CHAPTER 17

Functional Anatomy of the Elbow

Mary Lloyd Ireland, Yvonne E. Satterwhite, Craig C. McKirgan, Michael Stroyan, and Kevin E. Wilk

FUNCTIONAL ANATOMY OF THE ELBOW

Arthrology of the Elbow Complex

The elbow is a biomechanically complex joint composed of the humeroulnar, humeroradial, and proximal radioulnar articulations. Capsular and ligamentous structures provide restraints to motion and stress in addition to that achieved by the inherent stability of congruous bony contours. The elbow is shown diagrammatically from anterior (Fig. 1A) and medial (Fig. 1B) perspectives.

Humeroulnar Joint

The humeroulnar joint is a uniaxial, diarthrodial modified hinge joint. Motion ranges from 0° to 150° and occurs through a rotational axis in the center of the trochlea, in the coronal plane. At the extremes of flexion and extension, limited degrees of internal and external rotation are present (1).

The distal humerus has two components—the trochlea medially and the capitellum laterally. Diagrams show the distal humerus anterior (Fig. 2A), posterior (Fig. 2B), and axial (Fig. 2C) planes. The trochlea is spool-shaped and is covered with articular cartilage from the edge of the olecranon fossa posteriorly to the coronoid fossa anteriorly, a surface area covering approximately 300° to 330° (2). The

ML Ireland and YE Satterwhite: Kentucky Sports Medicine Clinic, Lexington, KY 40517.

CC McKirgan: Center for Orthopaedics and Sports Medicine, Indiana University of Pennsylvania, Indiana, PA 15701.

M Stroyan: FITRAC, Marysville, MD.

KE Wilk: HealthSouth Sports Medicine and Rehabilitation Center, Birmingham, AL 35205; Program in Physical Therapy, Marquette University, Milwaukee, WI.
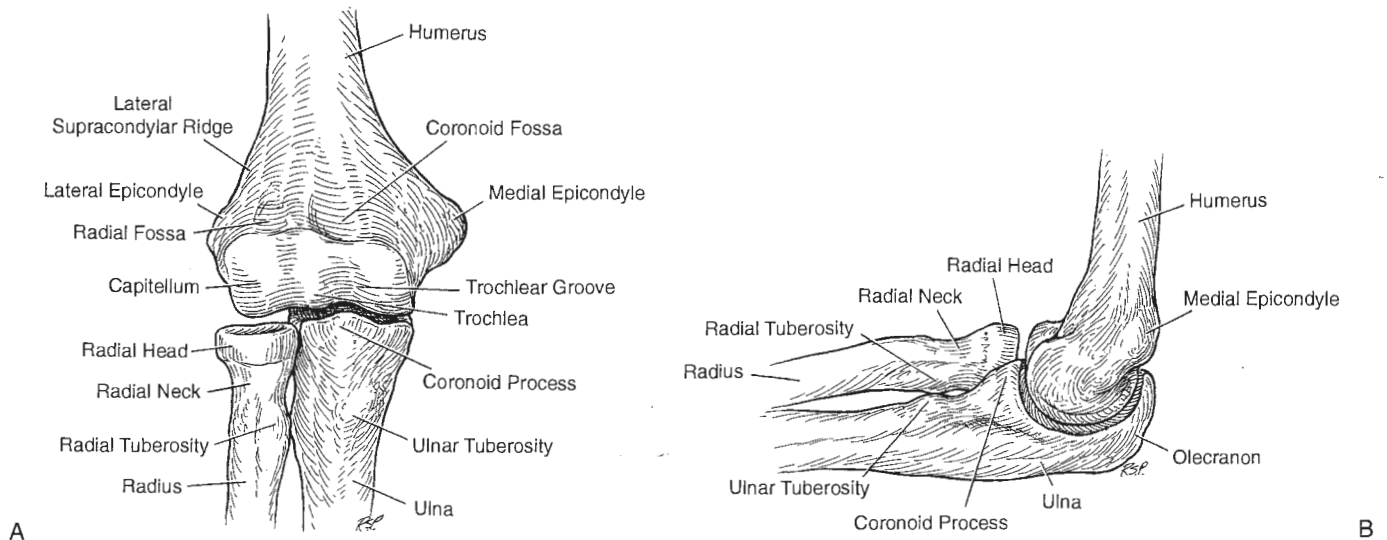
trochlea's central depression, the trochlear groove, is bound on either side by two unequal, convex segments of bone. The groove is obliquely oriented from anterior to posterior and contributes to the valgus carrying angle of the elbow. The carrying angle is measured in the frontal plane by the long axes of the humerus and ulna with the elbow extended (normal range in males 11° to 14° and females 13° to 16°) (3,4). The distal end of the humerus is rotated anteriorly 30 degrees with respect to the shaft of the ulna. In the frontal plane, the medial column of trochlea is longer than the lateral. This difference creates a valgus tilt of approximately 6° measured by the distal humerus to the long axis of the humerus. Immediately proximal to the articular surfaces of the distal humerus lie two fossae—the coronoid anteriorly and the olecranon posteriorly. These fossae receive the olecranon tip and the coronoid of the proximal ulna, respectively, as the elbow courses from full extension into flexion.

The anterior portion of the proximal ulna, the greater sigmoid notch, has a longitudinally oriented guiding ridge that articulates with the apex of the trochlear groove. Diagrammatically shown is the proximal ulna anteriorly (Fig. 3A) and medially (Fig. 3B). On either side of this ridge is a concave region, referred to as the "trochlear notch," articulating with the convex surface of the trochlea of the humerus. The greater sigmoid notch is angulated 30° posteriorly with respect to the ulnar shaft, thus lying parallel to the trochlea. This orientation and structural congruency permits maximum humeroulnar motion and enhances the bony stability of the elbow, particularly in full extension.

The medial humeral epicondyle serves as the origin of the flexor-pronator muscle group and the medial ulnar collateral ligament (5). The medial supracondylar ridge lies just superior to the medial epicondyle and is occasionally the site of origin of an additional medial prominence, the supracondylar process, from which the ligament of Struthers may arise and extend distally to attach

FIG. 1. (**A**) Bony configuration of the elbow is shown anteriorly of the articulations. Radial ulnar, radial humeral, proximal radial ulnar is shown anteriorly and medially from the side. (**B**) The coronoid fossa and olecranon fossa allow for bony contact in flexion and extension. The smooth articulation of the distal humerus, capitellum, and spool-like trochlea, radial head, and proximal ulna are necessary for normal function and range of motion of the elbow. The distal humerus is shown anteriorly with the capitellum laterally, trochlea medially. (Illustrated by Rich Pennell, CMI, Medical Illustrator, Medical Center Arts & Graphics, 509 Health Sciences Learning Center, 760 Rose Street Lexington, KY 40536-0232.)
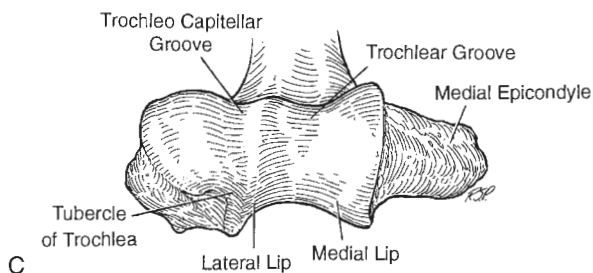

