Anatomy of Nerve Entrapment Sites in the Upper Quarter

Neal Pratt, PhD, PT
Department of Rehabilitation Sciences
Drexel University
Philadelphia, Pennsylvania

ABSTRACT: The purpose of this article is to review the anatomical features of the most common nerve entrapment sites of the brachial plexus and major peripheral nerves of the upper limb. In this account, the term "entrapment" is considered to be caused by compression, tension, or friction, or any combination of these factors. The anatomy, including important relationships of the brachial plexus, is reviewed and the points of potential entrapment of the plexus are described. Entrapment of the suprascapular and long thoracic nerves is also included. Particular attention is paid to the five major peripheral nerves that result from the brachial plexus and supply the peripheral aspect of the upper limb, i.e., the median, ulnar, musculocutaneous, radial, and axillary nerves. In each case, the nerve's course is described and the anatomical details of the entrapment points described. Where possible, the sites of entrapment are illustrated in cadaveric photographs.
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The purpose of this article is to review the anatomical courses of the brachial plexus and its major terminal nerves, and to indicate the specific anatomical points at which the nerve trunks and nerves are potentially susceptible to entrapment. The sites presented in this article are based on the literature and the logical correlation of symptomology and anatomy. The anatomical course of each structure is described from proximal to distal; in addition, any potential entrapment points (PEP) are described. It should be noted that the term "entrapment" is interpreted in the widest sense in this discussion. At the points of entrapment described, the nerves may be subjected to compression, tension/stretch, friction, or any combination thereof.

BRACHIAL PLEXUS

The brachial plexus (Figure 1) begins in the posterior cervical triangle and extends into the axilla where the major peripheral nerves of the upper limb are formed. In both the posterior triangle and the axilla, smaller nerves branch from the plexus. These nerves supply the muscles of the shoulder region.

The brachial plexus is formed by the ventral (primary) rami of spinal nerves C5 through T1.

(Anatomically, these rami are called the roots of the plexus which can be confusing because the spinal nerves are formed by the dorsal and ventral roots of the spinal cord.) These ventral rami enter the posterior cervical triangle by passing between the anterior and middle scalene muscles and superior to the first rib. This interval is referred to as either the scalene groove or triangle. With the exception of T1, these rami pass horizontally or descend through the groove. Ramus T1 ascends from the thorax and curls around the anterior surface of the first rib, passing through the superior thoracic aperture, to reach the posterior triangle. Rami C5 and C6 form the superior trunk, C7 continues as the middle trunk, and C8 and T1 unite to form the inferior trunk. Only the most proximal portion of the brachial plexus, the rami and parts of the trunks, is found in the posterior triangle. The trunks enter the axilla by passing between the clavicle and first rib, close to the sternoclavicular joint.

Each trunk divides into an anterior and a posterior division. The anterior divisions of the superior and middle trunks combine to form the lateral cord. The anterior division of the inferior trunk continues as the medial cord and all three posterior divisions unite to form the posterior cord. The cords are named by their relationships with the second part of the axillary artery, which is posterior to the pectoralis minor muscle. As the divisions and cords are formed, the brachial plexus and axillary vessels become enclosed by a sleeve of fibrous tissue called the axillary sheath.
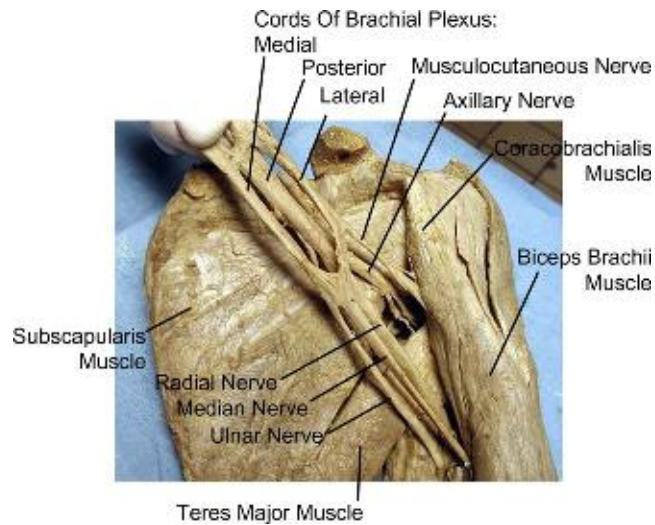
FIGURE 1. *Cadaver specimen: anterior view of the left brachial plexus distal to the point where the cords are formed. The trunks and divisions are obscured by the demonstrator's hand.*

The end result of the plexus is the formation of the large peripheral nerves that supply most of the upper limb. These nerves are all formed in the axillary region. The median nerve is formed by contributions from both the medial and lateral cords. The musculocutaneous nerve is the continuation of the lateral cord; the ulnar is the continuation of the medial cord. The posterior cord gives rise to the axillary nerve and the much larger radial nerve. There are many potential variant fibrous bands and muscle slips that can occur in the axillary region where these nerves are formed. By and large these variations are rare; and even though some can potentially interfere with

some of the nerves, their descriptions are omitted in this discussion.

PEP: The *superior thoracic aperture*[1] (Figure 2) is the junctional region between the neck and mediastinum. The boundary consists of the manubrium of the sternum, first ribs, and body of the first (or second) thoracic vertebra. This area is packed with soft-tissue structures including the lungs, esophagus, trachea, and a variety of neurovascular structures. The ventral ramus of T1 arises inferior to the first rib and must ascend and wrap around the rather sharp anterior surface of the first rib to get to the posterior cervical triangle (Figure 3). The
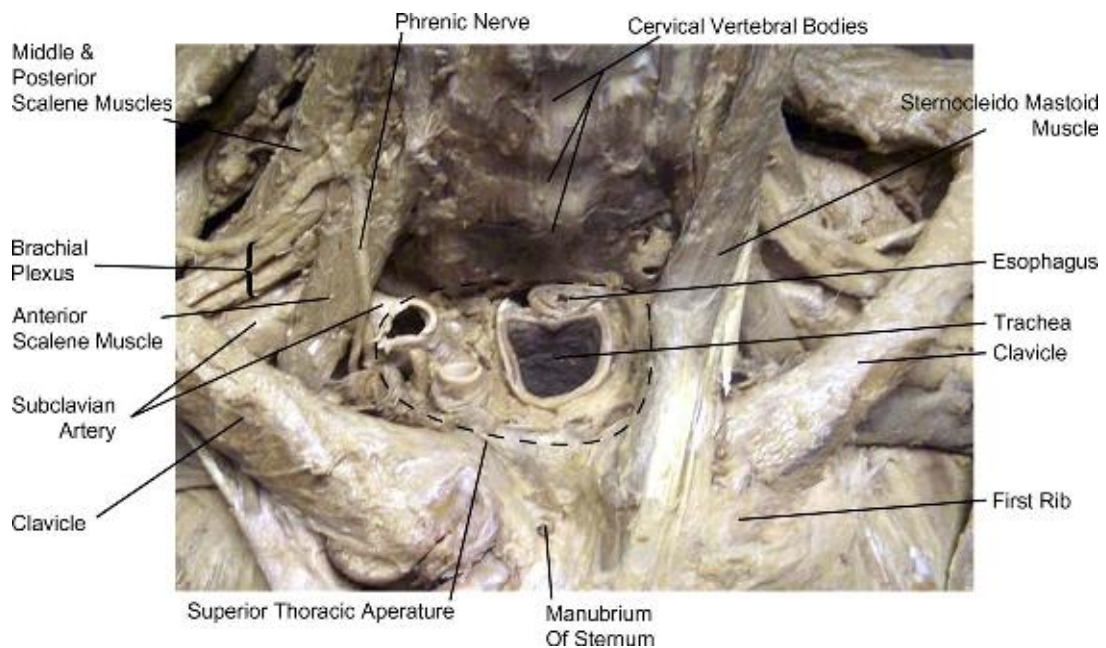

