, abductor pollicis longus, extensor pollicis brevis, and extensor pollicis longus (see Figure 15-2).

The brachial artery, the main artery of the arm and elbow, travels in the anterior compartment of the arm adjacent to the median nerve. Proximal to the elbow, it gives off collateral arteries that help form a rich plexus of vessels around the elbow. At the level of the radial head, the brachial artery bifurcates into the radial and ulnar arteries. The ulnar artery enters the forearm posterior to the pronator teres, whereas the radial artery travels between the brachioradialis and the supinator muscle.

The median nerve enters the forearm between the humeral and ulnar heads of the pronator teres and travels inferior to the flexor digitorum superficialis muscle (Figure 15-3). The anterior interosseous nerve branches innervate the index, and sometimes, the long finger component of the flexor digitorum profundus, the flexor pollicis longus, and the pronator quadratus. Because of the location of its fibers in the median nerve, isolated paralysis of the anterior interosseous nerve may occur with an elbow fracture. The rest of the median nerve innervates all the volar forearm muscles except the ulnar half of the flexor digitorum profundus (fourth and fifth fingers) and the flexor carpi ulnaris, both of which are supplied by the ulnar nerve.

The ulnar nerve exits the anterior compartment of the arm, passing behind the medial epicondyle into the cubital tunnel at the elbow, then enters the forearm between the two heads of the flexor carpi ulnaris (Figure 15-4). It innervates the flexor carpi ulnaris muscle, the ulnar half of the flexor digitorum profundus muscle, and, ultimately, the intrinsic muscles of the hand.

In the arm, the radial nerve travels within the posterior compartment, then enters the anterior compartment lateral to the humerus. In the antecubital fossa, the radial nerve innervates the brachioradialis and extensor carpi radialis longus before dividing into superficial (sensory) and deep (mostly motor) branches (Figure 15-5). The superficial radial nerve provides sensation to the radial dorsal wrist and hand. The deep branch innervates the remaining extensor muscles of the forearm. It travels deep and through the supinator muscle and exits this muscle as the posterior interosseous nerve. Distal to the radial tuberosity, the deep branch of the radial nerve may lie “on the bone” and, as such, is vulnerable to injury in fractures of the proximal radius or in operations at this site.

**PHYSICAL EXAMINATION**

Inspect the elbow for swelling and ecchymosis, and determine the carrying angle (the axial alignment of the humerus and the ulna with the elbow extended). The normal carrying angle is $10^\circ$ to $20^\circ$, with most studies observing slightly greater *cubitus valgus* in females. Angular deformities may occur secondary to previous trauma, growth disturb-
Figure 15-2: Bony Attachments of Muscles of Forearm

Anterior view

- Brachioradialis muscle
- Extensor carpi radialis longus muscle
- Common flexor tendon
- Pronator teres muscle (humeral head)
- Common extensor tendon
- Pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, flexor digitorum superficialis (humeroulnar head)

Posterior view

- Flexor carpi ulnaris muscle (ulnar origin)
- Flexor digitorum profundus muscle
- Extensor carpi ulnaris muscle (ulnar origin)
- Flexor digitorum superficialis muscle (humeroulnar head)
- Pronator teres muscle (ulnar head)

Note: Attachments of intrinsic muscles of hand not shown
Elbow and Forearm

bances, or genetic syndromes. Ecchymosis, swelling, or both about the elbow indicate a muscle or tendon injury, fracture, or elbow sprain or dislocation.

Palpate subcutaneous landmarks for sites of tenderness, deformity, or effusion that indicate the site of occult fracture, tendinosis, ligament sprain, or tendon rupture. From lateral to medial, the structures in the antecubital fossa are the biceps tendon, brachial artery, and median nerve. A palpable defect is key to diagnosing rupture of the distal biceps tendon or disruption of the triceps tendon. Joint effusion is best detected in the “soft spot” between the lateral epicondyle, radial head, and olecranon. Tenderness over the radial head or humeral condyles may indicate an occult fracture that is not visible on radiographs.

The zero starting position for measurement of elbow motion is a straight extremity (Figure 15-6). Young children commonly extend the elbow by 10° to 15°, but adults usually cannot extend the elbow past the zero starting position. The normal range of elbow flexion-extension is 0° to 145°. The plane of forearm rotation is pronation-supination. Pronation literally means “the state of being prone” or, as it relates to the forearm, “the palm being turned backward.” Likewise, supination literally means “the state of being supine” (ie, the

Figure 15-3: Median Nerve

![Median Nerve Diagram]
**Figure 15-4: Ulnar Nerve**

- **Ulnar Nerve (C8, T1)** (only muscles innervated by ulnar nerve are depicted)
- **Cutaneous Innervation**
- Flexor pollicis brevis m. (deep head only; superficial head and other thenar muscles supplied by median n.)
- Adductor pollicis m.
- Ulnar nerve (no branches above elbow)
- Articular branch (behind medial condyle)
- Flexor digitorum profundus m. (medial portion only; lateral portion supplied by anterior interosseous branch of median n.)
- Flexor carpi ulnaris m. (drawn aside)
- Dorsal branch
- Palmar branch
- Superficial cutaneous branch
- Deep motor branch
- Palmaris brevis
- Abductor digiti minimi
- Flexor digiti minimi brevis
- Opponens digiti minimi
- Common palmar digital n.
- Palmar and dorsal interossei mm.
- 3rd and 4th lumbrical mm. (turned down)
- Proper palmar digital nn. (dorsal digital nerves are from dorsal branch)
- Branches to dorsum of middle and distal phalanges
- Hypothenar muscles
  - Proper palmar digital nn.
Figure 15-5: Radial Nerve
palm turned forward, or anteriorly). In forearm rotation measurement, the patient’s arm is stabilized against the chest wall, and the elbow is flexed to 90° (Figure 15-7). The zero starting position occurs with the thumb aligned with the humerus. Normal motion in adults is 75° pronation and 85° supination. Mild elbow contractures are of limited functional consequence, as most activities of daily living are accomplished in an arc of motion from 30° to 130° flexion and 50° each of pronation and supination.