FIG. 2. (**A**) The lateral epicondyles and coronoid fossa and (**B**) posteriorly with the olecranon fossa, and (**C**) axially showing the articular aspect of the distal humerus. (Illustrated by Rich Pennell, CMI, Medical Illustrator, Medical Center Arts & Graphics, 509 Health Sciences Learning Center, 760 Rose Street Lexington, KY 40536-0232.)
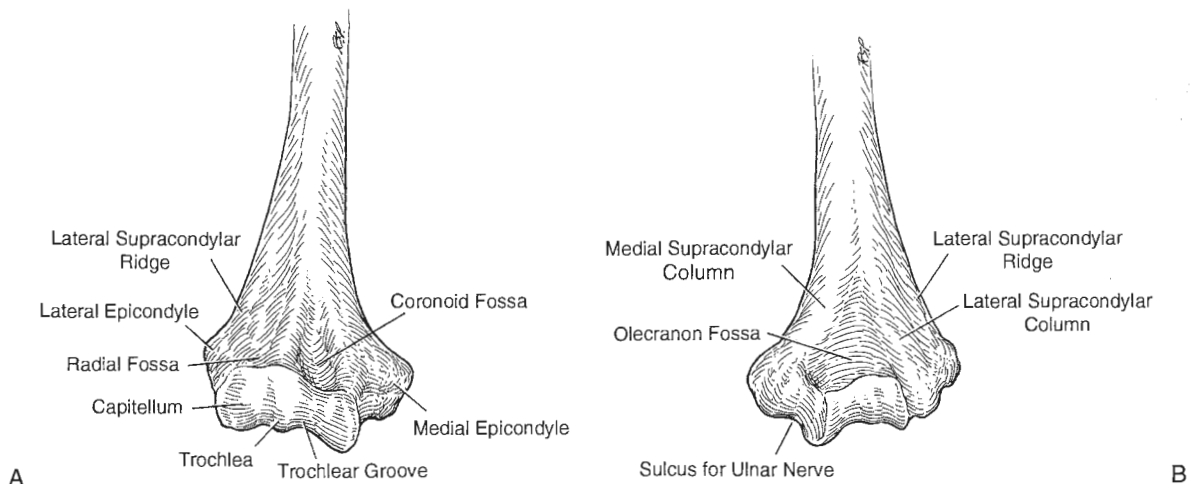
FIG. 3. (**A**) The proximal ulna is shown with the guiding ridge of the sigmoid notch, coronoid process, and ulna tuberosity from the anterior view, and (**B**) from the medial aspect the coronoid process, greater sigmoid notch olecranon. (Illustrated by Rich Pennell, CMI, Medical Illustrator, Medical Center Arts & Graphics, 509 Health Sciences Learning Center, 760 Rose Street Lexington, KY 40536-0232.)
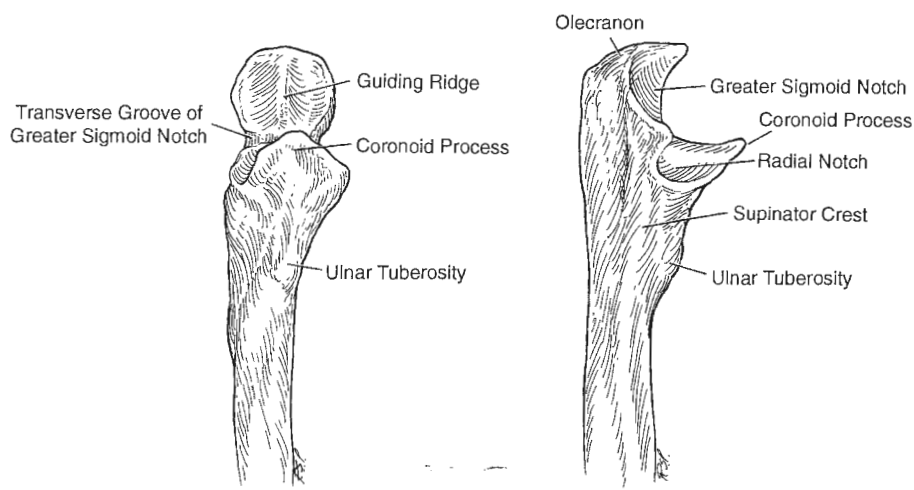
to the medial epicondyle (6). This anomalous structure is present in approximately 1% of the population.

Humeroradial Joint

The humeroradial joint is a uniaxial diarthrodial joint functioning as a hinge and pivot. As a hinge in coronal axis, flexion/extension movements occur at the humeroulnar joint. The humeroradial joint pivots about a longitudinal axis to permit rotational movements at the proximal radioulnar joint.

The humeroradial joint is created by the capitellum and the articular surface of the radial head. The capitellum is an anterior half of a sphere whose posterior mar-
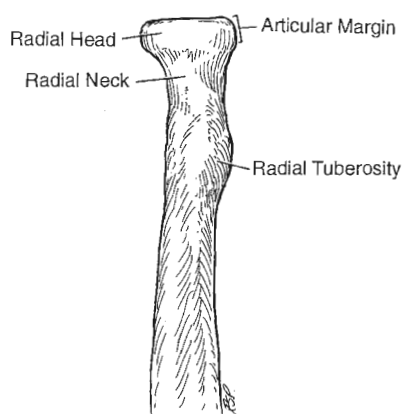

FIG. 4. The proximal radius is shown with radial head, neck, articular margin, as well as radial tuberosity. (Illustrated by Rich Pennell, CMI, Medical Illustrator, Medical Center Arts & Graphics, 509 Health Sciences Learning Center, 760 Rose Street Lexington, KY 40536-0232.)

gin does not extend as far as that of the adjacent trochlea. The capitellotrochlear groove separates the capitellum from the trochlea and guides the rim of the radial head in flexion and extension. The radial fossa is a depression on the anterior aspect of the humerus, just proximal to the capitellum, into which the radius seats when the elbow is fully flexed. Lateral to the radial fossa is the lateral humeral epicondyle, a bony eminence extending superiorly into the lateral supracondylar ridge and providing origin for the extensor supinator muscle mass.

The articular surface of the radial head is a concave depression that is slightly oval, not fully cylindrical, in shape. The anterior view of the proximal radius is shown (Fig. 4). Its head and surrounding rim narrow distally to form the radial neck. The radial head and neck angulate approximately 15° from the shaft of the radius (7). The radial head plays only a small role as a secondary restraint to valgus stress to the elbow unless the ulnar collateral ligament has been compromised. The bicipital tuberosity lies just distal to the radial neck and serves as the insertion site for the biceps tendon.