FIGURE 2. *Cadaver specimen: anterosuperior view of the superior thoracic aperture and right scalene triangle. Note the viscera and neurovascular structures passing through the aperture and the brachial plexus and subclavian artery passing through the triangle.*
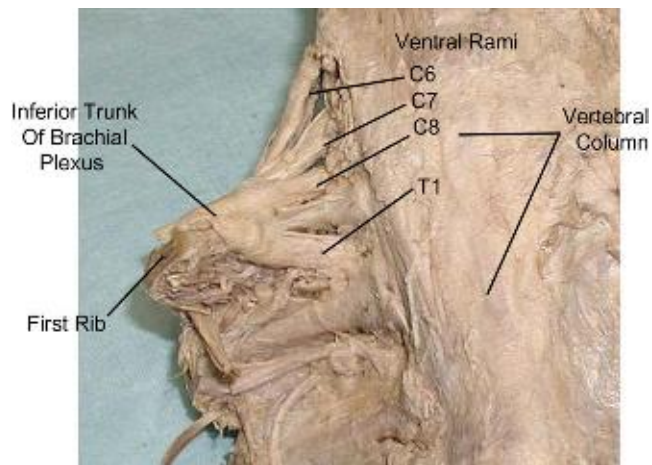
FIGURE 3. *Cadaver specimen: anterior view of the lower cervical and upper thoracic vertebra and the posterior aspects of right ribs 1–3. The ventral rami of spinal nerves C6, C7, C8, and T1 are also shown. Notice T1 ascending to cross the anterior aspect of the fist rib as it exits from the thorax and joins C8 to form the inferior trunk.*

aperture is packed with soft-tissue structures, and any increase in pressure, perhaps caused by a space taking lesion, could potentially compress root T1 against the first rib.

PEP: The *scalene triangle,*[1–7] (Figure 2) formed by the anterior and middle scalene muscles together with the first rib, typically has a narrow base and high sides; hence, the term groove is quite appropriate. Even so, the shape of the triangle varies considerably with body build and can range from a tall thin triangle to one with a wide base and short sides. The size of the triangle or the characteristics of its boundaries can be changed by a variety of anatomical variations. The floor (first rib) can be elevated by the existence of a cervical rib. It is interesting to note that a cervical rib, which develops from anlage that also gives rise to all other connective tissues, can also exist in a fibrous form. The geometry of the triangle can also be modified by a variety of fibrous bands[8] as well as hypertrophy of the scalene muscles, hence the term "scalene syndrome." A muscular variation, the "scalene minimus," (Figure 4) can pass across the opening and also reduce the space for the nerve trunks.

PEP: The *costoclavicular interval* (nutcracker)[1,3,5,9,10] (Figure 5) is formed by the medial aspects of the clavicle and first rib just lateral to their articulations with the manubrium of the sternum. Even though both of these bones are curved, the effect of their relationship resembles a nutcracker since the two bones articulate very close to one another on the manubrium. Depression of the shoulder and hence the clavicle, as well as elevation of the first rib, reduces the space between the bones. Since the closest structure to the sternum is the axillary vein it perhaps is the structure most vulnerable to compression.

PEP: The *coracoid/pectoralis minor loop*[1,3,5,11,12] (Figure 5) is formed by the pectoralis minor muscle

inserting on the coracoid process. Posterior to the muscle the cords of the brachial plexus and the axillary vessels form a neurovascular bundle that is tightly enclosed by a sleeve of fascia called the axillary sheath. With the upper limb at the side, the neurovascular bundle would appear to be in no jeopardy at this point. With the arm elevated and externally rotated, however, the bundle is held in
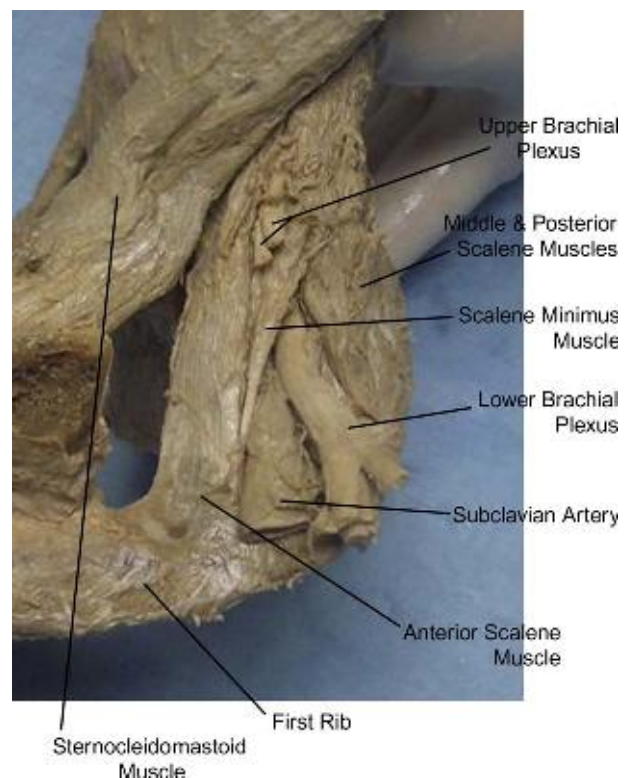