DEGENERATIVE DISORDERS OF THE ELBOW

Arthritis

Primary osteoarthritis of the elbow is relatively uncommon and accounts for 2% to 7% of elbow arthritis. These patients often work at a job or hobby that repetitively loads the elbow. Males and the dominant extremity are more commonly affected. Manifestations include stiffness, loss of motion, and pain with activity. Terminal extension typically increases pain. Secondary osteoarthritis of the elbow most often follows intra-articular fractures. Rheumatoid arthritis is by far the most common cause of inflammatory arthritis of the elbow. Of patients with rheumatoid arthritis, 20% to 50% eventually have elbow involvement.

Most patients with elbow arthritis can be treated with standard nonoperative modalities. Arthrotomy or arthroscopy may be indicated for loose body removal, osteophyte resection and capsular resection, or synovectomy. Elimination of locking and decreased pain are more predictable after removal of a loose body than is increased motion. Injury to neurovascular structures is a potential risk of elbow arthroscopy, but complications are generally minimal, and recovery time is shorter compared with open procedures.

Resection ulnohumeral arthroplasty that includes resection of the tip of the olecranon, débridement of the olecranon fossa, and resection of osteophytes from the coronoid may be used to treat patients with extensive humeral osteophytes and disabling pain at the extremes of motion, but no pain at rest or in the mid arc of motion. Patients should have good elbow stability and normal musculature. Concomitant transposition of the ulnar nerve is indicated for patients with symptoms of entrapment. Increased motion and decreased pain have been reported in 85% of patients who undergo this procedure. Symptoms often
return; however, the interval improvement and delay in the need for total joint arthroplasty are helpful. Resection arthroplasty that includes the distal humerus and radial head may be combined with interposition of autogenous fascia or dermis between the bone surfaces for patients with more severe arthritis.

Arthrodesis of the elbow is seldom indicated because no single position provides reasonable function. The rare indications include (1) incurable sepsis or (2) the need for a strong, stable joint in a young manual laborer who has a normal shoulder and contralateral limb.

Total elbow arthroplasty provides consistent short-term results. A semiconstrained prosthesis that depends on both the component and the surrounding soft tissues for joint stability provides the best compromise for function and the highest long-term survival rates (approximately 95% at 7 years) (Figure 15-8). Loosening of the implant with resultant instability and recurrent pain is the most common long-term complication. At the elbow, the rate of loosening is higher and prosthetic revision is less predictable and more complicated than at other sites of joint replacement. In general, total elbow arthroplasty is preferred in the older patient, whereas resection or interposition arthroplasty is preferred in the younger patient. Because of severe erosion and joint instability, total elbow arthroplasty is indicated in nearly all patients with rheumatoid arthritis.

**Lateral Epicondylitis**

Lateral epicondylitis, commonly known as “tennis elbow,” occurs secondary to a tendinosis of the extensor carpi radialis brevis origin immediately distal to the lateral epicondyle. The name is misleading because the lateral epicondyle is not the site of involvement, inflammation is not present, and most patients are not active tennis players. The typical patient is 35 to 50 years of age and expe-
Chapter 15

Figure 15-8: Prosthesis for Total Elbow Arthroplasty

Inherent stability by mechanical locking of components with hinge arrangement

Design of prosthesis allows 5°–7° of rotation about flexion-extension, varus-valgus and axial rotation

Three types of total elbow arthroplasty have been used. The constrained design replaced the elbow joint with a hinged prosthesis. All stability of the joint was dependent on the prosthesis which was not built to accommodate the rotational demands of the elbow joint. Due to an unacceptably high failure rate, this prosthesis has been abandoned. Results were better with an unrestrained prosthesis but with 5%–20% incidence of postoperative instability, most patients are now treated with a semi-constrained prosthesis, which has inherent stability by linking of the component usually with a hinge (shown above) or a snap-fit axis arrangement.

Medial Epicondylitis

Medial epicondylitis, commonly known as “golfer’s elbow,” occurs secondary to tendinosis of the flexor-pronator origin. Examination demonstrates tenderness just distal and anterior to the medial epicondyle. Pronation and wrist flexion against resistance exacerbated an insidious or acute lateral elbow pain that is exacerbated by activities that involve forceful wrist extension. Motions such as turning a screwdriver or opening a door can aggravate the symptoms. Over time, the pain can become severe and may interfere with routine activities.

Examination shows pain just distal and posterior to the lateral epicondyle that is exacerbated when the extensor carpi radialis brevis is stressed in an elongated position (wrist extension against resistance with the elbow extended) (Figure 15-9). Elbow motion and radiographic findings are normal. The differential diagnosis includes radial nerve (posterior interosseous branch) entrapment, arthritis involving the radiohumeral articulation, lateral elbow instability, and referred pain from cervical radiculopathy.

