Clinical Anatomy of the Elbow

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Key Learning Points

1. The elbow joint is comprised of three articulations; the humeroulnar, radiocapitellar and proximal radioulnar joints.
2. The articulations are surrounded buy a joint capsule with condensations that form the lateral ligament complex and medial collateral ligament.
3. Three important nerves cross the elbow joint; the ulnar nerve, median nerve and radial nerve.
4. The elbow is supplied by the brachial, radial and ulnar arteries and their recurrent branches. The radial head is intracapsular and relies on retrograde blood flow.

1.1 Introduction

A thorough understanding of the anatomical structures is fundamental to correct diagnosis and safe treatment of disorders of the elbow. This chapter provides an overview of the surgical anatomy, and is divided into four anatomical sections: osteoarticular, capsuloligamentous, muscular and neurovascular.

1.2 Osteoarticular Anatomy

The elbow joint is comprised of three articulations: the humeroulnar, radiocapitellar and proximal radioulnar joints (although located within the capsule of the elbow joint this is really a part of the forearm joint).

1.2.1 The Humerus

The humerus terminates distally as a medial and lateral column, each forming a condyle and an epicondyle. These two columns hold the trochlea and the capitellum. The trochlea is an asymmetrical spool-shaped surface that articulates with the greater sigmoid notch of the olecranon. Its medial aspect projects further distally. The capitellum is hemispherical in shape and articulates with the concave surfaced radial head. The trochlear groove separates the two articular surfaces (Fig. 1.1).

The trochlear-capitellar articular surface is internally rotated approximately 5–7° in relation to the epicondylar axis [1]. Additionally, this surface has a valgus angle of between 6 and 8° when compared to the long axis of the humerus [2]. This is an important issue when the joint axis of rotation is to be surgically reproduced (fixation of fracture or application of a dynamic external fixator). In the sagittal plane the articular surface of the humerus protrudes approximately 30° anterior to the long axis of the humerus.

On the anterior surface of the humerus, proximal to the articular surface, lie the coronoid and radial fossae. These accommodate the coronoid process and radial head when the elbow is in full flexion. Similarly, on the posterior aspect of the humerus, the olecranon fossa accommodates the olecranon process of the ulna, permitting full extension of the elbow. The normal range of elbow flexion/extension is approximately 0–150°, with 30–130° necessary to maintain a functional arc [3]. A sulcus, posterior to the medial epicondyle, accommodates the passage of the ulna nerve (Fig. 1.2).

1.2.2 The Ulna

The main articulating portion of the proximal ulna is the greater sigmoid (or trochlear) notch. It is formed predominantly by the olecranon, with the coronoid process extending the joint surface anteriorly (Fig. 1.3). It is elliptical in shape, with a longitudinal ridge conveying a stable and congruent articulation with the trochlea, forming the humeroulnar joint. It is oriented approximately 30° posterior to the long axis of the ulna to match the anterior angulation of the distal humerus. The coronoid process is comprised of a large antero-

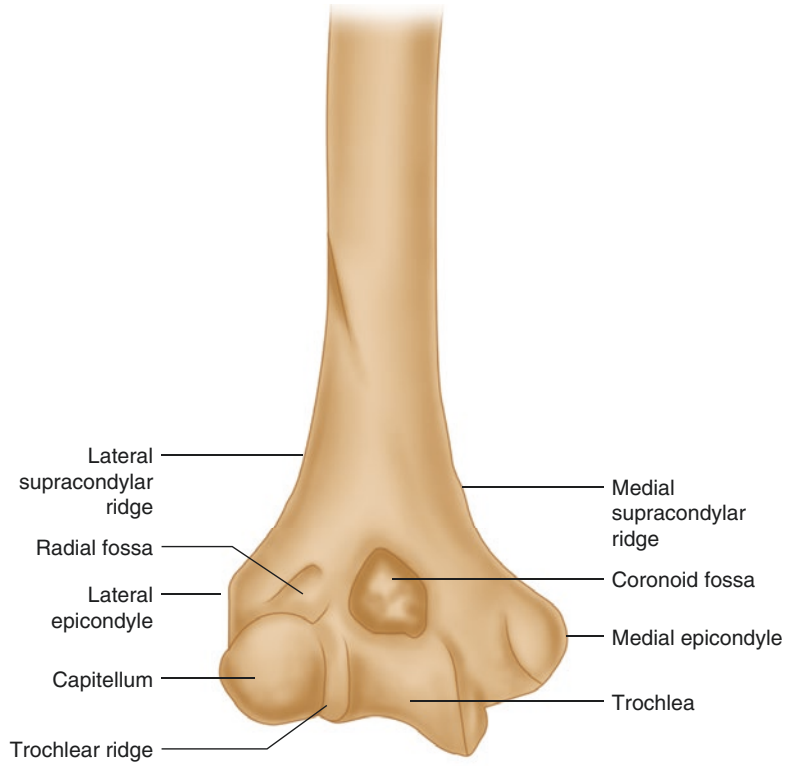


Fig. 1.1 Anterior view of right distal humerus

medial facet and smaller anterolateral facet that articulate with the medial trochlea and lateral trochlea respectively.