FIGURE 4. *Cadaver specimen: lateral view of the left scalene triangle. Note how the scalene minimus muscle crosses the scalene triangle and separates components of the brachial plexus.*
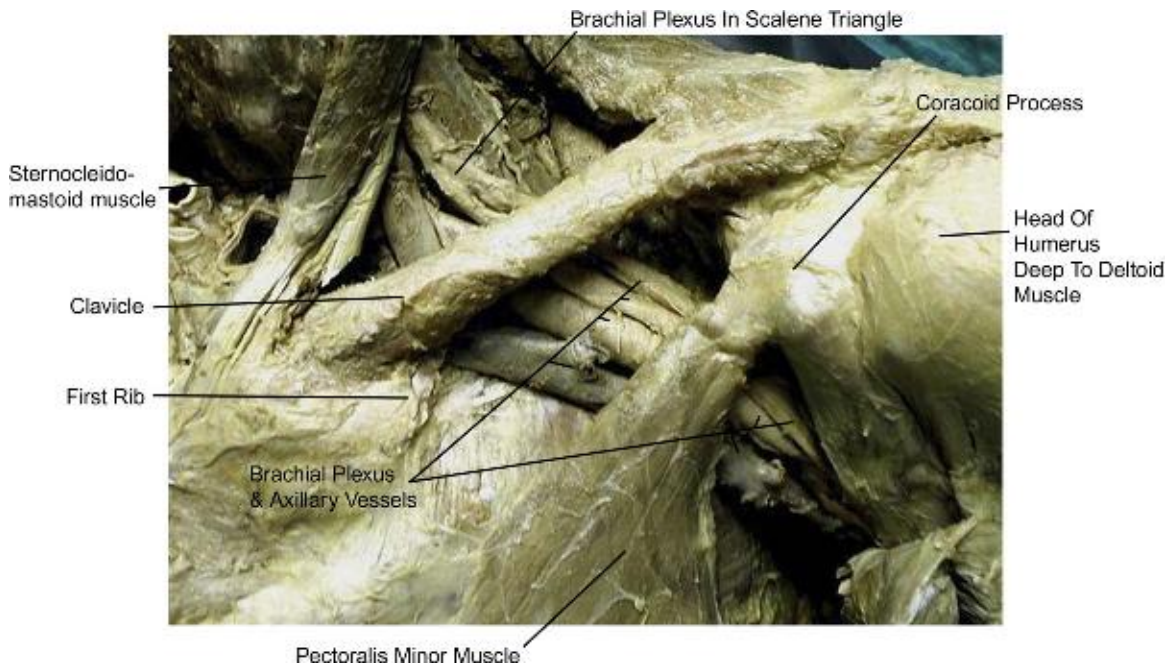
FIGURE 5. *Cadaver specimen: anterior view of the left posterior cervical triangle and axillary region. The brachial plexus and axillary vessels can be seen emerging from the scalene triangle, passing between the clavicle and first rib and passing inferior to the coracoid process and posterior the pectoralis minor muscle. Note also the position of the humeral head relative to the coracoid process and neurovascular bundle.*

place by the loop and stretched around the coracoid process.

PEP: The *head of the humerus* (Figure 5) is positioned just lateral and posterior to the coracoid process; the neurovascular bundle passes just below the humeral head. This potential point of entrapment seems directly related to the coracoid-pectoralis minor loop. As the arm is elevated and externally rotated the neurovascular bundle is held in place by the loop, ensuring that the bundle must pass around the head and thus be further stretched.

BRANCHES OF THE PLEXUS THAT SUPPLY SHOULDER GIRDLE MUSCLES

The suprascapular nerve arises from the superior trunk of the plexus and passes laterally and a bit inferiorly toward the coracoid process. Just medial to the coracoid, it passes through the suprascapular foramen which is formed by the suprascapular notch and transverse scapular ligament. It supplies the suprascapular muscle in the suprascapular fossa, then curves around the spinoglenoid notch to supply the infraspinatus muscle. The spinoglenoid notch is sometimes converted into the spinoglenoid foramen by the presence of an inferior transverse scapular ligament.

PEP: The *suprascapular foramen* (Figure 6) and *spinoglenoid notch* are anatomically close points of entrapment.[3,13–17] Suprascapular neuropathies have been documented in such athletes as

pitchers and volleyball players. The nerve is short and under some tension and presumably is subjected to friction and perhaps increased tension during significant scapular excursion. Another interesting consideration is the role the nerve might play in the formation of capsulitis of the glenohumeral joint. In addition to innervating the two muscles, the suprascapular nerve supplies the posterior and superior aspects of the shoulder joint capsule but has no cutaneous distribution. Entrapment of the nerve could presumably produce deep shoulder pain with motion, and thus lead to reduced shoulder activity and perhaps capsulitis.

The long thoracic nerve begins as separate branches of roots C5, C6, and C7. These branches unite to form the nerve posterior to the brachial plexus. The nerve descends on the lateral aspect of the rib cage, providing a branch to each of the digitations of origin of the serratus anterior muscle.

PEP: A specific anatomical point of entrapment is difficult to identify for the *long thoracic nerve*.[3,18–22] Unlike most nerves it is anchored at regular and short intervals throughout its course, which greatly limits its potential to lengthen or glide. As a result, it is vulnerable to extreme excursions of the shoulder girdle and to prolonged static situations where the shoulder girdle might be elevated for extended periods. For example, if someone were to fall asleep for a protracted period with his/her shoulder draped over the back of a
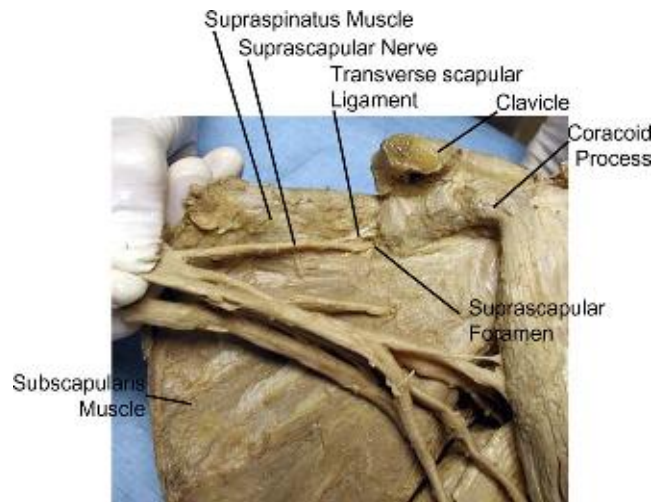
FIGURE 6. *Cadaver specimen: anterior view of the left axillary and shoulder regions. Note the suprascapular nerve as it arises from the superior trunk of the brachial plexus then passes laterally through the suprascapular foramen.*

chair, the nerve could be subjected to an extended stretch (Saturday night palsy). The nerve is superficial and hence vulnerable to external compression; it also crosses the field of a number of surgical approaches.