Nonoperative treatment consists primarily of patience, modification of activities, and progressive strengthening exercises. Patients should be taught to “grasp and lift only in supination.” A counterforce strap worn around the proximal forearm may decrease pain during lifting activities. Corticosteroid injections at the site of maximum tenderness should be infrequently used. Operative treatment, which is infrequently required, involves excision of the pathologic area of degenerated tendon. It results in an 85% to 90% return to full activity without pain. Persistent pain usually occurs secondary to an incomplete resection or an incorrect diagnosis.
Epicondylitis (tennis elbow)
Exquisite tenderness approximately
1 cm distal to the lateral epicondyle

Figure 15-9: Epicondylitis

Elbow and Forearm

bete the pain. As in lateral epicondylitis, elbow motion and radiographic findings are usually normal. The differential diagnosis includes ulnar nerve entrapment, medial elbow instability, and cervical radiculopathy. Treatment principles for the noncompetitive athlete are similar to those used for lateral epicondylitis.

NERVE ENTRAPMENT SYNDROMES

Ulnar Nerve Entrapment

Compression of the ulnar nerve at the elbow, or cubital tunnel syndrome, is the most common cause of peripheral nerve entrapment after carpal tunnel syndrome (Figure 15-10). The cubital tunnel extends from 8 cm above the medial epicondyle, where the ulnar nerve passes from the anterior to the posterior compartment of the arm, to 5 cm distal to the elbow, where the ulnar nerve enters the anterior compartment of the forearm. Compression of the nerve may occur at any site within this tunnel. A hypermobile or subluxating ulnar nerve also may produce symptoms, and this condition may be aggravated by increased mobility and snapping of the medial triceps.

Symptoms vary with the duration and the severity of compression. Aching on the medial aspect of the elbow and numbness on the dorsal and palmar surfaces of the fingers innervated by the ulnar nerve that is aggravated by elbow flexion are typical (see Figure 15-4). Examination shows a positive Tinel sign and altered ulnar nerve sensation in the fingers that typically is exacerbated by flexion of the elbow and pressure on the ulnar nerve. Loss of sensation on the dorsoulnar aspect of the wrist and hand and weakness of the intrinsic muscles causing decreased pinch and grip strength may or may not be present. The differential diagnosis includes ulnar nerve entrapment at the wrist, cervical radiculopathy, thoracic outlet syndrome, and medial epicondylitis.

Nonoperative treatment may include nighttime splinting to keep the elbow in a relatively extended position, as well as avoidance of prolonged leaning on the elbow, use of vibrating tools, or activities that repetitively flex the elbow. Operative treatment is recommended for persistent moderate or severe symptoms. The procedure most commonly used is decompression and transposition of the nerve anterior to the medial epicondyle.

Median Nerve Entrapment

At the elbow, entrapment of the median nerve can occur at several locations, including an anomalous supracondylar process of the humerus and the lacertus fibrosus (Figure 15-11). Fibrous constriction arches also may entrap the nerve as it passes beneath the two heads of the pronator teres or flexor digitorum superficialis. The most common location of entrapment is the pronator teres—hence, the alternative name, pronator syndrome.

Typical symptoms include an aching pain in the mid to proximal forearm that is aggravated by repetitive lifting activities. Numbness and weakness in the median nerve distribution are variable and may be absent. Aggravation of symptoms after 90 seconds of resisted pronation or resisted activity of the flexor digitorum superficialis of the long finger suggests median nerve entrapment. Nerve conduction tests are less useful in this syndrome but should be performed. A lidocaine and corticosteroid injection may be beneficial and diagnostic.
Figure 15-10: Cubital Tunnel Syndrome

Clinical signs
- Interosseous muscle wasting
- Motor weakness and muscle wasting in severe cases
- Paresthesias in distribution of ulnar nerve
- Tinel sign
- Elbow flexion test

Nonsurgical management
- Elbow pad
- Furniture pad
- Padding of elbow or of furniture may prevent compression
- Night splinting of elbow in mild flexion prevents nocturnal paresthesias

Submuscular transposition of ulnar nerve
- Biceps brachii m.
- Brachialis m.
- Medial intermuscular septum
- Triceps brachii m.
- Medial epicondyle
- Exposure of ulnar nerve
- 90° Z-plasty incision and lengthening of flexor-pronator muscle mass
- Flexor-pronator muscle mass
- Flexor carpi ulnaris m.
- Anterior transposition of ulnar nerve
- Divided tendon of origin
- Lengthened and repaired flexor-pronator over transposed nerve
Figure 15-11: Proximal Compression of Median Nerve

- **Pronator syndrome**
  - Pain location
  - Provocative maneuvers
    - Compression by flexor digitorum superficialis muscle
      - Flexion of middle finger against resistance
    - Compression by pronator teres muscle
      - Pronation against resistance with forearm in supination
    - Compression by lacertus fibrosus
      - Flexion of wrist against resistance

- **Anterior interosseous syndrome**
  - Normal
  - Abnormal

**Anatomical structures**:
- Median nerve
- Supracondylar process
- Ligament of Struthers
- Medial epicondyle
- Lacertus fibrosus
- Pronator teres muscle
- Anterior interosseous nerve
- Flexor digitorum superficialis muscle and arch
- Flexor pollicis longus muscle

**Legend**:
- Hypoesthesia and activity-induced paresthesias
- Compression by flexor digitorum superficialis muscle
- Compression by pronator teres muscle
- Compression by lacertus fibrosus
The differential diagnosis includes muscle tears in the proximal forearm and carpal tunnel syndrome. Carpal tunnel syndrome can be ruled out if there is loss of sensation at the thenar eminence (supplied by the palmar branch originating proximal to the wrist) or weakness of the flexor pollicis longus. If avoidance of inciting activities does not relieve the symptoms, surgical decompression is indicated. All areas of possible compression should be explored.