The articular cartilage surface of the trochlear notch is interrupted by a variable transverse 'bare area' of bone, located midway between the tip of the olecranon and the coronoid process (Fig. 1.4).

Distal to the trochlear notch, on the lateral aspect of the coronoid process, lies the lesser sigmoid (or radial) notch. This accommodates the radial head, forming the proximal radioulnar joint. The supinator crest originates at the distal part of the lesser sigmoid notch, and provides the origin of the supinator muscle and on the most proximal part of it, the insertion for the lateral ulnar collateral ligament (LUCL).

On the medial coronoid, lies an important bony prominence—the sublime tubercle. This provides the insertion site for the anterior bundle of the anterior medial collateral ligament (AMCL), and is fundamental to both the valgus stability of the elbow (see capsuloligamentous anatomy section) and maintaining the trochlea within the greater sigmoid notch.

1.2.3 The Radius

The surface of the radial head is concave in shape. Both the proximal end and approximately its circumference are covered with articular cartilage, allowing a smooth articulation with both the capitellum, and the lesser sigmoid notch. The radial neck constitutes the most distal intra-articular portion of the proximal radius.

On the anteromedial surface of the radius, just distal to the neck, lays the bicipital tuberosity. This is the point of insertion for the biceps brachii tendon.

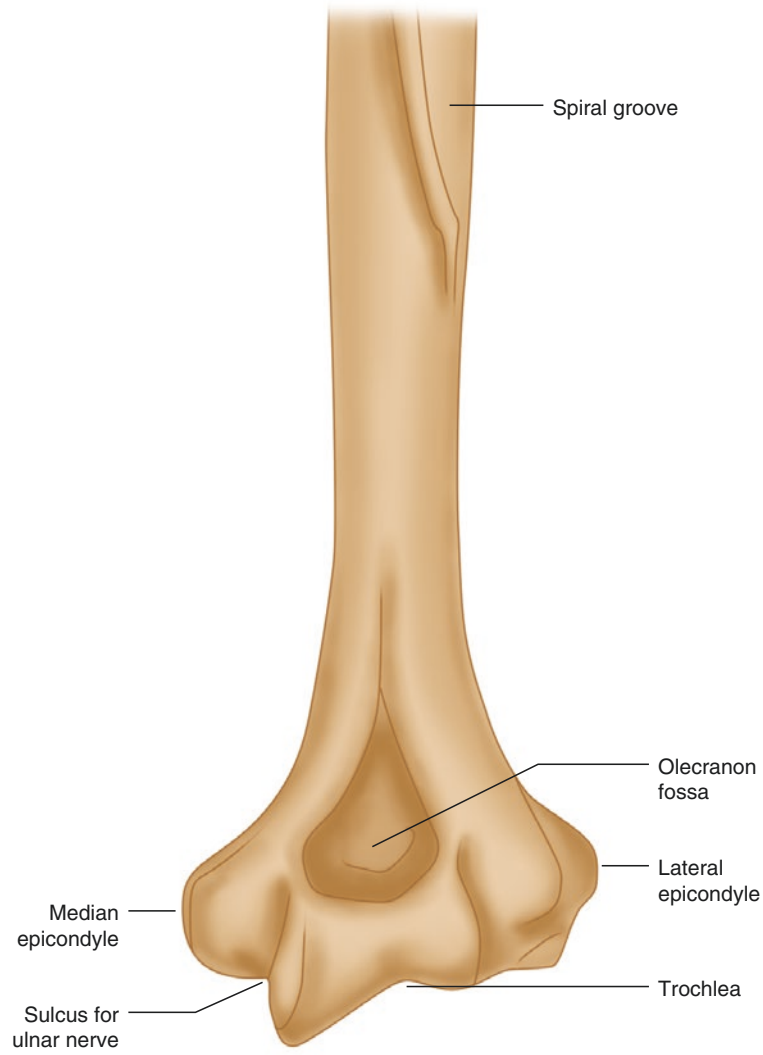


Fig. 1.2 Posterior view of right distal humerus

1.3 Capsuloligamentous Anatomy

1.3.1 Joint Capsule

The three elbow articulations are surrounded by a joint capsule and form a synovial joint. The anterior capsule inserts proximally above the radial and coronoid fossae of the humerus, and attaches to the anterior surface of the coronoid medially (sparing the tip, which remains intra-articular) and the annular ligament laterally. Posteriorly it attaches above the olecranon fossa and around the medial and lateral margins of the sigmoid notch.