Proximal Radioulnar Joint

The proximal radioulnar joint is a uniaxial, diarthrodial joint that functions in concert with the distal radioulnar joint to produce forearm supination and pronation. Rotation occurs in the transverse plane around a longitudinal axis and normally encompasses a range of up to 180°. The joint is comprised of the convex medial rim of the radial head and the concave lesser sigmoid notch (radial notch) of the ulna. During rotational movements, there is minimal motion of the ulna. The radial head rotates within a

ring formed by the annular ligament and the lesser sigmoid notch while the radial shaft crosses over the ulnar shaft with pronation and uncrosses with supination.

Ligamentous Anatomy

The capsuloligamentous anatomy of the elbow may be divided into anterior, posterior, medial, and lateral structures. The anterior capsule extends proximally to the radial and coronoid fossae and attaches distally to the coronoid. With the elbow extended, the anterior capsule becomes taut and provides resistance to distraction and hyperextension forces. The posterior capsule attaches proximally to the olecranon fossa and distally into the olecranon tip. Posteriorly, the capsule tightens with elbow flexion, but contributes only minimally to overall elbow stability.

Ulnar Collateral Ligament

The ulnar collateral ligament (UCL) is the primary static stabilizer of the medial elbow. Referred to as the "ACL of the elbow," the UCL contributes significantly to overall elbow stability and function, particularly in the overhead athlete. Recent cadaveric dissections, along with histologic, radiographic, and arthroscopic studies have led to a much improved appreciation of the complexity of the UCL. The UCL is composed of three segments: anterior oblique, posterior oblique, and transverse (Fig. 5). The transverse ligament segment consists of horizontally oriented capsular fibers that course from the medial olecranon tip to the coronoid. Often difficult to distinguish from the capsule, this transverse bundle itself does not significantly contribute to elbow stability.

The anterior oblique ligament originates from the inferior surface of the medial epicondyle, which is slightly
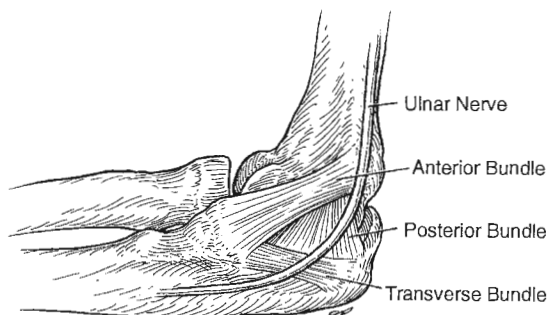

FIG. 5. The ulnar collateral ligament is shown and consists of important anterior bundle. Also demonstrated are the transverse and posterior bundle. The ulnar nerve is also shown. (Illustrated by Rich Pennell, CMI, Medical Illustrator, Medical Center Arts & Graphics, 509 Health Sciences Learning Center, 760 Rose Street Lexington, KY 40536-0232.)

posterior to the center axis of the elbow rotation, and attaches to the sublime tubercle medial to the coronoid. The ligament's eccentric position, posterior to the rotational axis, creates a cam effect, with ligament tension varying, depending on the degree of elbow flexion. Histologically, two layers of the ligament have been identified. The medial joint capsule has a superficial and deep layer. The anterior oblique ligament has a thick deep portion that lies within the two layers of the joint capsule and a thin superficial portion, which is external to the joint capsule's superficial layer and may be confluent with the overlying flexor muscles (8). Functionally, the anterior oblique has been divided into three groups of fibers or bands: anterior, middle, and posterior. Each group has an arc through which the majority of its fibers are taut. This arc changes slightly if varus or valgus stress is imposed upon the elbow joint (9). The anterior oblique ligament's anterior fibers exhibit greatest tension in extension and the posterior fibers in flexion. With sectioning of the anterior oblique ligament, maximum valgus instability occurs at 70° (10). Instability begins at approximately 30° or more of elbow flexion as the unique bony configuration becomes less of a factor and (the elbow unlocks).

The posterior oblique segment bundle of the UCL originates posterior and inferior to the medial epicondyle and inserts along the posteromedial edge of the greater sigmoid notch. The ligament is a distinct fan-shaped bundle of fibers lying within the two layers of the joint capsule (8). Occupying a position more eccentric of the elbow's rotational axis than the anterior oblique ligament, the posterior oblique bundle is taut from 60° to 120°. Functionally, the posterior oblique ligament has also been divided into fiber groups, anterior and posterior, with ligament tension noted to increase sequentially in the more posterior fibers as the elbow reaches a greater angle of flexion (9). Isolated sectioning of the posterior oblique ligament has not been found to cause valgus nor internal rotation instability in the elbow (10).

An intermediate bundle on segment of the UCL has not been consistently demonstrated but has been described as a "guiding bundle" that exists between the anterior and posterior oblique ligaments and is taut in all positions of flexion or extension (11).

Lateral Ligament Complex

The lateral ligament complex demonstrates greater variability than the UCL. The ligaments laterally include the radial collateral ligament, lateral ulnar collateral ligament, accessory posterior ligament, and annular ligament (Fig. 6). The radial collateral ligament (RCL) is a poorly demarcated fan-shaped structure that originates from the lateral epicondyle and attaches and becomes confluent with the annular ligament. The superficial surface of the ligament interdigitates with the fascia of the supinator
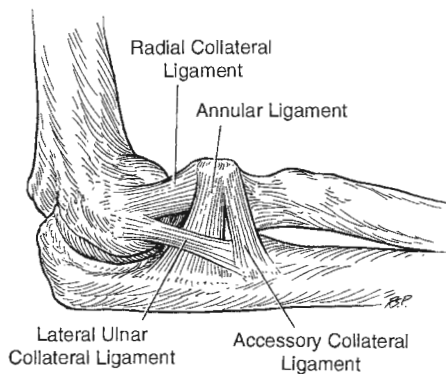
FIG. 6. Lateral ligamentous complex demonstrated showing the radial collateral ligament, annular ligament, lateral ulnar collateral ligament, and accessory collateral ligament. (Illustrated by Rich Pennell, CMI, Medical Illustrator, Medical Center Arts & Graphics, 509 Health Sciences Learning Center, 760 Rose Street Lexington, KY 40536-0232.)

muscle. The RCL's axis of rotation passes directly through the elbow's center locus of rotation; thus, little change is seen in this ligament's uniform length from 0° to 120° of flexion. The three fiber groups functionally are anterior, middle, and posterior (8). The middle fibers are taut through a full range of motion while the anterior fibers are more taut in extension and the posterior fibers in flexion. The RCL contributes to the stability of the elbow joint by maintaining humeroradial joint apposition in the presence of varus stress (12).