Radial Nerve Entrapment

Radial nerve entrapment at the elbow typically involves compression of the posterior interosseous branch of the radial nerve, most commonly as it passes beneath the proximal edge of the supinator muscle at the arcade of Frohse (Figure 15-12). Because the posterior interosseous nerve is purely motor, the posterior interosseous syndrome affects only motor function of the thumb, finger extensors, and extensor carpi ulnaris (see Figure 15-5). Symptoms and signs of motor weakness are often vague in the early phase of the condition, and radial tunnel syndrome sometimes masquerades as a resistant lateral epicondylitis.

Diagnosis is based on history and an examination that typically shows tenderness over the proximal supinator muscle (approximately 5 cm distal to the lateral epicondyle). Pain is typically exacerbated by extension of the long finger against resistance with the elbow extended.

Surgical decompression with release of the impinging fibrous bands of the supinator muscle is usually helpful if symptoms are severe or do not resolve after a period of observation. The course of the posterior interosseous nerve through the full extent of the supinator muscle should be explored because entrapment also may occur in the midsubstance of the muscle and in its distal margin.

MISCELLANEOUS CONDITIONS

Acute Sprains

The medial collateral ligament (MCL) complex includes the anterior bundle, the posterior bundle, and the transverse ligament (Figure 15-13). The anterior bundle of the MCL originates at the midportion of the medial epicondyle and inserts onto the coronoid tubercle of the ulna. The anterior bundle is the primary restraint to valgus stress. Its eccentric location provides valgus restraint throughout the full arc of flexion-extension. With the elbow in full extension, stability to valgus stress is conferred equally by the MCL, anterior capsule, and bony articulation. With the elbow in 90° of flexion, the MCL provides 55% of valgus stability. The contribution of the radiocapitellar articulation to valgus stability is secondary and significant only when the anterior bundle is disrupted.

The lateral collateral ligament (LCL) complex includes the radial collateral ligament, the annular ligament, the accessory lateral collateral ligament, and the lateral ulnar collateral ligament. The lateral ulnar collateral ligament originates from the anteroinferior portion of the lateral epicondyle, inserts on the supinator crest of the proximal ulna, and is the primary lateral stabilizer. The annular ligament serves as a checkrein for the radial head.

Patients with acute sprains report a history of acute pain after a fall or forceful throwing injury. Valgus distraction injuries transmit loads primarily to the MCL complex and the medial flexor-pronator muscular origin. Injuries to the LCL typically occur with a varus stress to the elbow joint when it is in extension and the forearm is in pronation. In acute injuries, the global swelling and tenderness, as well as the unreliability of stress maneuvers, make it virtually impossible for the clinician to determine precisely which ligament components are injured. Avulsion fractures may be seen on radiographs. Short-term immobilization and gradual resumption of activities are successful in treating most acute elbow sprains.

Chronic Medial Elbow Pain and Instability

Medial elbow pain and MCL instability typically develop in athletes involved in repetitive throwing activities. Pain is usually gradual
Motor signs

Pain locations in radial tunnel syndrome

Provocative tests for radial tunnel syndrome

Figure 15-12: Radial Nerve Compression
in onset, localized to the medial aspect of the elbow, and most severe during the acceleration phase of pitching (ie, the phase of pitching in which maximum valgus stress is transmitted to the elbow). MCL disruption or attenuation is most often noted at the mid-substance of the anterior bundle. Concomitant symptoms of lateral elbow pain may occur secondary to the valgus overload, causing compression, shear injury, and osteochondral fragments and/or osteochondritis dissecans of the capitellum.

Examination reveals tenderness on the medial aspect of the elbow. Valgus instability is assessed with the elbow in 25° of flexion to relax the ulnohumeral articulation. The patient should be evaluated for the presence of a concomitant ulnar entrapment neuropathy. Radiographs should be inspected for signs of osteochondral loose bodies, medial osteophytes, and osteochondritis dissecans. Magnetic resonance imaging (MRI) can be helpful in preoperative planning.

Nonoperative treatment includes activity modification followed by a gradual rehabilitation program. For persistent symptomatic instability, operative treatment includes reconstruction of the MCL with a tendon graft, removal of any associated osteophytes or loose bodies, and decompression of ulnar neuritis.

Posterolateral Rotatory Elbow Instability

Posterolateral rotatory instability develops after injury to the ulnar collateral component of the LCL. With a lax or attenuated ligament, patients report lateral elbow pain and catching or giving way of the elbow. The lateral pivot test may be difficult to perform except when the patient is completely relaxed under anesthesia. MRI studies often identify the ligament disruption. Reconstruction of the lateral ulnar collateral ligament with a tendon graft is required for treatment of persistent and disabling symptoms.

Rupture of the Distal Biceps Tendon

Rupture of the distal biceps brachii tendon is uncommon; however, timely diagnosis of these injuries is important because failure to recognize and repair the lesion before the onset of irreversible muscle contraction decreases the strength of elbow flexion and forearm supination by 30% to 50%. Predisposing factors include a male older than 40 years and the presence of preexisting degenerative changes in the tendon. Rupture typically occurs at the insertion of the biceps tendon into the radial tuberosity (see Figure 15-13).