The maximum capacity of the capsule is 25–30 mL at approximately 80° of flexion [4]. The capsule is innervated by the nerves that cross it; namely the musculocutaneous, radial, median and ulnar nerves.

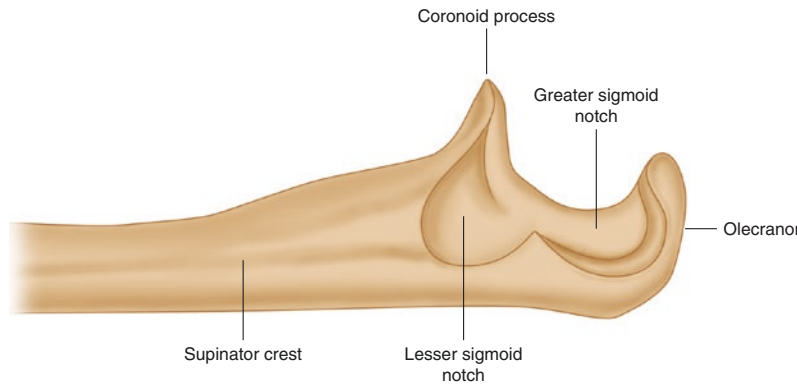


Fig. 1.3 Lateral view of right proximal ulna

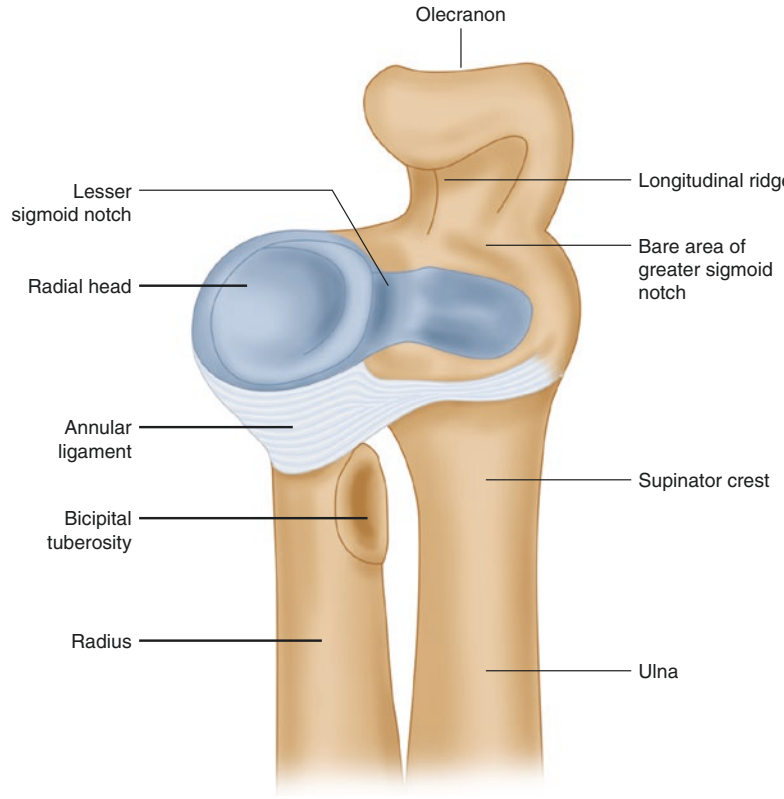


Fig. 1.4 Right proximal radioulnar joint

1.3.2 Ligaments

1.3.2.1 Medial Collateral Ligament Complex

The medial collateral ligament comprises an anterior and posterior bundle, and a supporting transverse ligament; the function of which is not well understood (Fig. 1.5).

The anterior bundle originates from the anteroinferior aspect of the medial epicondyle [5], and inserts on the sublime tubercle of the ulna, on average 18 mm posterior from the tip of the coronoid [6]. The centre of the anterior bundle origin lies at the axis of rotation of the elbow [7, 8], however, it is comprised of an anterior and posterior band, which are maximally