RADIAL NERVE

The radial nerve is the larger terminal branch of the posterior cord (Figure 1). It arises proximal to the lower border of the subscapularis muscle and then inclines obliquely laterally and posteriorly, passing inferior to the latissimus dorsi and teres muscles as they insert into the humerus. The nerve then passes obliquely around the posterior aspect of the midshaft of the humerus in the spiral or radial groove, and between the origins of the medial and lateral heads of the triceps brachii muscle. While in this groove, the nerve is accompanied by the deep brachial vessels and all structures are immediately adjacent to the bone. The groove ends just distal to the deltoid tuberosity, on the lateral aspect of the humerus. At that point the radial nerve enters the anterior compartment of the arm by passing through the fibrous lateral intermuscular septum.

PEP: The radial nerve and deep brachial vessels are vulnerable to injury secondary to fracture as they pass around the humerus in the spiral groove. The nerve can potentially become entrapped in callus formation during the healing process. As the nerve leaves the spiral groove, and the interval between the origins of the lateral and medial heads of the triceps, it passes through the fibrous lateral intermuscular septum of the arm. The literature supports the notion that the radial nerve can be entrapped by the *lateral head of the triceps*.[23,24] Because the lateral head of the triceps attaches to

the lateral intermuscular septum and to the humerus, the reported point of entrapment closely coincides to the point where the nerve passes through the septum (Figure 7). As it passes through the septum, the nerve is both directly on the bone and superficially positioned so it is vulnerable to external compression, e.g., tourniquet.

The radial nerve enters the anterior compartment of the arm in a deep position between the brachioradialis and brachialis muscles. As it continues to descend, it is related superficially to the extensor carpi radialis longus and brevis along with the brachioradialis (mobile wad); its deep relationship becomes the most lateral aspect of the capsule of the elbow joint. This part of its course is sometimes referred to as the radial tunnel. At about the level of the elbow joint line, the nerve divides into its superficial and deep branches. The superficial branch (radial sensory nerve) continues through the forearm deep to the brachioradialis muscle; in the distal third of the forearm it enters the subcutaneous tissue and provides the cutaneous innervation to the dorsolateral hand. The deep branch, clinically called the posterior interosseous, curves around the neck of the radius between the two layers of the supinator muscle. It emerges from the supinator muscle as multiple branches, most of which supply the deep posterior muscles of the forearm. The posterior interosseous branch (anatomical designation) descends to the wrist joint that it supplies.

PEP: The *radial tunnel* (Figure 8) and *arcade of Frohse* (Figure 9) are combined because they are anatomically continuous and contain a series of hazards that potentially can affect the radial nerve.[25–29] The literature is a bit unclear as to whether the arcade of Frohse, which is the proximal portion of the
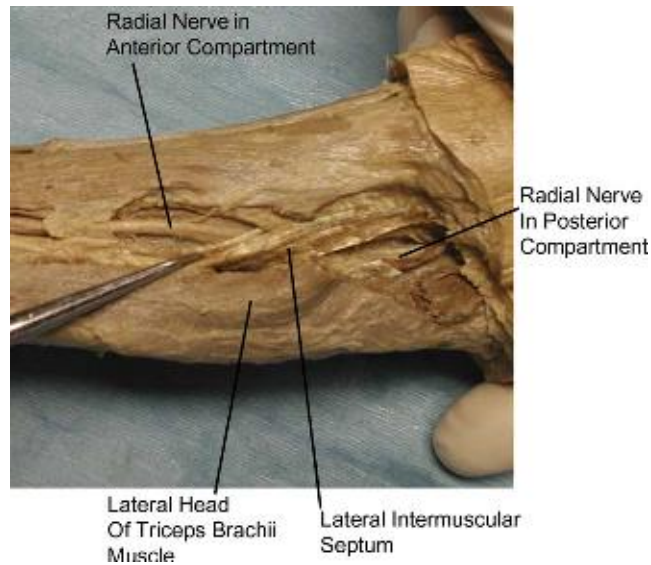
FIGURE 7. *Cadaver specimen: lateral view of the left mid-arm region. The radial nerve can be seen as it passes through the lateral intermuscular septum to go from the posterior to the anterior compartment. To expose the radial nerve in the posterior compartment the lateral head of the triceps brachii had to be separated from the lateral intermuscular septum.*

superficial layer of the supinator muscle, should be included in the radial tunnel. The radial tunnel has been described as extending from several centimeters proximal to the elbow to either the arcade of Frohse or to the distal edge of the supinator muscle. The important point is that there are a number of anatomical hazards that can potentially affect the radial nerve along this part of its course. The first is a fibrous band that passes superficial to the nerve at about the level of the radial head. The second is the radial recurrent artery that crosses the nerve on its way to supplying the muscles of the mobile wad.

This vessel frequently is represented as multiple vessels that form a sheet of vessels (leash of Henry) that crosses the nerve. The third is the tendinous edge of the extensor carpi radialis brevis muscle. This tendinous edge, like other tendinous edges, is quite variable in development so it can be very prominent or barely present. The arcade of Frohse is a prominent hazard. This layer of tissue has been described as tendinous in 30% of the population.[30] Finally, there is the course of the nerve within the supinator and the distal edge of the muscle where the nerve emerges. The distal edge can be tendinous
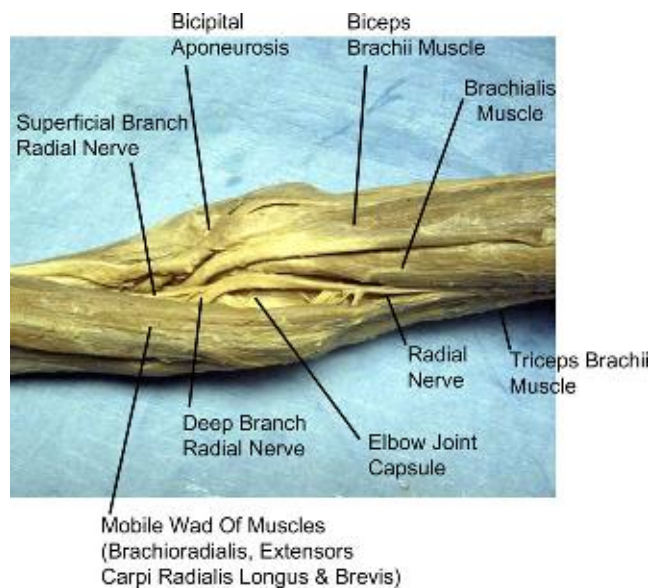