The lateral ulnar collateral ligament (LUCL) is a superficial continuation of the RCL posterior fibers attaching from the mid-lateral epicondyle to the ulna at the crista supinatoris. The LUCL is primarily taut in marked flexion unless a varus stress is simultaneously applied, which results in a larger arc of ligament tension ranging from 0° to 140°. Utilizing less constrained testing procedures than previously used, O'Driscoll was able to show that the LUCL is a major stabilizer for rotational and varus stability of the elbow (13). He also demonstrated that with selective sectioning of the LUCL, an instability pattern was created that was consistent with clinical findings of the entity "posterolateral rotatory instability" of the elbow (14). Their findings suggested that the LUCL has a guide-wire-type function that complements the anterior oblique portion of the UCL.

The accessory lateral collateral ligament originates from the anterior inferior margin of the annular ligament and inserts on the crista supinatoris. This accessory ligament becomes taut and stabilizes the annular ligament when varus stress is applied to the elbow. The length or tension of the accessory ligament does not change significantly with pure elbow flexion and extension (2,15,16).

The annular ligament is a fibro-osseous ring that encircles and stabilizes the radial head in the lesser sigmoid notch of the ulna. Its attachment sites are on the anterior and posterior edges of the lesser sigmoid notch. The ligament comprises four fifths of a circle and is slightly funnel-shaped. Histologically, the ligament may be subdivided into three layers: a deep capsular, an intermediate forming the annular ligament proper, and a superficial (16). Functionally, the anterior portion of the ligament becomes taut with extreme supination, while the posterior portion becomes taut with extreme pronation movements.

Quadrate Ligament and Oblique Cord

The quadrate ligament originates at the inferior edge of the lesser sigmoid notch and inserts distally into the radial neck. The functional importance of this ligament has been debated. However, Spinner and Kaplan have suggested that this ligament may stabilize the proximal radioulnar joint by limiting the spin of the radial head during supination and pronation (15,17). The quadrate ligament may also serve as a reinforcement of the inferior joint capsule.

The oblique cord is a small bundle of fibrous tissue that courses from the proximal ulna to just distal to the bicipital tuberosity of the radius. Although the ligament tightens with full forearm supination, its true functional contribution is believed to be minimal. Contractures of the oblique cord may have implications in idiopathic limitations of forearm supination (18).

Neurological Structures of the Elbow

Four nerves play significant roles around the elbow: median, radial, musculocutaneous, and the ulnar nerve. The anatomical variations that frequently exist in many of these structures will not be detailed in this review.

Median Nerve

The median nerve arises from the lateral and medial cords of the brachial plexus with nerve root levels of C5–8 and T1. This nerve proceeds distally over the anterior medial portion of the brachium, passing beneath the brachial fascia and over the brachialis muscle (Fig. 7). Its continued descent is straight to the medial aspect of the antecubital fossa, where it lies medial to the brachial artery and biceps tendon. In the presence of a ligament of Struthers, the median nerve may lie deep to and hence be compressed by this ligament.

From the antecubital fossa, the median nerve continues its course under the bicipital aponeurosis and passes most often between the two heads of the pronator teres. Just inferior to the border of the pronator teres, the anterior interosseous branch arises and descends along the anterior aspect of the interosseous membrane. The anterior
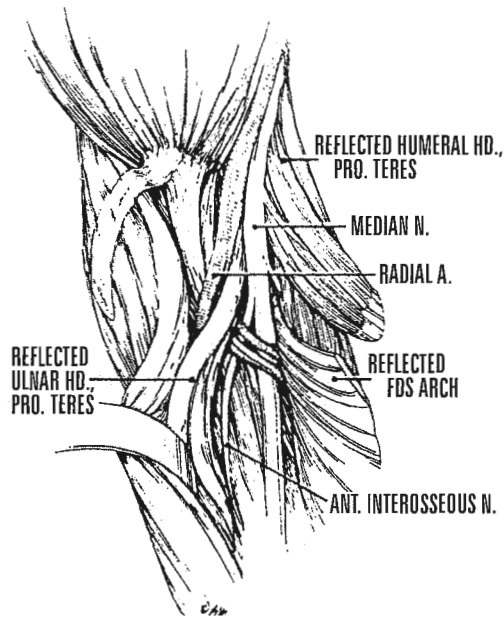
FIG. 7. The median nerve is shown as it enters the elbow area emerging from the pronator teres heads. Branches of the anterior interosseous nerve are shown and their relationship with the radial artery.

interosseous branch innervates the pronator quadratus, flexor pollicis longus, and lateral portion of the flexor digitorum profundus muscles. Anterior interosseus syndrome occurs when this branch is compressed and the square pinch paralysis is seen. Anomalous structures may compress the nerve throughout its course.

The median nerve can be compressed between the two heads of the pronator teres or via compression from the lacertus fibrosus (bicipital aponeurosis). Because of the same nerve involvement, pronator syndrome can overlap, but not as often as one would expect. Compression of the median nerve in the proximal forearm can result in pronator syndrome. The complaints are vague pain and fatigue after repetitive flexion and pronation. Although relatively uncommon, highly repetitive and strenuous pronation of the forearm can lead to entrapment of this nerve (6).

Ulnar Nerve

The ulnar nerve originates from nerve root levels C8 and T1 of the medial cord of the brachial plexus. This nerve passes from the anterior to posterior compartments of the brachium through the arcade of Struthers, which is located 8 cm proximal to the medial epicondyle (19) (Fig. 8A). This arcade represents a fascial bridging between the medial head of the triceps and the medial intermuscular septum (17). The nerve continues distally, passing behind the medial epicondyle and through the cubital tunnel (Fig. 8B). At the cubital tunnel, little protection is provided for the nerve by the bony anatomy. The cubital tunnel is the most frequent site for ulnar nerve injury, which occurs most often by compression or stretching. Morrey has found, through anatomical dissections, a discrete structure that helps form the cubital tunnel. This structure, referred to as the cubital tunnel retinaculum (CTR), tightens with elbow flexion, thereby reducing the cubital tunnel volume (20). The
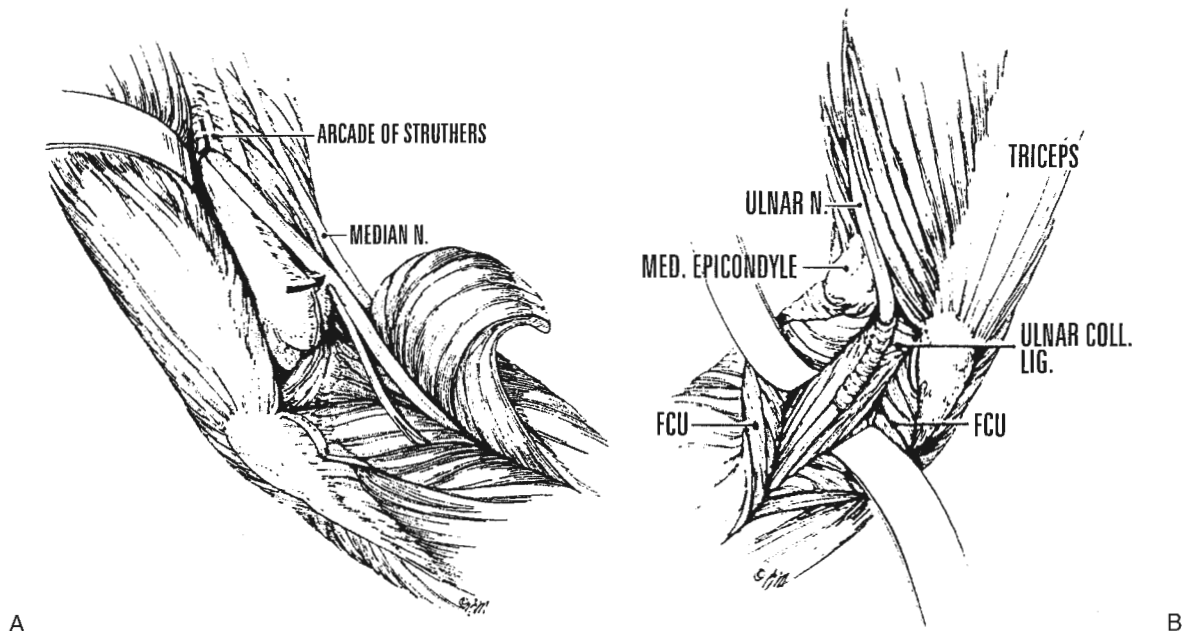