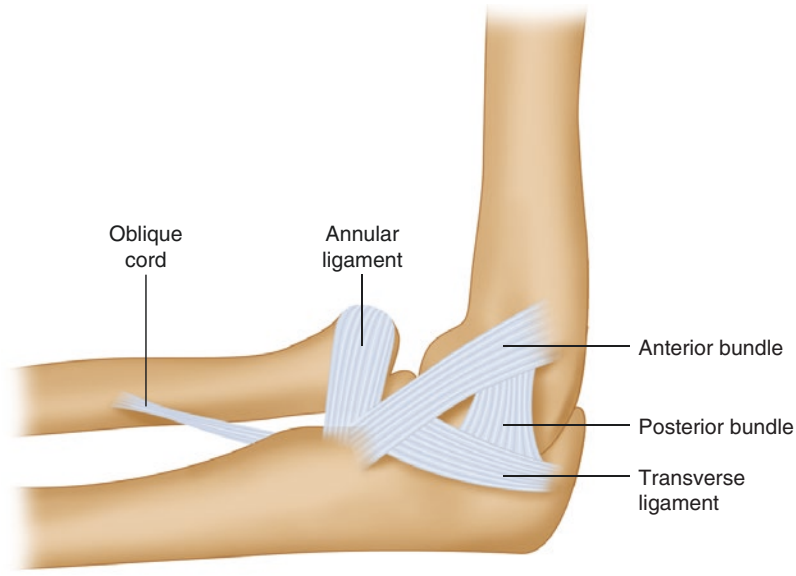


Fig. 1.5 Medial collateral ligament complex

tight (functional) at different ranges of flexion-extension arc [9, 10].

The posterior bundle originates posterior to the anterior bundle on the medial epicondyle, and inserts along the mid-portion of the greater sigmoid notch. The posterior bundle is lax in extension due to its posterior relationship to the axis of rotation. It, therefore, restrains valgus stress in flexion only [8, 10].

The anterior band of the anterior bundle is the primary constraint to valgus and internal rotatory forces. The posterior band is the secondary, and the posterior bundle is the tertiary constraint [9].

1.3.2.2 Lateral Collateral Ligament Complex

The lateral collateral ligament complex comprises the radial collateral ligament (RCL), the annular ligament, the lateral ulnar collateral ligament (LUCL), and the accessory lateral collateral ligament (ALCL) (when it exists) (Fig. 1.6).

The RCL and LUCL both originate from the centre of rotation on the lateral epicondyle, and thus are isometric throughout elbow flexion [11]. The RCL inserts along the annular ligament and the LUCL inserts onto the tubercle of the supinator crest of the ulna. Both ligaments resist varus stress, with the LUCL fundamental to holding the greater sigmoid notch onto the trochlea [12].

The annular ligament attaches to the anterior and posterior margins of the lesser sigmoid notch, maintaining the proximal radioulnar joint. The ALCL stabilises the annular ligament during varus stress of the elbow but sometimes it is not distinctly different from the capsule of the joint.

Recent evidence suggests a fifth element, the posterolateral or Osborn-Cotterill ligament arising from the posterolateral aspect of the capitellum and inserting in to the margin of the greater sigmoid notch proximal to the supinator crest. This has been shown to contribute to posterior stability of the radial head at around 60° elbow flexion.