FIGURE 8. *Cadaver specimen: anterolateral view of the left elbow region. The radial nerve is shown passing through the distal aspect of the arm, crossing the elbow joint line and branching into its superficial and deep branches. Part or all of this course is considered the radial tunnel.*
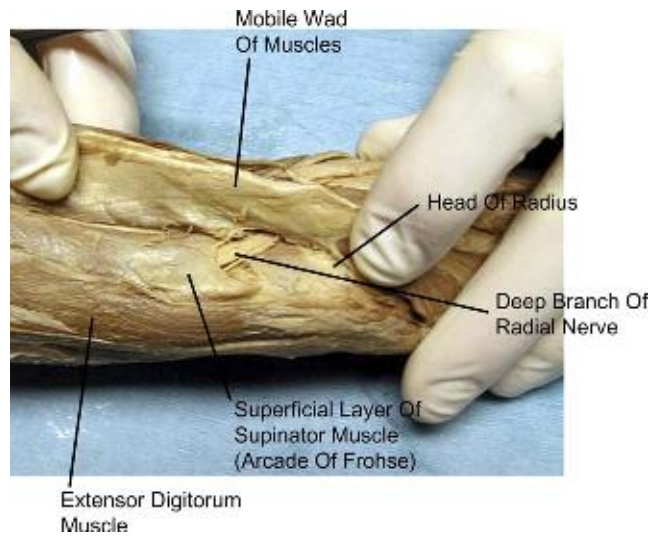
FIGURE 9. *Cadaver specimen: anterolateral view of the left proximal forearm. The mobile wad of muscles (brachioradialis, extensors carpi radialis longus and brevis) is retracted to show the deep branch of the radial nerve as it wraps around the neck of the radius between layers of the supinator muscle. The superficial tendinous layer is called the arcade of Frohse.*

and fibrous bands have been described within the muscle.

PEP: The *superficial radial nerve* enters the subcutaneous tissue in the dorsolateral aspect of the distal third of the forearm (Figure 10). It does so by passing between the tendons of the brachioradialis and extensor carpi radialis longus muscles then through the antebrachial fascia. This passage is considered a point of entrapment.[31,32] The nerve then continues distally, branching across the dorsolateral wrist and hand. This part of its course is within the subcutaneous tissue where the nerve is very close to the underlying radius and just beneath the skin because there is only minimal subcutaneous tissue. Furthermore, it is just superficial to the tendons of the extrinsic thumb and radial extensor

muscles of the forearm. Along this part of its course it is vulnerable to external compression, injury during surgery and entrapment during healing after trauma or surgery.[32–34]

AXILLARY NERVE

The axillary nerve is the smaller of the terminal branches of the posterior cord (Figure 1) and the shortest of the major terminal nerves of the brachial plexus. From its origin on the ventral aspect of the subscapularis muscle, the nerve passes laterally toward the inferior aspect of the shoulder joint. It passes just inferior to the head of the humerus and above the tendons of the latissimus dorsi and teres
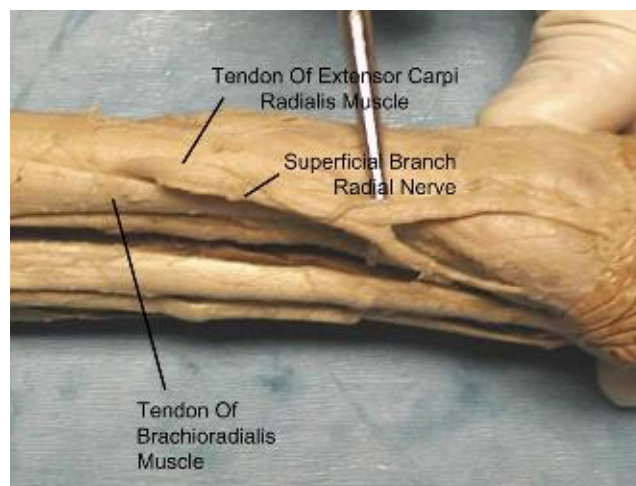

FIGURE 10. *Cadaver specimen: medial view of the left distal forearm and wrist. The superficial branch of the radial nerve can be seen as it enters the subcutaneous tissue by passing through the investing fascia and between the tendons of the brachioradialis and extensor carpi radialis longus muscles.*

major; it then passes through the quadrangular space which is bounded medially by the humerus and laterally by the long head of the triceps muscle, and superiorly and inferiorly by the teres minor and teres major respectively. It then wraps horizontally around the posterior aspect of the surgical neck of the humerus, accompanied by the deep brachial vessels, and enters the deltoid muscle which it supplies. It also supplies the teres minor muscle and has a cutaneous branch which curves around the posterior aspect of the deltoid and supplies the skin in the area of the deltoid tuberosity.

PEP: This point of "entrapment," caused by a repositioning of the head of the humerus, is secondary to the trauma of an anterior shoulder dislocation.[35,36] The axillary nerve is short, under some tension, and crosses the infraclavicular fossa before passing close to the anteroinferior aspect of the humeral head. The humeral head typically moves into the infraclavicular fossa when it dislocates; the nerve can be stretched anteriorly around the head of the humerus. This, perhaps, is not a true example of an entrapment, but the damage to the nerve can be caused by tension.

PEP: The *quadrangular space*[37–40] (Figure 11) would appear to be a questionable potential point of entrapment because the literature is sparse and somewhat equivocal. This space can contain a variety of fibrous bands that may interfere with both vascular and nerve function in certain positions of the upper limb. The size of the space is reduced with the arm in abduction and external rotation and the soft-tissue structures that form the boundaries are stretched considerably. This position is also considered to be a provocative test for the reproduction of the symptoms. Even though the cause of entrapment is not well documented, the axillary nerve and deep brachial vessels passing through the space may be vulnerable to compression from variant fibrous bands or perhaps the structures that form the boundaries.

MEDIAN NERVE

The median nerve is formed by contributions from both the medial and lateral cords (Figure 1). It descends in the medial neurovascular bundle of the arm, along with the ulnar nerve and the brachial artery. At about the distal third of the arm it inclines a bit laterally to enter the cubital fossa where it is positioned lateral to the brachial artery and superficial to the brachialis muscle. It passes deep to the bicipital aponeurosis (lacertus fibrosus), which is a strong fibrous band between the biceps brachii tendon and the investing fascia. Either in the cubital fossa or a bit distally, it has an anterior interosseous branch which is muscular and supplies the radial half of the flexor digitorum profundus (index and middle fingers), flexor pollicis longus, and pronator quadratus. The median exits the cubital fossa by passing between the two heads of the pronator teres muscle, and just distal to that point it passes deep to the fibrous arch between the two heads of origin (medial humeral epicondyle and radius) of the flexor digitorum superficialis (sublimis bridge [old name is "sublimus"]). The median nerve appears to be vulnerable to a variety of potential hazards in the region of the elbow.