Injury results from an extension force on a partially flexed and contracting biceps muscle.
Patients frequently report the acute onset of sharp pain in the anterior aspect of the elbow, followed by a chronic, dull ache that is exacerbated by lifting activities. Examination shows tenderness and a defect in the antecubital fossa resulting from absence of the normally prominent bicipital tendon. If the aponeurosis remains intact, the defect is not as obvious. If the tendon rupture is incomplete, no defect is obvious, but the patient experiences pain and weakness on flexion of the elbow against resistance. Radiographs are usually normal. MRI may be helpful in evaluation of equivocal cases.

Partial ruptures can be managed with splinting and activity modifications. Complete ruptures are treated more successfully with operative repair. Injury to the radial nerve is a possible complication of surgical repair.

Olecranon Bursitis

The olecranon bursa is easily irritated because of its superficial location (see Figure 15-13) and the tendency for people to lean on their elbows. Precipitating factors include falls or direct blows, an inflammatory arthritis such as rheumatoid arthritis or gout, and occupations and avocations that cause prolonged irritation. Olecranon bursitis also may develop in patients with chronic lung disease who lean on their elbows to aid breathing. Septic bursitis (infection) may occur primarily, but it is more likely to develop as a secondary complication of aseptic olecranon bursitis.

The onset of pain and swelling is relatively rapid when caused by trauma or infection but is indolent when caused by other conditions. Pain is variable, exacerbated by elbow flexion, and more intense with infection. Examination reveals a boggy swelling over the olecranon process. Erythema and increased warmth are common in patients with acute bursitis and universal in individuals with septic bursitis. Tenderness is less marked in chronic, recurrent aseptic bursitis.

If the olecranon bursitis is small and only mildly symptomatic, treatment should include observation, avoidance of direct pressure, and, occasionally, short-term splinting with the elbow extended. Patients with more symptomatic bursitis should have the bursa aspirated for Gram stain and culture. Patients without infection should have the elbow protected and immobilized in relative extension with a foam or compressive dressing. Patients with septic bursitis require limited surgical drainage or daily aspiration and antibiotic administration that covers penicillin-resistant Staphylococcus aureus. Excision of a chronically inflamed olecranon bursa should be avoided if at all possible because recurrence is common and operative treatment may lead to chronic infection.

FRACTURES

General Considerations

When a patient reports an injury to the elbow or forearm, inspect for swelling, ecchymosis, deformity, and open wounds. Palpate the area of maximum tenderness, and assess joint swelling and distal pulses. Assess function of the median, radial, and ulnar nerves. Anteroposterior and lateral radiographs of the elbow are adequate for assessing most elbow injuries, but complicated intra-articular injuries may necessitate oblique views and computed tomographic (CT) scans. The radial head should point to the capitellum in both anteroposterior and lateral views; otherwise, a dislocation or subluxation is present. Look for a fat pad sign if no fracture is obvious. In a normal elbow, the anterior fat pad can be seen on a lateral radiograph, but the posterior fat pad is not visualized. Any process that causes an elbow effusion elevates both anterior and posterior fat pads (Figure 15-14). Forearm injuries necessitate anteroposterior and lateral radiographs that visualize bony anatomy from the elbow to the wrist.

Fractures about the Elbow in Adults

Distal Humerus

In adults, fractures of the distal humerus are usually caused by high-speed injuries with the elbow flexed more than 90°. As a result, these fractures are frequently comminuted
Fracture patterns include supracondylar, transcondylar, T or Y intercondylar, and lateral/medial condylar, as well as the rare isolated capitellar or trochlear fracture.

Displaced fractures usually require open reduction. The type of internal fixation used depends on the bony anatomy. The distal end of the humerus is triangular, with medial and lateral columns (condyles). As the distal humerus widens in the medial-lateral plane, it thins in the anterior-posterior plane. Only the columns are thick enough to support plate fixation. Single-condyle fractures may be fixed with screws only, but two plates placed at right angles provide the best fixation for supracondylar, transcondylar, and intercondylar fractures. The lateral column is fixed with a posteriorly positioned plate, and the medial column, with a plate on the medial ridge (Figure 15-15). Protection and transposition of the ulnar nerve is an appropriate adjunct of surgical management.

**Radial Head**

Fracture of the radial head is the most common elbow fracture in adults. The radial head typically fails under a compressive axial and valgus load when the person falls on an outstretched hand with the forearm pronated and the elbow slightly flexed. Females are twice as likely as males to fracture the radial head. Associated injuries may include fracture of the capitellum, coronoid, or olecranon; disruption of the ulnar collateral ligament; or tear of the interosseous ligament with dislocation of the distal radioulnar joint.

The Mason classification is helpful in determining the appropriate treatment for simple radial head or neck fractures (Figure 15-16). Type I fractures are treated with limited immobilization for a few days, followed by early...
Fracture of lateral condyle of humerus. Fracture of medial condyle less common. Fractured condyle fixed with one or two compression screws.

Articular surface of distal humerus reconstructed and fixed with transverse screw and buttress plates with screws. Ulnar nerve may be transposed anteriorly to prevent injury. Lateral column fixed with posterior plate and medial column fixed with plate on the medial ridge.

Olecranon reattached with longitudinal Kirschner wires and tension band wire wrapped around them and through hole drilled in ulna.
range-of-motion exercises. Type II fractures with acceptable fracture patterns should be treated with open reduction and internal fixation. In equivocal situations, particularly if the patient has a low-demand occupation, type II injuries can be treated nonoperatively, with delayed excision of the radial head if persistent pain or significant limitation of forearm rotation occurs. Uncomplicated type III fractures should be treated with excision of the radial head. When radial head fractures are associated with dislocation of the elbow and severe ligament injury or disruption of the forearm interosseous, the fragments should be removed and the radial head replaced by a prosthesis.