A

B

FIG. 8. (A) The ulnar nerve (*arrow*) passes from the anterior to posterior compartments of the brachium through the arcade of Struthers, which is located 8 cm proximal to the medial epicondyle. **(B)** The ulnar nerve relationship to the ulnar collateral ligament and entering the forearm between the heads of the flexor carpi ulnaris is shown. The retinaculum overlies the ulnar nerve and the cubital tunnel.

CTR stabilizes the ulnar nerve in the cubital groove and when absent, in 10% of individuals, may permit anterior subluxation of the ulnar nerve over the medial epicondyle.

At the level of the cubital tunnel, a few small branches of the ulnar nerve provide innervation to the elbow joint capsule. The nerve enters the forearm by passing between the two heads of the flexor carpi ulnaris and the flexor digitorum profundus (Fig. 8B). Compression neuritis can occur at the arcade of Struthers or between the two heads of the flexor carpi ulnaris.

Radial Nerve

The radial nerve originates from the posterior cord of the brachial plexus and derives its nerve supply from the C6, C7, and C8 levels, with variable contributions from C5 and T1 levels. At the mid-portion of the brachium, the nerve descends laterally through the (radial) spiral groove in the humerus. It continues in a path laterally and distally to penetrate the lateral intermuscular septum. After penetrating the septum, the nerve descends anteriorly to the lateral epicondyle behind the brachioradialis and brachialis muscles (Fig. 9). At the antecubital space near the level of the radiocapitellar joint, the nerve divides into the posterior interosseous and superficial radial branches. The superficial branch continues distally in front of the lateral epicondyle and runs under the brachioradialis muscle while lying on top of the supinator and pronator
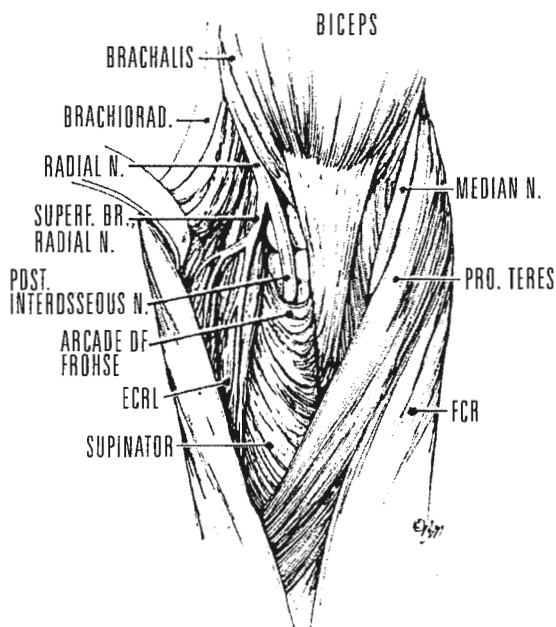

FIG. 9. The radial nerve as it emerges between the brachialis musculature is shown. Branches of the radial nerve into the superficial branch and the posterior interosseous is shown.

teres muscles. The nerve's terminal branches provide sensory function over the lateral two thirds of the posterior surface of the hand and posterior surface of the lateral two and a half fingers.

The posterior interosseous branch curves around the posterior lateral aspect of the radius and passes between the two heads of the supinator muscle. This branch continues its course distally and emerges approximately 8 cm below the elbow joint, where it divides into terminal motor branches. In approximately 30% of the population, the proximal edge of the supinator forms a fibrous arch, the arcade of Froshe (6), where entrapment most frequently occurs. Any activity involving repetitive or forceful supination or pronation of the forearm can lead to symptoms. Athletes involved with throwing sports, tennis, or racquetball are usually most susceptible (21). Strictly a motor nerve, the posterior interosseous branch innervates the supinator muscle. The recurrent branch of the posterior interosseous nerve innervates extension digitorum minimi, extensor carpi ulnaris, and occasionally anconeus. Also innervated by the posterior interosseous nerve are abductor pollicis longus, extensor pollicis longus, extensor pollicis brevis, and extensor indicis. Above the level of the elbow, small branches emanate from the radial nerve to supply the three heads of the triceps, the anconeus, and the elbow joint capsule.

Musculocutaneous Nerve

The musculocutaneous nerve originates from the lateral cord of the brachial plexus at the nerve root levels C5–7 and innervates the biceps brachii, brachialis, and coracobrachial muscles of the anterior brachium. The nerve passes between the biceps and brachialis muscles to pierce the brachial fascia lateral to the biceps tendon. It continues distally to terminate as the lateral antebrachial cutaneous nerve, which provides sensation over the anterolateral aspect of the forearm.

Entrapment of this nerve can occur via compression between the biceps tendon and the brachialis fascia. Bassett and Nunley describe the mechanism of entrapment as elbow hyperextension and pronation (22).