1.4 Muscular Anatomy

Muscular anatomy is summarised in Table 1.1

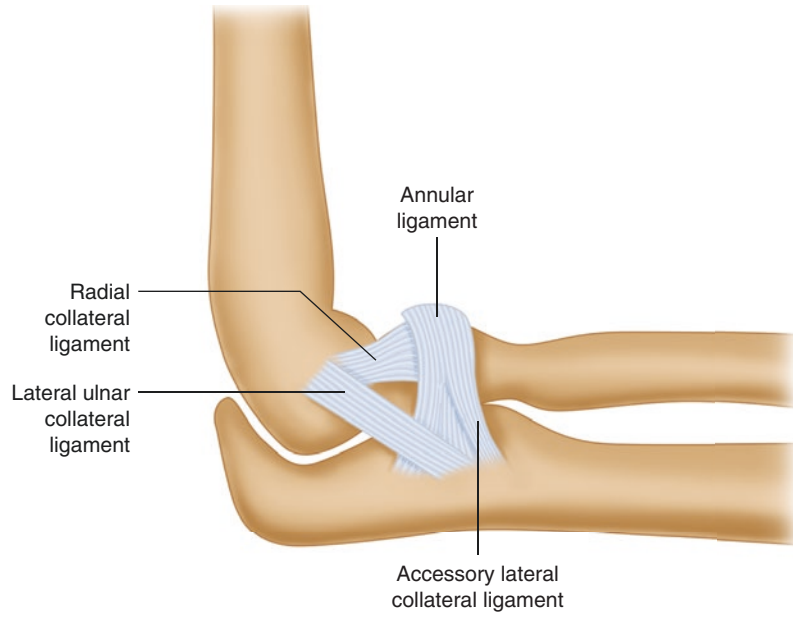


Fig. 1.6 Lateral collateral ligament complex

Table 1.1 Details the muscles that act upon or cross the elbow joint

Muscle	Origin	Insertion	Innervation	Action
Triceps brachii	• Long head—infraglenoid tubercle of scapula • Lateral head—superior to spiral groove of humerus • Medial head—inferior to spiral groove of humerus	• Olecranon • Additional attachment to dorsal fascia of forearm	• Radial nerve • Axillary nerve recognised variation for long head [13]	• Elbow extension
Anconeus	• Posterior lateral epicondyle	• Lateral posterior proximal ulna	• Radial nerve	• Elbow extension and stabilisation
Supinator	• Anterior lateral epicondyle • Lateral collateral ligament complex • Supinator crest of proximal ulna	• Lateral proximal radial diaphysis	• Posterior interosseous nerve	• Forearm supination
Brachioradialis	• Lateral supracondylar ridge of humerus • Lateral intermuscular septum	• Radial styloid	• Radial nerve	• Elbow flexion • Forearm pro- and supination
Extensor carpii radialis longus	• Lateral supracondylar ridge of humerus • Lateral intermuscular septum • Common extensor origin of lateral epicondyle	• Dorsal, radial surface of index finger metacarpal	• Radial nerve	• Wrist extension and radial deviation
Extensor carpii radialis brevis	• Common extensor origin of lateral epicondyle • Radial collateral ligament	• Dorsal surface of middle finger metacarpal	• Posterior interosseous nerve	• Wrist extension

(continued)

Table 1.1 (continued)

Muscle	Origin	Insertion	Innervation	Action
Extensor digitorum communis	• Common extensor origin of lateral epicondyle	• Extensor expansions of index, middle, ring and little fingers	• Posterior interosseous nerve	• PIPJ/DIPJ of Fingers (and wrist) extension
Extensor digiti minimi	• Common extensor origin of lateral epicondyle	• Extensor expansion of little finger	• Posterior interosseous nerve	• Little finger PIPJ/DIPJ extension
Extensor carpii ulnaris	• Common extensor origin of lateral epicondyle • Posterior aspect of ulna	• Dorsal base of little finger metacarpal	• Posterior interosseous nerve	• Wrist extension • Ulnar deviation of wrist • Dynamic stabiliser of distal radioulnar joint
Brachialis	• Distal anterior humerus • Lateral and medial intermuscular septum	• Ulnar tuberosity	• Musculocutaneous nerve	• Elbow flexion
Biceps brachii	• Long head—supraglenoid tubercle of scapula • Short head—coracoid process	• Bicipital tuberosity of radius	• Musculocutaneous nerve	• Forearm supination • Elbow flexion
Flexor carpi ulnaris	• Humeral head—common flexor origin of medial epicondyle • Ulnar head—medial olecranon	• Base of little finger metacarpal via the pisiform and hamate	• Ulnar nerve	• Wrist flexion • Ulnar deviation of wrist
Flexor digitorum superficialis	• Humeroulnar head—common flexor origin of medial epicondyle, medial collateral ligament and the medial side of the coronoid • Radial head—anterior radial aspect	• Volar middle phalanges of index, middle, ring and little fingers	• Median nerve	• Finger flexion at proximal interphalangeal joint
Palmaris longus	• Common flexor origin of medial epicondyle	• Palmar aponeurosis	• Median nerve	• Wrist flexion
Flexor carpi radialis	• Common flexor origin of medial epicondyle	• Volar base of index finger metacarpal	• Median nerve	• Wrist flexion • Radial deviation of wrist
Pronator teres	• Humeral head—common flexor origin of medial epicondyle • Ulnar head—coronoid process	• Radial surface of midshaft radius just distal to insertion of supinator	• Median nerve	• Forearm pronation • Elbow flexion

1.5 Neurovascular Anatomy

1.5.1 Radial Nerve

The radial nerve is derived from the C5-T1 nerve roots, and is a terminal branch of the posterior cord of the brachial plexus. It exits the axilla through the lateral triangular space (teres major superiorly, long head of triceps medially, humerus laterally) accompanied by the profunda brachii artery, and passes into the posterior compartment of the arm. It winds around the humerus

over the spiral (or radial) groove, to appear on the lateral aspect of the humerus, where it pierces the lateral intermuscular septum to enter the anterior compartment of the arm. It then approaches the elbow between the brachialis and brachioradialis muscles. It is readily identified 1–2 cm proximal to the medial tip of triceps aponeurosis as an intraoperative landmark. Its course, interestingly, follows the superior border of the aponeurosis coming out of intermuscular septum 1–2 cm proximal to the lateral tip of aponeurosis [14].

The radial nerve then passes under the cover of extensor carpi radialis longus and brevis, and emerges anterior to the lateral epicondyle. At the level of the radiocapitellar joint, it divides into the superficial radial and posterior interosseous nerves.

The superficial radial nerve continues distally in the forearm under the brachioradialis muscle towards the wrist. The posterior interosseous nerve passes between the two heads of supinator to enter the posterior compartment of the forearm. The proximity of the nerve to the proximal radius is dependent on rotational position of the forearm [15], where the nerve is more proximal and under tension in full supination and relaxed and 'away' in pronation.