Results of treatment are uniformly good for type I fractures and often satisfactory for simple type II and type III fractures. Potential complications include loss of motion, elbow instability, posttraumatic arthritis, myositis ossificans, and distal radioulnar symptoms.

**Olecranon Fractures**

Olecranon fractures are caused by a direct blow or an indirect avulsion injury (eg, a fall on an outstretched hand with the elbow...
slightly flexed while the triceps is contracting). Avulsion injuries create a transverse or slightly oblique fracture pattern. Direct blows typically are associated with some degree of comminution. A palpable defect is present with displaced fractures. The skin should be evaluated carefully for possible open injury. Radiographs should be scrutinized for detection of associated fractures of the radial head or coronoid process.

Nondisplaced fractures can be treated with a splint or cast (Figure 15-17). The elbow is positioned in approximately 45° of flexion to relax the pull of the triceps. Displaced fractures require open treatment. Tension band wiring, which transforms distraction forces into compression, is the most common form of fixation. Plate fixation is required for fractures that extend to the coronoid or ulnar shaft. Comminuted fractures can be managed by excision of the fragments and repair of the triceps tendon. If the collateral ligaments are intact, as much as 70% of the proximal olecranon can be excised without resultant instability.

Monteggia Fractures/Dislocations

The Monteggia fracture/dislocation is a fracture of the ulna that is associated with dislocation of the radial head (Figure 15-18). Bado classified these injuries into four types. The radial head is dislocated anteriorly in type 1, posteriorly in type 2, and laterally in type 3, and the ulnar fracture is angulated in the direction of the radial head dislocation. In a type 4 injury, the proximal radius and ulna are fractured, and the radial head is dislocated anteriorly. Type 1 and type 2 account for 70% to 90% of Monteggia injuries. Type 1, the most common, may be caused by a direct blow or a fall on the outstretched hand with the forearm in full pronation. Type 2 injuries occur most often in adults. Radial nerve injury, often isolated to the posterior interosseous branch, is relatively common in Monteggia lesions.

These injuries are frequently misdiagnosed, particularly in children, in whom palpation of an anteriorly displaced radial head is more difficult. Another common mistake is to recognize the fracture of the ulna but miss the dislocated radial head, either because the radiograph did not adequately show the elbow or because the evaluator did not understand that on both anteroposterior and lateral radiographs, a line through the axis of the proximal radius and the radial head should pass through the capitellum.

If recognized early, Monteggia injuries in children usually can be treated by closed reduction and cast immobilization. Adults require open reduction and internal fixation of the ulnar fracture. When the ulna is anatomically reduced, the radial head typically reduces and becomes stable without additional surgical intervention.
Type 1 Monteggia fracture/dislocation with anterior dislocation of radial head and anterior angulation of proximal or middle third ulna fracture.

Less common type 2 Monteggia fracture/dislocation with ulna fracture angulated posteriorly and radial head dislocated posteriorly.

Fracture of ulna treated with open reduction and internal fixation using compression plate and screws. After reduction of ulna, radial head spontaneously reduced.

Preoperative radiograph shows Type I Monteggia fracture/dislocation.

Postoperative radiograph shows compression plate in place.

If radial head does not reduce after angulation of ulna is corrected, open reduction of radial head dislocation and repair of annular ligament are needed. Typically, this is done through a separate incision between the anconeus and extensor carpi ulnaris muscles.
Fractures of the Diaphysis of the Radius and Ulna

In adults, motor vehicle accidents or falls from a considerable height usually cause both-bone forearm fractures. Displacement, angulation, and shortening are common when both the radius and the ulna are fractured. A direct blow usually fractures only one bone—typically the ulna, as the forearm is positioned to stop the oncoming injury (“nightstick” fracture). Because only one component of the “structural rectangle” has been disrupted, direct-blow injuries of the ulna or radius are minimally displaced and usually can be treated by nonoperative methods. However, a fall on the outstretched hand with the forearm pronated can cause a fracture at the middle/distal third junction of the radius with associated disruption of the distal radioulnar ligaments (Galeazzi fracture). In this injury, two sides of the structural rectangle are injured; therefore, the fracture of the radius is displaced and unstable.

Displaced forearm fractures in adults are best treated by open reduction and internal fixation. This procedure minimizes the relatively high rates of malunion, nonunion, and loss of forearm rotation associated with management by closed techniques. Bone grafting should be considered with comminution of more than a third of the diameter of the bone or with a segmental fracture.

Fractures About the Elbow in Children

Fractures about the elbow are more common in children than in adults, and treatment in children often differs from treatment of injuries at similar locations in adults. Occult fractures are more common in children, particularly young children, in whom low-impact falls are common. A significant portion of the bone in young children has not ossified, so some fractures are more difficult to visualize on initial radiographs. A child who has a history of injury, tenderness about the elbow, and a positive posterior fat pad sign should be assumed to have an occult fracture and should be immobilized for 3 weeks.

Supracondylar Fractures

Fracture of the supracondylar humerus is the most common elbow fracture in children. The typical age group is 2 to 12 years—a time when a child is able to hyperextend the elbow. The typical mechanism of injury is a fall on the outstretched arm with the elbow in full extension. The distal fragment is displaced posteriorly (Figure 15-19). The less common flexion injuries cause anterior displacement of the distal humerus and are more common in the adolescent years.