Cutaneous Innervation of the Elbow

A total of five sensory nerves provides cutaneous innervation about the elbow. Sensory function around the elbow is derived from four nerve root levels: C5, C6, T1, and T2. The natural distribution of these segments is illustrated anteriorly (Fig. 10A) and posteriorly (Fig. 10B). The lower lateral cutaneous nerve of the forearm is a branch from the radial nerve, supplying sensation to the anterior and lateral aspects of the lower brachium. The posterior cutaneous nerve of the arm and forearm, also a branch of the radial nerve, provides cutaneous innervation over the posteromedial aspects of the arm and fore-
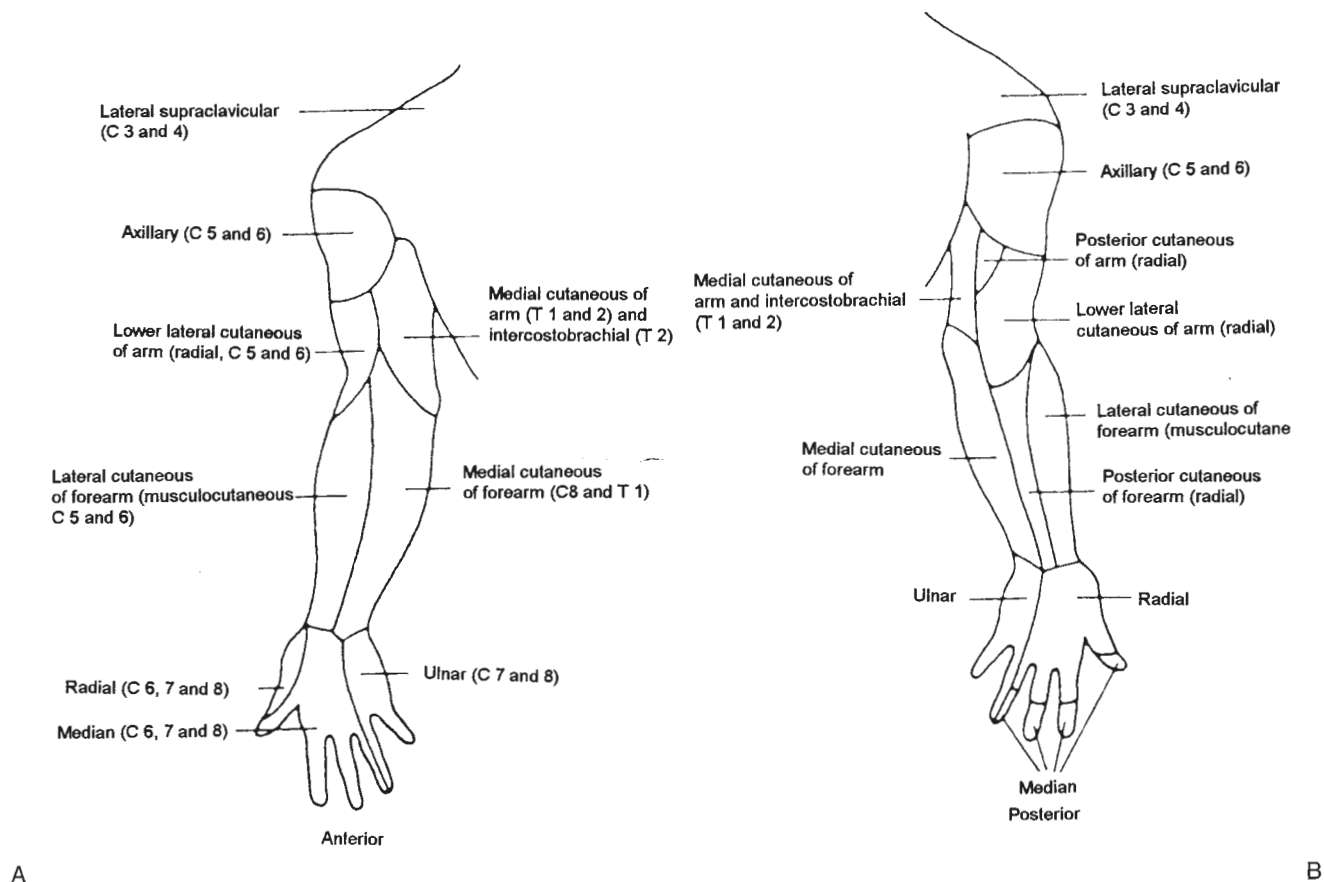
FIG. 10. (A) Sensory distribution of the nerves of the arm is shown from the anterior, and **(B)** posterior aspect.

arm. The lateral antebrachial cutaneous nerve of the forearm provides sensory distribution over the lateral aspect of the forearm and is the terminal branch of the musculocutaneous nerve. Lastly, the medial brachial cutaneous and antebrachial cutaneous nerves provide sensory coverage to the medial aspects of the arm and forearm. Both of these nerves originate from the medial cord of the brachial plexus.

Muscles

The musculature directly contributing to elbow function may be divided into four main groups: elbow flexors, extensors, flexor-pronators, and extensor-supinators. The origins and insertions are shown anteriorly (Fig. 11A) and posteriorly (Fig. 11B). The primary pronator and supinators will be discussed separately. In addition to joint motion, muscles traversing the elbow joint may provide increased joint stability via joint reaction forces created by the active compression of articular surfaces. This contribution to joint stability is position-dependent.

Elbow Flexors

The three primary flexor muscles of the elbow include the biceps brachii, brachioradialis, and brachialis. The biceps long head originates on the supraglenoid tubercle, and, in most cases, proximally directly to the glenoid labrum forming the biceps glenoid labrum complex (23). The long head of the biceps passes distally through the capsule of the glenohumeral joint and through the intertubercular groove until it joins with the short head, which originates from the apex of the coracoid process of the scapula to form a common muscle. Insertion of the two heads occurs at the posterior portion of the radial tuberosity and via the bicipital aponeurosis, which attaches to the anterior capsule of the elbow. The biceps receives its innervation from the musculocutaneous nerve at nerve root levels C5–6.