PEP: The *ligament of Struthers* and *supracondylar process*[41–44] (Figure 12) are reported to be found in the distal third of the medial aspect of the arm.

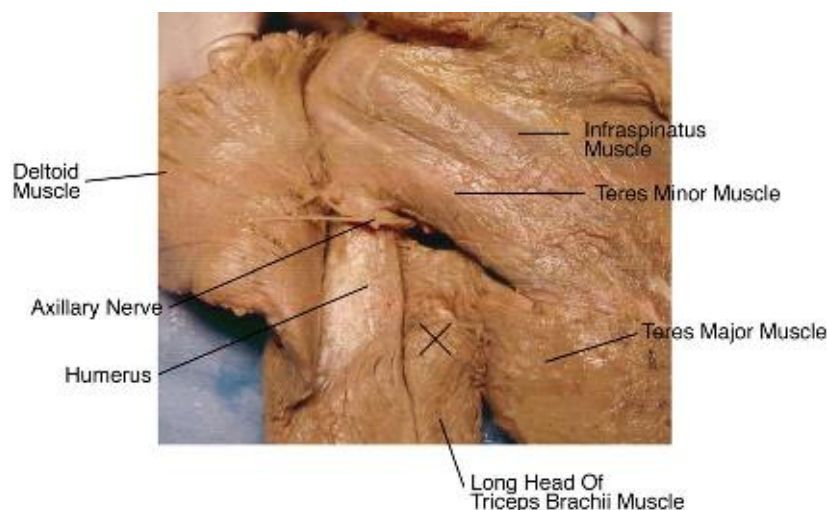**FIGURE 11.** *Cadaver specimen: posterior view of the left shoulder region. The axillary nerve is seen as it wraps around the posterior aspect of the surgical neck of the humerus and enters the deltoid muscle. Only three boundaries of the quadrangular space, the humerus and teres major and minor muscles, are visible because the long head of the triceps brachii muscle has been removed above the X.*
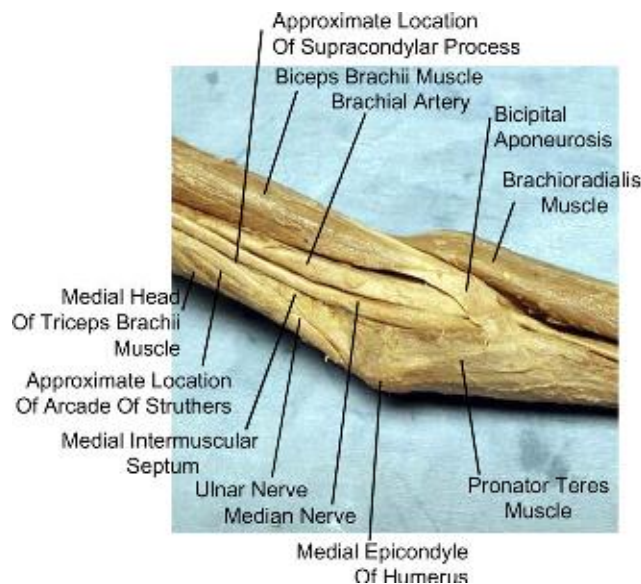
FIGURE 12. *Cadaver specimen: anteromedial view of left arm, elbow and forearm. The courses of both the median and ulnar nerves through the distal arm are visible. Both nerves are in the medial neuromuscular bundle at the mid-arm level. The median then inclines anteriorly and laterally into the cubital fossa; the ulnar enters the posterior compartment and occupies a groove in the medial head of the triceps muscle as it passes toward the posterior aspect of the medial epicondyle of the humerus.*

Their presence in man, a rare legacy from lower forms, is reported to interfere with the normal course of the median nerve. The anatomical causes of this entrapment occur in the medial supracondylar region of the humerus where the median nerve inclines laterally to enter the cubital fossa. The supracondylar process is a bony hook which springs from the supracondylar area of the humerus; the ligament of Struthers extends from the medial epicondyle of the humerus to the supracondylar area of the humerus. These structures can be present at the same time and be continuous or they can occur separately. In either case the course of the nerve could be altered around either the ligament or the bony process, perhaps introducing a friction-generating angle.

PEP: The median nerve passes deep to the *bicipital aponeurosis*[41,45] (Figure 12) and superficial to the brachialis muscle, which is a massive muscle and the major flexor of the forearm in any position. The bicipital aponeurosis is a very strong fibrous structure. Strongly resisted flexion of the forearm may compress the nerve between the underlying muscle and sharply edged aponeurosis.

PEP: The two heads of origin of the *pronator teres muscle*[46,47] (Figure 13), between which the median nerve passes, are quite different in structure. The superficial head (lateral humeral epicondyle) is large and typically only minimally tendinous. The deep head (radius) is much smaller and rather flat and usually has a sharp tendinous edge. As the forearm is pronated, the two heads are approximated and the median nerve can be compressed.

PEP: The *sublimis bridge*[48] (Figure 14) is variable in development. Sometimes it is very difficult to identify and other times it is quite prominent and tendinous. As the nerve reaches this arch it is passing posteriorly to pass deep to this arch and assume its position between the flexors digitorum