Supracondylar fractures are associated with a relatively high incidence of neurovascular injury. Usually only one nerve is injured. The median, radial, or ulnar nerve may be

Figure 15-19: Supracondylar Fracture of the Humerus

<table>
<thead>
<tr>
<th>Extension type</th>
<th>Flexion type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior displacement of distal fragment (most common). In general, supracondylar fractures occur more frequently in children</td>
<td>Anterior displacement of distal fragment (uncommon in children)</td>
</tr>
</tbody>
</table>
involved. Median nerve injury, the most common type, may be limited to the anterior interosseous branch. Compartment syndrome of the forearm may occur, and failure to treat this problem in a timely fashion may result in Volkmann ischemic contractures of the wrist and fingers. Malunion with resultant cubitus varus is another potential complication.

To minimize the risk of complications, displaced fractures typically are treated with closed manipulation and percutaneous pinning. If the radial and ulnar pulses are absent, the fracture is reduced. Frequently, the pulse returns after the fracture is reduced and the proximal fragment no longer stretches the brachial vessels. If the pulse does not return but the capillary refill is normal and there are no signs of compartment syndrome, the patient may be treated with observation with careful monitoring. If the pulse does not return after the fracture has been reduced and the fingers or forearm show signs of ischemia, the vessels should be explored.

Cubitus varus, the “gunstock deformity,” results from malrotation and the resultant tilt of the distal fragment. The thin, spadelike shape of the distal humerus, in combination with a swollen arm and the small size of a child’s bone, is a predisposing factor. The deformity is primarily a cosmetic rather than a functional problem.

Transphyseal Fracture Separation of the Distal Humerus

Transphyseal separations of the distal humerus typically occur in infants and young children as a result of child abuse. Radiographs may be difficult to interpret because the secondary centers of ossification have not developed in children this young. Typically, the proximal forearm is displaced medially and posterior to the humeral shaft. Arthrography, MRI studies, or ultrasonography may be necessary to distinguish this lesion from an elbow dislocation or lateral condylar fracture.

Lateral and Medial Condyle Fractures

Fracture of the lateral condyle of the distal humerus is the second most common elbow injury in children. Lateral condylar fractures result from a fall on a varus, supinated elbow, with the condyle avulsed by attached extensor muscles. Medial condylar fractures are uncommon, but the treatment principles are the same as for lateral condylar fractures. When these fractures cross the articular surface, displacement >1 mm at the joint requires reduction and pinning to minimize associated problems of nonunion, cubitus valgus, tardy ulnar nerve palsy, and traumatic arthritis.

Lateral and Medial Epicondyle Fractures

Lateral epicondylar fractures are uncommon in children, but avulsion of the medial epicondyle by forceful contraction of the flexor-pronator muscles with the elbow in valgus is the third most common pediatric elbow fracture. The injury typically occurs in a 10- to 15-year-old child. A concomitant posterior dislocation of the elbow may occur. In this situation, open reduction should be performed if the medial epicondyle fragment is incarcerated in the joint. Otherwise, medial epicondylar fractures, even when markedly displaced, do not commonly cause residual disability and can be treated with short-term splinting.

Radial Neck Fractures

In children, fracture of the proximal radius typically involves the physis, with extension into the neck of the radius (Peterson II or Salter II). The typical age group is 7 to 12 years. Associated injuries may include fracture of the olecranon or medial epicondyle, as well as dislocation of the elbow. Isolated fractures result from a fall on an extended elbow with valgus stress.

Treatment depends on the age of the child and the degree of angulation. Tilt of more than 30° may result in loss of forearm rotation. With more than 30° angulation, closed reduction with or without percutaneous manipulation of the fracture should be attempted with the goal of reducing angulation to less than 30°. Open reduction may be required but has a greater risk of osteonecrosis of the radial head and synostosis between the radius and ulna. Premature fusion of the
Elbow and Forearm

Physis usually is of little significance, because 80% of the growth of the radius occurs at the distal physis.

Olecranon Fractures and Diaphyseal Fractures of the Radius and Ulna

Olecranon fractures are uncommon in children and are likely to be nondisplaced. Displaced fractures usually require open reduction and tension band wire and pin fixation.

Most diaphyseal forearm fractures in children can be managed by closed techniques. Proximal and middle third forearm fractures account for only 15% to 20% of pediatric forearm fractures, but these injuries are more likely to develop complications such as compartment syndrome, malunion, or synostosis.

Dislocation of the Elbow

The elbow is the most commonly dislocated joint in children and the second most common site of dislocation in adults (Figure 15-20). Posterior dislocations are most common. Anterior dislocation is rare because of the shape of the olecranon process. Divergent dislocation with separation of the radius and the ulna results from severe disruption of the soft tissues.

Posterior dislocations typically occur in a fall on the outstretched hand with the shoulder abducted. Axial compression at the elbow combined with an external and valgus stress at the elbow (the body internally rotates) results in a continuum of ligamentous injury that typically starts laterally and moves...