Damage to the radial nerve most commonly occurs following fractures of the humeral shaft or the proximal radius.

1.5.2 Median Nerve

The median nerve is derived from the C6-T1 nerve roots, and is a terminal branch of both the medial and lateral cords of the brachial plexus. It leaves the axilla at the inferior margin of teres major. It descends in the anterior compartment of the arm between the biceps brachii and brachialis muscles, in association with the brachial artery. In the upper arm it lies lateral to the artery, but crosses over in the mid-arm to lie medial to it. The artery and nerve then pass deep to the bicipital aponeurosis at the elbow, lying medial to the biceps brachii tendon and anterior to the brachialis muscle.

The nerve then passes under the humeral head of pronator teres, and between the humeroulnar and radial heads of the flexor digitorum superficialis muscle to continue distally in the anterior compartment of the forearm. The median nerve gives off the anterior interosseous nerve in the forearm between 5 and 8 cm distal to the level of the lateral epicondyle, usually immediately distal to the humeral head of pronator teres [16].

1.5.3 Ulnar Nerve

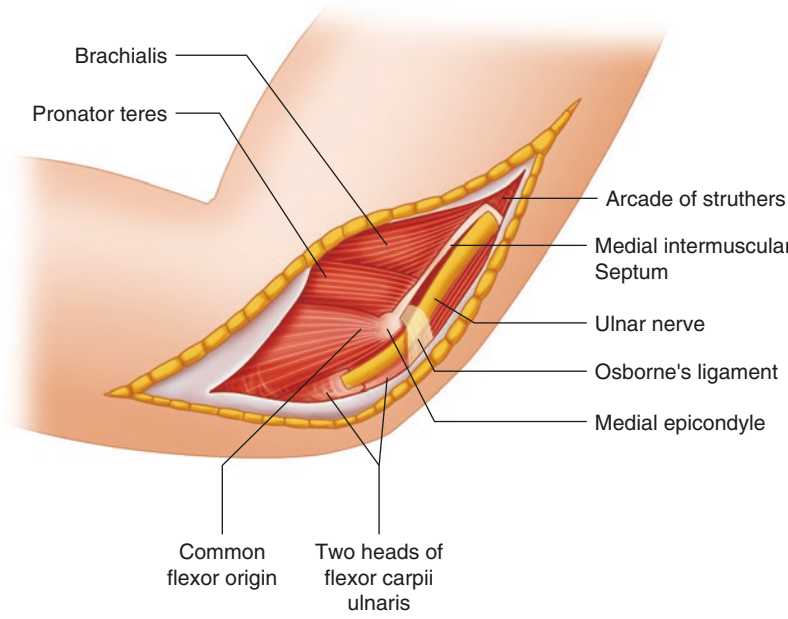
The ulnar nerve is the largest branch of the medial cord of the brachial plexus, with nerve roots originating from spinal levels C8-T1. It exits the axilla between the axillary nerve and vein, and descends medial to the brachial artery.

Half-way down the arm it pierces the medial intermuscular septum to lie on the posteromedial aspect of the humerus. The nerve passes between the medial intermuscular septum (anterior) and the medial head of triceps (posterior), and into the sulcus of the ulna nerve—a depression on the back of the medial epicondyle of the humerus (Fig. 1.2). It then passes into the anterior compartment of the forearm through the cubital tunnel (Fig. 1.7).

The cubital tunnel is approximately 5 cm in length. The medial epicondyle forms the medial wall and base proximally, and the olecranon comprises the lateral wall. A fibrous aponeurosis called Osborne's ligament forms the roof, connecting the medial epicondyle and olecranon proximally, and is continuous with the fascia of the humeral and ulnar heads of flexor carpii ulnaris distally. The floor is comprised of the joint capsule and the medial collateral ligaments.

After passing through the cubital tunnel, the ulna nerve passes between the two heads of flexor carpii ulnaris, and continues in the forearm on the muscle belly of flexor digitorum profundus, beneath the flexor carpii ulnaris muscle.

Fig. 1.7 Cubital tunnel



1.5.4 Medial Cutaneous Nerves of the Arm and Forearm

The medial cutaneous nerve of the arm is the smallest branch of the medial cord of the brachial plexus. It leaves the axilla posterior to the axillary vein, then passing to its medial side, where it contributes fibres to the intercostobrachial nerve. It descends medial to the brachial artery and pierces the brachial fascia in the middle third of the arm. It provides cutaneous innervation to the medial aspect of the distal third of the arm, extending as far as the elbow.