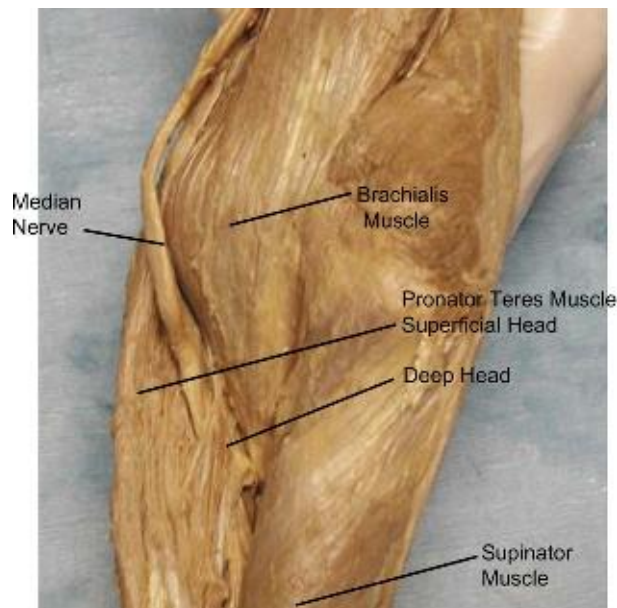

FIGURE 13. *Cadaver specimen: anterior view of the elbow region. This is a deep dissection showing the median nerve as it passes between the superficial and deep heads of the pronator teres muscle. Note the sharp proximal edge of the deep head.*
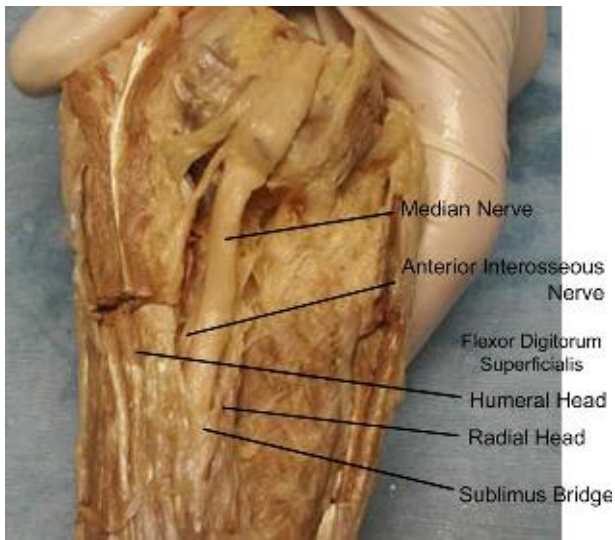
FIGURE 14. *Cadaver specimen: anterior view of the proximal forearm and elbow. This deep dissection shows the median nerve as it passes deep to the arch (sublimis bridge) between the two heads of origin of the flexor digitorum superficialis. Also visible is the anterior interosseous nerve as it branches from the posterior aspect of the median nerve.*

superficialis and profundus muscles, the course it follows until it reaches the wrist.

PEP: It is important to note that the *anterior interosseous nerve*[49–51] (Figure 14), the largest branch of median in the forearm, can branch from the median either before the pronator teres or after the sublimis bridge. As a result, either the anterior interosseous or the median or both could be entrapped at either place. In addition, there are other anatomical structures, mostly variant, that have been implicated. The forearm is a particularly fertile location for the occurrence of extraneous fibrous bands and extra muscles, usually rather small. These fibrous bands are usually offshoots of existing fibrous structures that cross the longitudinally oriented nerves and vessels obliquely or even horizontally. The variant muscles are usually slips of existing muscles (e.g., Gantzer's muscle is an accessory head of the flexor pollicis longus) that can also cross neurovascular structures.

The course of the median nerve through most of the forearm is in a deep position, between the flexor digitorum superficialis and the flexor digitorum profundus muscles. Just proximal to the wrist the median nerve curves around the lateral aspect of the tendons of the flexor digitorum superficialis and assumes a position on the volar surface of that muscle's tendons. There it is relatively deep and positioned between the tendons of the palmaris longus and flexor carpi radialis muscles. In the distal third of the forearm, the superficial palmar nerve

branches from the nerve; this branch is cutaneous, does not pass through the carpal tunnel, and supplies the skin at the base of the thenar eminence. The median nerve passes through the carpal tunnel as the most volar structure on the radial side, crammed between the long digital flexor tendons and the transverse carpal ligament.

The carpal tunnel has two distinct parts; the more distal segment is the smaller. The proximal segment is at the level of the pisiform and tubercle of the scaphoid. The transverse carpal ligament is thin and slack and the transverse area of the tunnel is large. The distal segment is between hamulus (hook) of the hamate and tubercle of the trapezium. Here the transverse carpal ligament is much thicker and tauter, and the transverse area is smaller than proximally.

PEP: The *carpal tunnel*[52–54] (Figure 15) very likely is the best known point of nerve entrapment in the upper limb. The literature is massive, at times a bit confusing, but very informative on the issues. The distal half of the tunnel would appear to be the point where the nerve is most vulnerable, particularly given its position between the thick and taut transverse carpal ligament and the underlying tendons. The contents of the canal, in addition to the nerve, consist of the nine tendons of the flexors digitorum superficialis and profundus along with that of the flexor pollicis longus. The radial and ulnar bursae, the synovial tendon sheaths of these muscles, are commonly omitted as contents of the tunnel but they extend from the hand into the distal forearm. The potential causes of entrapment seem endless. I think the bottom line is simply that the structures passing through this tunnel are very

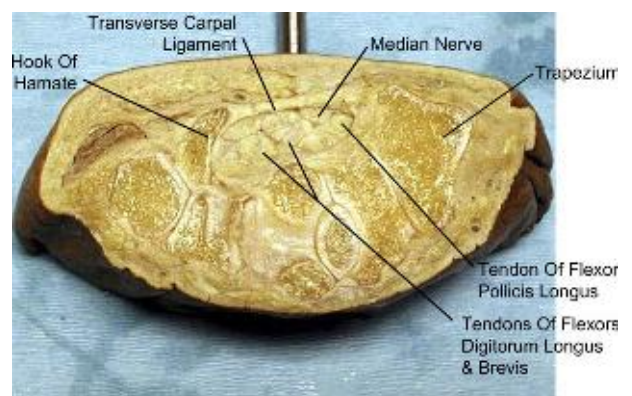**FIGURE 15.** *Cadaver specimen: cross section through the distal part of the carpal tunnel. The transverse carpal ligament (deep part of flexor retinaculum) is seen attaching to the hook of the hamate and the tubercle of the trapezium. Note the position of the median nerve just deep to transverse carpal ligament on the radial side of the tunnel. Note also how tightly the structures are packed in the tunnel.*

tightly packed and any addition to that space can affect the median nerve. It is the "softest" structure and frequently its cross-sectional shape indicates it is squeezed into whatever space is available.

Distal to the carpal tunnel, the median nerve typically branches into its terminal branches. It usually has the recurrent (thenar, muscular) branch to the thenar muscles, a single proper palmar digital nerve to the radial side of the index finger and three common palmar digital nerves to the thumb, index, middle and ring fingers. (Common digital nerves branch into two proper digital nerves.) The recurrent branch passes laterally to supply the thenar muscles and can either wrap around the distal aspect of the transverse carpal ligament or pierce the ligament. The digital nerves are predominantly cutaneous to the lateral (radial) three and a half digits. The common digital nerves to the index, middle, and ring fingers pass toward the web spaces where they divide into proper digital nerves. Proximal to the web spaces, at the level of the metacarpal heads (distal volar palmar crease), these nerves are sandwiched between the superficial and deep transverse ligaments.

PEP: The *recurrent branch of the median nerve*[55,56] is vulnerable to entrapment when it either pierces the transverse carpal ligament or recurs around its distal edge. In either case the nerve can be compressed against the ligament and produce muscular symptoms.