Figure 15-20: Dislocation of Elbow Joint

Posterior dislocation. Note prominence of olecranon posteriorly and distal humerus anteriorly

Fracture of coronoid process of ulna with posterior dislocation of elbow. Coronoid fracture may occur occasionally without dislocation

Posterior dislocation with fracture of both coronoid process and radial head. Rare but serious; poor outcome even with good treatment. May require total elbow replacement

Divergent dislocation, anterior-posterior type (rare). Medial-lateral type may also occur (extremely rare)
medially. The first stage tears the ulnar portion of the lateral collateral ligament (LCL), followed by disruption of the entire LCL complex, then the anterior and posterior capsules, then the posterior band of the medial collateral ligament (MCL), and lastly, the anterior band of the MCL. Associated injuries may include avulsion of the medial and lateral epicondyles, radial head and radial neck fractures, and coronoid fractures. These additional injuries increase instability and may necessitate internal fixation.

Isolated dislocation of the elbow is treated by closed reduction. Distal traction is applied with the elbow in extension and the forearm in supination. After reduction, elbow stability is assessed with the forearm in pronation. If ligament disruption involves the anterior band of the medial collateral ligament, instability is noted with the elbow in extension. This injury will need 3 to 6 weeks of protection, starting with the elbow in pronation and 90° of flexion. More stable injuries should be immobilized for a short time (1 to 2 weeks) to prevent the complications of elbow stiffness and loss of extension. Other complications, such as heterotopic ossification, brachial artery injury, ulnar nerve injury, and compartment syndrome, are associated with high-energy injuries and concomitant fractures.

**Subluxation of the Radial Head**

Subluxation of the radial head, also called a “pulled elbow” or “nursemaid’s elbow,” is the most common elbow injury in children younger than 5 years. Subluxation occurs with a pull on the forearm when the elbow is extended and the forearm pronated. The annular ligament (see Figure 15-13) slips proximally and becomes interposed between the radius and the ulna. This injury is associated with ligamentous laxity, a condition that is almost universal in young children and typically occurs when a young child is “helped along” or lifted by pulling on the forearm.

Immediately after the injury, the child will cry, but the initial pain quickly subsides. Thereafter, the child is reluctant to use the arm but otherwise does not appear to be in great distress. The extremity is held with the elbow slightly flexed and the forearm pronated. Tenderness over the radial head and resistance on attempted supination are the only consistent findings. Radiographic findings are normal.

Reduction is accomplished by applying pressure over the radial head, followed by quick supination. If this maneuver fails to produce the snap of reduction, the elbow should be flexed. Resistance is perceived just before full flexion. As the elbow is pushed through that resistance, the annular ligament will reduce, and a snap will be perceived as the radial head is reseated. If the reduction is successful, the child will resume use of the extremity in a few minutes. In a child who presents for evaluation 1 to 2 days after injury, however, swelling may obscure the snap of reduction and deter the immediate resumption of normal function. If the elbow has full flexion and supination, the radial head has been reduced. Immobilization is ineffective as slings are quickly discarded.

**PEDIATRIC DISORDERS**

**Congenital Dislocation of the Radial Head**

Isolated congenital dislocation of the radial head, although present at birth, is usually not diagnosed until a child is 2 to 5 years of age, when the parents note mild limitation of elbow extension and an abnormal prominence (Figure 15-21). The dislocation may be bilateral or unilateral. Most dislocations are posterior or posterolateral, but they may be anterior. The limitation of motion is rarely dysfunctional, and most patients are asymptomatic. Excision of the radial head, after completion of growth, is indicated for relief of pain from joint incongruity; however, elbow motion does not improve after the procedure.

**Congenital Radioulnar Synostosis**

Congenital radioulnar synostosis is an uncommon congenital abnormality caused by failure of separation of the proximal radius and ulna during fetal development. As a result, forearm rotation is lost. The synostosis is frequently an isolated event but may be
associated with other conditions. Most cases involve some degree of fixed pronation. The degree of disability depends on the amount of fixed pronation and whether the condition is unilateral or bilateral. Patients with bilateral involvement and forearms fixed in greater than 60° of pronation have the greatest difficulty with activities such as holding a fork, dressing, and maintaining good personal hygiene after bowel movements. Patients with less fixed pronation often can substitute shoulder motion.

Surgery to resect the synostosis and restore motion has not been successful. Rotational osteotomy through the synostosis to change the position of the forearm varies according to the amount of functional impairment. Typically, the dominant forearm is positioned in 0° to 20° of pronation. Compartment syndrome is the most common postoperative complication.

**Osteochondrosis of the Elbow**

Children involved in repetitive throwing activities or gymnastics repetitively overload the elbow into valgus with tension on the medial epicondyle and compression on the capitellum. Traction apophysitis of the medial epicondyle, better known as “little leaguer’s elbow,” may develop. The resultant pain responds well to a relatively short period of rest.

Chronic lateral elbow pain in pediatric athletes usually occurs secondary to osteonecrosis of the capitellum and is more problematic.
When osteonecrosis occurs in children younger than 10 years, the condition is called Panner disease and has a good prognosis for healing with a period of rest and, sometimes, immobilization. When the condition occurs during adolescence, it is called osteochondritis dissecans of the capitellum and has a more guarded prognosis.

Adolescents with osteonecrosis of the capitellum report the insidious onset of lateral elbow pain that is aggravated by throwing activities. Examination shows tenderness over the lateral elbow, tenderness at the extremes of passive elbow motion, and a flexion contracture of 10° to 30°. Typical radiographic changes include lucency and fragmentation of the anterior central capitellum (Figure 15-22). Osteochondral loose bodies may be present. An MRI study often helps define the extent of osteonecrosis. Treatment for patients in this age group includes activity modification, excision of osteochondral fragments, and occasionally, drilling of the defect to stimulate a fibrocartilaginous response.

**ADDITIONAL READINGS**