The long head of the biceps is a two-joint muscle spanning the glenohumeral and elbow articulations. For this reason, the muscle is susceptible to active insufficiency when full flexion of the elbow is performed with simultaneous shoulder flexion (24). The biceps is the most efficient in elbow flexor when the forearm is
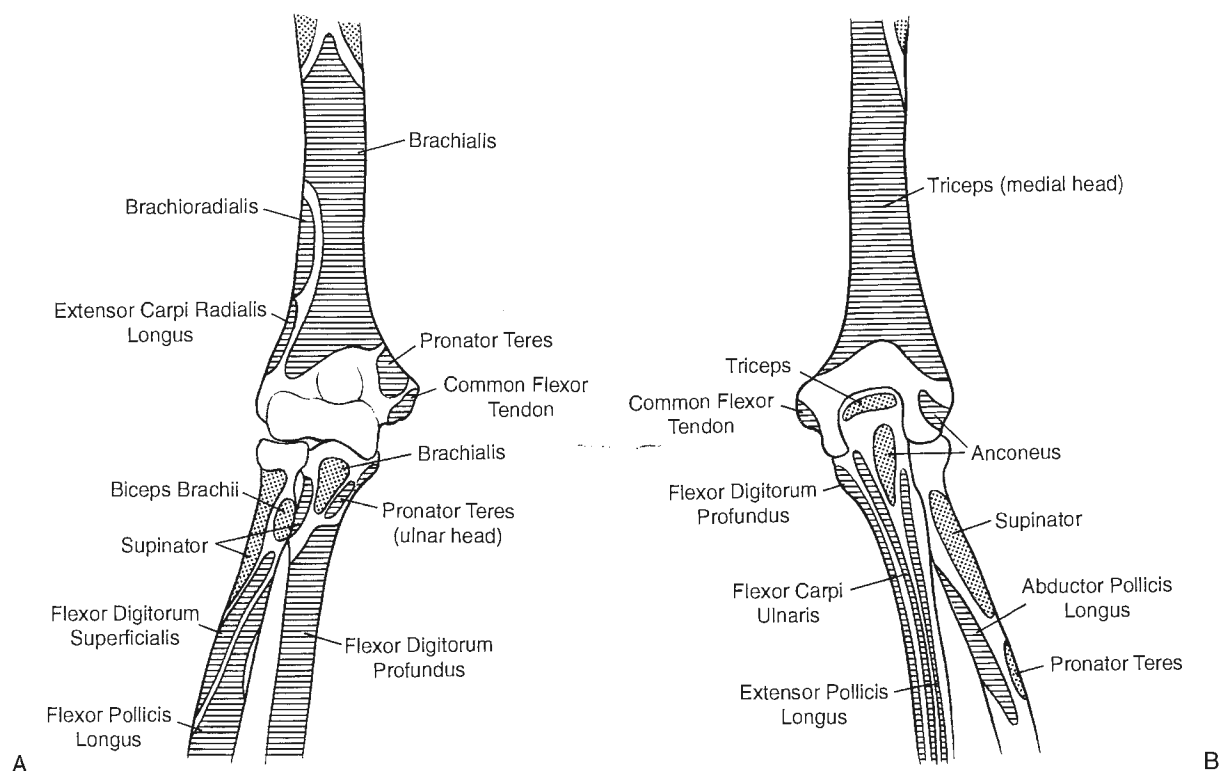
FIG. 11. **(A)** The muscular origins and insertions about the elbow are shown from the anterior aspect of the flexor pronator, and **(B)** posterior aspect of the extensor supinator is diagrammatically shown. (Illustrated by Rich Pennell, CMI, Medical Illustrator, Medical Center Arts & Graphics, 509 Health Sciences Learning Center, 760 Rose Street Lexington, KY 40536-0232.)

supinated and generates its highest torque values when the elbow is flexed between 80° and 100° (24). The biceps also functions as a supinator of the forearm, primarily in the flexed position. With the elbow extended, the biceps is a supinator only with rapid movements or when firmly resisted (24).

The brachialis muscle, which exhibits the largest cross-sectional area of all the elbow flexors, originates from the lower one half anterior surface of the humerus and the medial and lateral intermuscular septums. The brachialis muscle extends distally to cross the anterior aspect of the elbow joint and inserts into the ulnar tuberosity and coronoid process. Some of its fibers attach directly to the anterior capsule and retract the capsule during elbow flexion. The brachialis, like the biceps, attaches close to the axis of rotation (24). Basmajian reported that this muscle is active in flexing the elbow in all positions of the forearm (25). As a one-joint muscle, and because of its insertion on the ulna, the brachialis is not affected by the position of the shoulder or whether the forearm is in a supinated or pronated position. The musculocutaneous nerve innervates the brachialis muscle.

The brachioradialis muscle originates from the proximal two thirds of the lateral supracondylar ridge of the humerus and along the lateral intermuscular septum distal to the spiral groove. It runs distally over the anterolateral aspect of the radioulnar joint and inserts into the lateral aspect of the base of the styloid process of the radius. This muscle receives its nerve supply from the radial nerve at levels C5–6. A unique feature of this muscle is that it inserts a long distance from the joint axis and, as such, manifests the greatest mechanical advantage of any of the elbow flexors (24). Information pertaining to this muscle's role as a supinator or pronator is not conclusive (26). From what is presently understood about this muscle, the brachioradialis functions primarily as an elbow flexor.

Elbow Extensors

Two muscles, triceps brachii and the anconeus, serve as primary extensors of the elbow. The triceps brachii is a large, three-headed (long, lateral, and medial) muscle that comprises almost the entire posterior brachium. The long head crosses both the shoulder and the elbow, while the other two heads originate below the level of the shoulder joint. By crossing two joints, the long head of the triceps is susceptible to active insufficiency when the shoulder is

hyperextended with simultaneous elbow extension (24). The long head originates from the infraglenoid tubercle, while the lateral and medial heads originate from the posterior and lateral aspects of the humerus. At the lower end of the humerus, the three heads converge to form a common muscle inserting onto the posterior surface of the olecranon. An insertion also exists by way of fibrous expansion into the deep fascia of the posterior forearm. The triceps muscle receives its innervation from branches of the radial nerve arising from levels C7 and C8.

The small, anconeus muscle originates from a broad area on the posterior aspect of the lateral epicondyle and inserts into the olecranon. As the muscle courses from origin to insertion, it covers the lateral portion of the annular ligament, the radial head, and the posterior surface of the proximal ulna. The muscle is innervated by a branch of the radial nerve from C7 and C8. Interestingly, this muscle has been the focus of several extensive studies. Pavly et al. (27) noted the anconeus to be active in the early phases of elbow extension and attributed an elbow stabilization role during pronation/supination movements.

Extensor-Supinator Muscles

The extensor-supinator muscles include the brachioradialis, extensor carpi radialis brevis and longus, supinator, extensor digitorum, extensor carpi ulnaris, and extensor digiti minimi. Each muscle originates near or directly onto the lateral epicondyle of the humerus. Their primary functions involve the wrist and hand, as well as providing dynamic support over the lateral aspect of the elbow. These muscles are all innervated by the radial nerve. The extensor-supinator muscles, like the flexor pronator group, are susceptible to various overuse muscle strain injuries.

Flexor-Pronator Muscles

In addition to the primary elbow flexors, several accessory flexors comprise a mobile wad of muscles referred to collectively as the flexor-pronator group. This group of muscles includes the pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and flexor digitorum superficialis. All of these muscles originate completely or in part from the medial humeral epicondyle. All serve secondary roles as elbow flexors, with their primary roles being associated with the wrist and hand. Since these muscles span two or more joints, often their elongation strengths are exceeded and microtraumatic musculotendinous type injuries result. As a group, the flexor-pronator muscles provide dynamic stability to the medial aspect of the elbow and serve as the first line of defense against valgus stress (28). Recent cadaveric dissections have demonstrated that, with the elbow flexed 30° or more, the flexor carpi ulnaris directly overlies the medial ulnar collateral ligament and the large flexor digitorum sublimis lies just adjacent. Therefore, these two muscles are the best biomechanically positioned of the entire group to provide dynamic medial support (29).

Pronator Muscles

Two primary muscles act on the radioulnar joints to produce pronation movements, the pronator teres and the pronator quadratus. The brachioradialis and the flexor carpi radialis play a minor role in pronation.

The pronator quadratus originates from the anterior surface of the lower one fourth of the ulna. Insertion occurs at the distal one fourth of the lateral border of the radius. Electromyographic analysis of this muscle reveals consistent activity levels in all elbow positions (30). Whether pronation is slow, fast, resisted, or unresisted has little effect on its overall activity level. This unchanged pattern of activity is consistent with the fact that this muscle spans one joint. The pronator quadratus receives its nerve supply from the anterior interosseous branch of the median nerve at levels C8 and T1.