The medial cutaneous nerve of the forearm also originates from the medial cord of the brachial plexus. It descends the arm with the medial cutaneous nerve, and pierces the brachial fascia with the basilic vein. It divides into an anterior and posterior branch, and passes anterior to the medial epicondyle of the humerus. The anterior branch passes in front of the median basilic vein, and descends on the ulnar side of the forearm. The posterior branch passes obliquely on the medial side of the basilic vein to the posterior aspect of the forearm. It is often encountered during decompression of the ulnar nerve around the cubital tunnel, and injury can lead to painful neuroma [17]. The nerves provide cutaneous innervation to the anteromedial, medial and posteromedial aspect of the forearm to the level of the wrist.

1.5.5 Lateral Cutaneous Nerves of the Arm and Forearm

The skin of the lateral arm is innervated by the terminal branch of the posterior cord of the axillary nerve (superior lateral cutaneous nerve of the arm), and a branch of the radial nerve (inferior lateral cutaneous nerve of the arm), which supply the superolateral and inferolateral aspects, respectively.

The lateral cutaneous nerve of the forearm is the sensory continuation of the musculocutaneous nerve. The musculocutaneous nerve arises from the lateral cord of the brachial plexus, from nerve roots C5-C7. It passes into the arm in the coracobrachialis muscle, and passes between the biceps brachii and brachialis muscles to the lateral side of the arm. It pierces the brachial fascia lateral to the biceps tendon, to become the lateral cutaneous nerve of the forearm. At the level of cubital crease, it usually lies just lateral to the

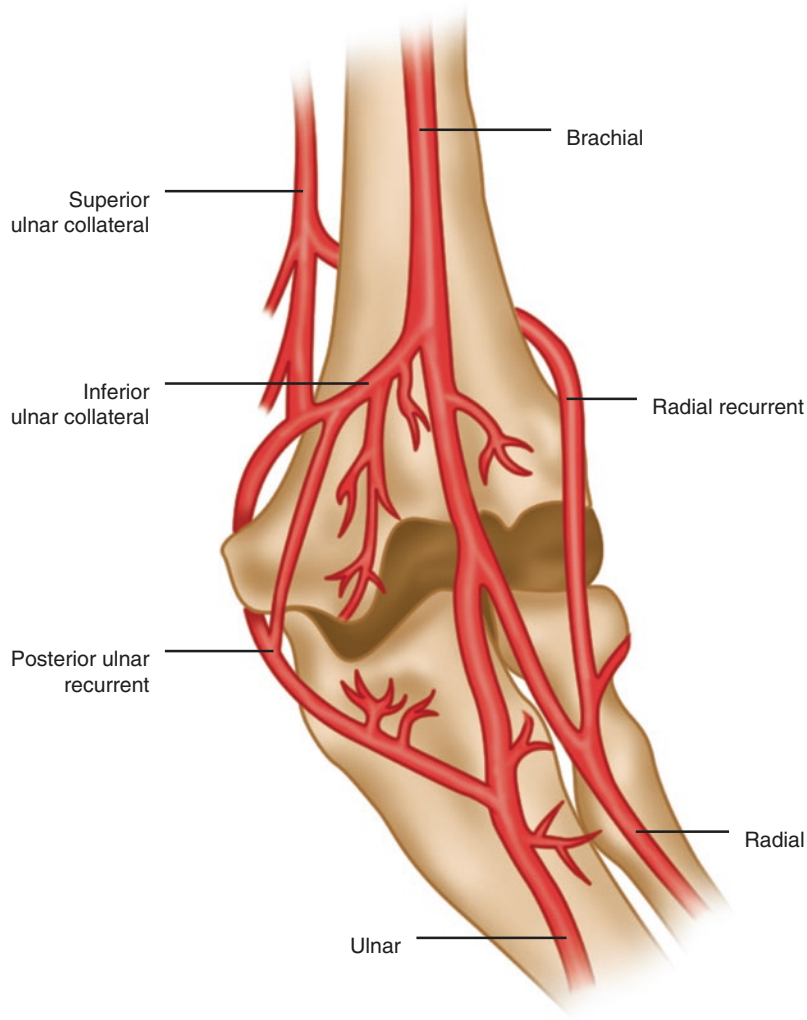


Fig. 1.8 Anterior extraosseous vascular anatomy

cephalic vein. It then passes over the anterolateral aspect of the elbow, and divides into an anterior and posterior branch, innervating the skin of the lateral forearm.

1.5.6 Arteries

The elbow is supplied by the brachial, radial and ulnar arteries and their recurrent branches.

The brachial artery is the continuation of the axillary artery at the inferior border of teres major. At this level it gives off its major branch, the profunda brachii, which passes through the lateral triangular space with the radial nerve towards the anterolateral elbow. The brachial artery courses the medial arm between the median and ulnar nerves. After passing under the lacertus fibrosus, it enters the antecubital fossa in the midline of the elbow, lying medial to the tendon of biceps brachii. At the level of the radial neck, it bifurcates into the radial and ulnar arteries.