The pronator teres, with humeral and ulnar heads, originates from the medial epicondyle and coronoid process of the ulna, respectively. These two heads join together and insert along the middle of the lateral surface of the radius. The origin of the pronator teres muscle places the muscle in a position where changes in elbow position will effect its moment arm and, therefore, its ability to develop tension. Strength decreases of this muscle are noted when the elbow is positioned in full extension (24). The pronator teres is a strong pronator muscle that generates its highest contractile force during rapid or resisted pronation (26).

This muscle receives its nerve supply from the median nerve at levels C6–7. The pronator teres is also a weak flexor of the elbow. The flexor carpi radialis plays a minor role in pronation with its chief function of wrist flexion.

Supinator Muscles

The primary supinators of the forearm are the biceps brachii and the supinator. As previously noted, the biceps and brachioradialis also serve to supinate the forearm.

The supinator muscle takes origin from three separate locations, the lateral epicondyle of the humerus, the proximal anterior crest and depression of the ulna distal to the radial notch, and the radial collateral and annular ligaments. This muscle then winds around the radius to insert into the dorsal and lateral surfaces of the proximal radius. The muscle receives its nerve supply from a deep branch of the radial nerve, derived primarily from the C6 nerve root level. Morrey noted that although the supinator muscle is a significant forearm supinator, it is generally weaker than the biceps (12). Kapandji found that the supinator acts alone only with unresisted slow supination

in all elbow/forearm positions and with unresisted fast supination with the elbow extended (3). The effectiveness of the supinator is not altered by elbow position; however, elbow position does significantly affect the biceps. The supinator's origin at the radial collateral ligament and annular ligament may point to an additional supportive or stabilizing role over the lateral aspect of the elbow (31).

CONCLUSIONS AND SUMMARY

Understanding the functional anatomy of the elbow, including bony, ligamentous, neural, and muscular details, enables the medical team member to correlate biomechanics of sport and injury patterns. An organized approach to care and treatment is easy when functional anatomy is remembered and kept on the front lines.

REFERENCES

1. Morrey BF, Askew LJ, Chao EY. Biomechanical study of normal functional elbow motion. *J Bone Joint Surg* 1981;63A:872–877.
2. Morrey BF, An RN. Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med* 1983;11:315–319.
3. Kapandji JA. *The physiology of the joints*. Vol. 1. London: E & S Livingstone, 1970:82–83,112–117.
4. Yocum Y, Dryer RF, Thambyrajah K, et al. Biomechanical analyis of forearm pronation-supination and elbow flexion-extension. *J Biomech* 1979;12:245–255.
5. Hoppenfeld S. *Physical examination of the spine and extremities*. New York: Appleton-Century-Crofts, 1976:35–55.
6. Magee DJ. *Orthopedic physical assessment*. Philadelphia, PA: WB Saunders, 1987:100–101.
7. Evans EM. Rotational deformity in the treatment of fractures of both bones of the forearm. *J Bone Joint Surg* 1945;27:373–379.
8. Timmerman LA, Andrews JR. Histology and arthroscopic anatomy of the ulnar collateral ligament of the elbow. *Am J Sports Med* 1994;22: 667–673.
9. Regan WD, Korinek SL, Morrey BF, et al. Biomechanical study of ligaments around the elbow joint. *Clin Orthop* 1991;271:170–179.
10. Sojbjerg JO, Ovesen J, Nielsen S. Experimental elbow instability after transection of the medial collateral ligament. *Clin Orthop* 1987;218: 186–190.
11. Fuss, FK. The ulnar collateral ligament of the human elbow joint. Anatomy, function, and biomechanics. *J Anat* 1991;175:203–212.
12. Morrey BF. Anatomy of the elbow. In: Morrey BF, ed. *The elbow and its disorders*. Philadelphia, PA: WB Saunders Co., 1985:
13. O'Driscoll SW, Morrey BF, Korinek SL. The patho-anatomy and kinematics of posterolateral rotatory instability (pivot shift) of the elbow [Abstract]. *Trans Orthop Res Soc* 1990;15:6.
14. O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow: Clinical and radiographic features. *J Bone Joint Surg* 1991;73A:440–446.
15. Markin BF. The oblique of the forearm. *J Anat* 1958;52:609–611.
16. Martin BF. The annular ligament of the superior radioulnar joint. *J Anat* 1958;52:473–482.
17. Spinner M, Kaplan EB. The relationship of the ulnar nerve to the medial intermuscular septum and its clinical significance. *Hand* 1976; 8:239–246.
18. Bert JM, Linschied RL, McElfresh EC. Rotatory contracture of the forearm. *J Bone Joint Surg* 1980;62A:1163–1168.
19. Hollinshead WH. *Anatomy for surgeons. Vol 3: The back and limbs*. 3rd ed. New York, NY: Harper & Row, 1982.
20. Morrey BF. Anatomy and kinematics of the elbow. In: Tullos HS, ed. *American Academy of Orthopaedic Surgeons instructional course lectures, XL*. St. Louis, MO: CV Mosby, 1991.
21. Davies F, Laird M. The supinator muscles and the deep radial (posterior interosseous) nerve. *Anat Rec* 1948;101:243–246.
22. Bassett FH, Nunley HA. Compression of the musculocutaneous nerve at the elbow. *J Bone Joint Surg* 1982;64A:1050.
23. Andrews JR, Carson WG, McLeod WD. Glenoid labrum tears related to the long head of the biceps. *Am J Sports Med* 1985;13:337–341.
24. Norkin C, Levangie P. *Joint structure and function: A comprehensive analysis*. Philadelphia, PA: FA Davis, 1985:191–210.
25. Basmajian JV, DeLuca CJ. *Muscles alive: Their functions revealed by electromyography*. Baltimore, MD: Williams & Wilkins, 1985:279–280.
26. Soderberg GL. *Kinesiology application to pathological motion*. Baltimore, MD: Williams & Wilkins, 1986:131–142.
27. Pavly JE, Rushing JL, Scheving LE. An electromyographic study of some muscles crossing the elbow joint. *Anat Rec* 1967;159:47–53.
28. Jobe FW, Moynes DR, Tibone JE, et al. An EMG analysis of the shoulder in pitching. 2nd report. *Am J Sports Med* 1984;12:218–220.
29. Davidson P, Pink M, Perry J, et al. *Functional anatomy of the flexor pronator muscle group in relationship to the medial collateral ligament of the elbow*. Presented at the AOSSM specialty day meeting at the annual meeting of the AAOS, New Orleans, LA, 1994.
30. Morrey BF, Chao YS. Passive motion of the elbow. *J Bone Joint Surg* 1976;58(A):501–508.
31. Stroyan M, Wilk KE. The functional anatomy of the elbow complex. *J Orthop Sports Phys Ther* 1993;17(6):279–288.