The radial artery runs distally under brachioradialis towards the wrist, medial to the superficial radial nerve. The ulnar artery passes deep towards the anteromedial aspect of the forearm, to lie first upon brachialis and later flexor digitorum profundus as it courses to the wrist.

The collateral supply of the elbow has been described to comprise three arcades: medial,

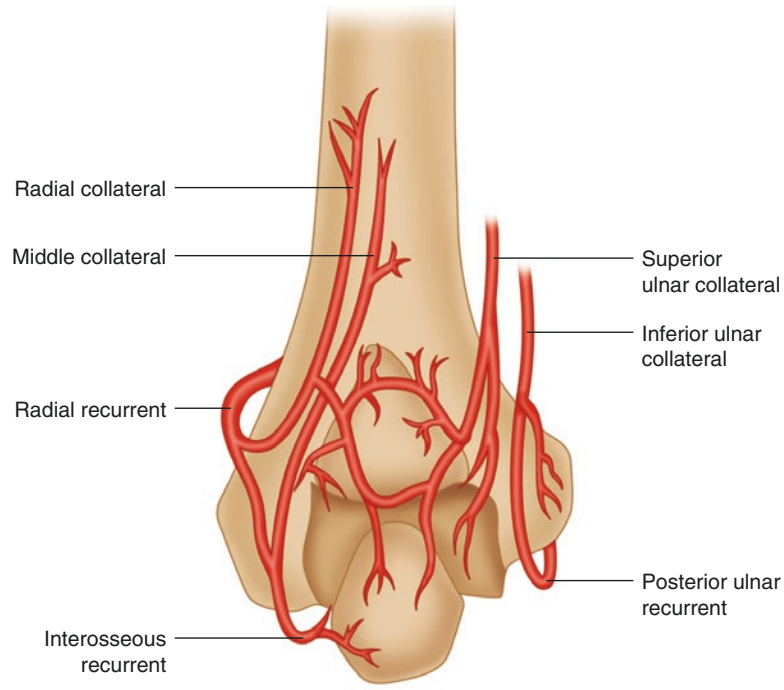


Fig. 1.9 Posterior extraosseous vascular anatomy

lateral and posterior [18]. The medial arcade is formed by the superior and inferior ulnar collateral branches from the brachial artery, which anastomose the posterior ulnar recurrent branch of the ulnar artery around the medial epicondyle (Fig. 1.8). The medial arcade supplies the medial epicondyle, medial aspect of the trochlea, and the posteromedial olecranon.

The lateral arcade is formed by the descending radial and middle collateral arteries (originating from the profunda brachii), anatomising with the ascending interosseous recurrent and radial recurrent arteries on the posterior aspect of the lateral epicondyle. The lateral arcade supplies the lateral epicondyle and the capitellum.

The posterior arcade is formed in the olecranon fossa by anastomosis of the superior ulnar, radial and middle collateral arteries proximally, and the interosseous recurrent artery distally. The posterior arcade supplies the lateral aspect of the trochlear, the supracondylar region and also branches to the olecranon (Fig. 1.9).

The radial head is intracapsular and receives its blood supply from branches of the recurrent radial artery that pass retrograde up the neck of the radius. The olecranon receives its supply from the posterior ulnar recurrent and the interosseous recurrent arteries, and from the posterior arcade.

1.5.7 Veins

The deep veins of the upper limb are the venae comitantes of the arteries, ending at the inferior border of teres major, where they are joined by the basilic vein to form the axillary vein.

The major superficial veins are the cephalic and basilic veins, which communicate over the antecubital fossa via the median cubital vein. The cephalic vein drains the lateral upper limb, and joins the axillary vein after piercing the deltopectoral fascia. The basilic vein drains the medial upper limb and pierces the brachial fascia to join the brachial vein in the arm.

Q&A

- What are the important elements of the coronoid process?

  The coronoid process is the primary stabiliser of the elbow joint and is made of two facets, anteromedial and anterolateral, that

articulate with the trochlea and also has a medial projection the sublime tubercle into which the anterior band of the medial collateral ligament inserts

- What is the lateral ligament complex?

  The lateral ligament complex is a thickening of the lateral joint capsule that can be considered as five elements that contribute to the stability of the lateral ulnohumeral joint and radial head. The complex arises from the lateral epicondyle and has a primary element, the lateral ulna collateral ligament, that passes to the supinator crest, the radial collateral that inserts to the annular ligament that surrounds the radial head, the accessory ulna collateral ligament and the posterolateral ligament that inserts along the margin of the greater sigmoid notch posteriorly.

- Why is the radial head at risk of non-union or avascular necrosis after fracture?

  The radial head is an intracapsular structure that receives a blood supply from a branch of the radial recurrent artery that travels up the neck of the radius from distal to proximal and is at risk of disruption by fracture or surgery.

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