PEP: The intervals through which the digital nerves to the index, middle and ring pass, between the metacarpal heads, are referred to as the *metacarpal tunnels*.[57,58] The floor of each tunnel is the strong, deep transverse metacarpal ligament which interconnects the volar plates of adjacent metacarpophalangeal joints. The roof is the less-well-developed superficial transverse metacarpal ligament. When the digits are extended at the metacarpophalangeal joints, the digital nerves are forced against the deep transverse metacarpal ligaments. In this position blunt trauma is thought to affect the nerves as is chronic use of vibrating tools such as jackhammers. Digital neuropathies can also occur in musicians, again presumably by chronic compression.

ULNAR NERVE

The ulnar nerve begins in the axilla as the continuation of the medial cord of the brachial plexus (Figure 1). It descends through the proximal half of the arm in the medial neurovascular bundle and enters the posterior compartment in the distal third. It enters the posterior compartment by passing through the medial intermuscular septum; it descends along the supracondylar area just posterior

to the medial intermuscular septum in a groove in the medial head of the triceps brachii muscle. It is held firmly in this groove by the investing (brachial) fascia of the arm which blends with the triceps fascia and attaches firmly to the intermuscular septum. Since the nerve is held firmly in the groove, it presumably has little ability to slide proximally and distally.

The nerve crosses the posterior aspect of the elbow in a groove (condylar groove) in the posterior and distal aspects of the medial epicondyle. It continues into the forearm by passing between the medial epicondyle and olecranon and then passes deep to a fibrous connection (arcuate ligament) between the two heads of origin (ulna and medial epicondyle) of the flexor carpi ulnaris muscle.

PEP: The *arcade of Struthers*[59,60] is found along the supracondylar course of the nerve just distal to where the nerve enters the posterior compartment and is anchored in the groove in the medial head of the triceps muscle (Figure 12). At that point a portion of the investing fascia that interconnects the intermuscular septum and the triceps fascia can be thickened and perhaps produce a constricting point in the nerve's course.

PEP: It could be argued with good cause that the *condylar groove*[61–64] (Figure 16) is a point where the nerve is vulnerable to trauma rather than entrapment. It is included here because the nerve is passing directly on bone and has a superficial position and thus is subjected to chronic low-level compression insults, and thus is likely to exist in a state of chronic inflammation. In addition, the
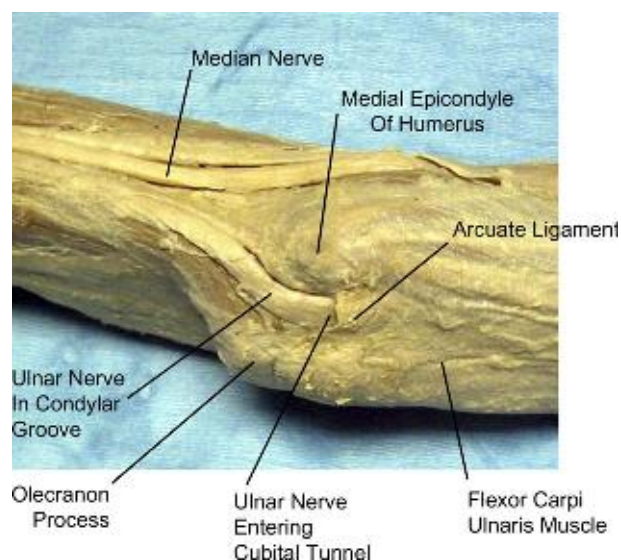

FIGURE 16. *Cadaver specimen: medial view of the left elbow. The ulnar nerve is seen in the condylar groove and as it enters the cubital tunnel. The roof of the cubital tunnel is formed by a fibrous arch that stretches between the humeral and ulnar heads of origin of the flexor carpi ulnaris muscle.*

nerve is stretched every time the forearm is flexed. In this groove the ulnar nerve is subject to entrapment; the insult happens to come from external compression rather than internal. It should be noted that in a large number of cadavers, my estimate is 80% or more, the ulnar nerve is enlarged in the condylar groove and where it enters the cubital tunnel. This could be an indication of chronic inflammation.

PEP: The *cubital tunnel*[61–64] ([Figure 16](#)) unquestionably is a well-documented point of entrapment. The roof (superficial boundary) of the tunnel is formed by the fibrous arch (arcuate ligament) of the flexor carpi ulnaris described earlier. The floor is the medial (ulnar) collateral ligament of the elbow joint. This ligament is triangular; its apex is proximal and attaches to the medial humeral epicondyle; its base is distal and attaches from the medial aspect of the coronoid process to the olecranon. The important point is that both the flexor carpi ulnaris and parts of the medial collateral ligament attach to similar areas. These points of attachment are farther apart when the forearm is flexed than when it is extended. The result is tightening of both roof and floor of the tunnel. Furthermore, the trochlea (spool) of the humerus is just deep to the medial collateral ligament. This spool is not symmetrical. As the forearm is flexed, a wider part of the trochlea rotates under the medial collateral ligament and thus further tightens the ligament and elevates the floor of the ulnar tunnel. The potential for compression of the ulnar nerve with forearm flexion is anatomically rational; its compression if inflamed seems unquestionable.

The ulnar nerve passes through the entire forearm deep to the flexor carpi ulnaris muscle, and just proximal to the wrist it is deep to that muscle's tendon. As the tendon of the flexor carpi ulnaris attaches to the pisiform, the nerve passes lateral to that bone, crosses the pisohamate ligament and then passes medial to the hamulus (hook) of the hamate. Superficial to the nerve at this point is the variably developed palmaris brevis muscle, which is within the subcutaneous tissue at the base of the hypothenar eminence. This part of the nerve's course is referred to as Guyon's canal or the ulnar tunnel. In the canal the nerve branches into its superficial and deep parts. The superficial branch is cutaneous, branching into one proper and one common digital nerve to supply the little and ulnar half of the ring fingers. The deep branch is muscular. It passes dorsally through the hypothenar muscles and then crosses the deep palm, along with the deep palmar arterial arch, to end in the adductor pollicis muscle. In the distal third of the forearm there is a dorsal cutaneous branch which crosses the medial aspect of the wrist and supplies the dorsomedial hand.

PEP: In *Guyon's canal (ulnar tunnel),*[65–69] the nerve crosses the very strong pisohamate ligament and is superficial in position, covered only by the palmaris brevis muscle and subcutaneous tissue. As the hand is extended the nerve is stretched around the ligament, which becomes more taut. In that position the nerve is particularly vulnerable to external compression because of the rigid base it crosses. Of course, it is also vulnerable to laceration for the same reason. Because there are several points at which the nerve can be entrapped in this region, the entire nerve or either the superficial or deep branch could be affected individually.

PEP: There is a *tendinous arch of the adductor pollicis muscle*[70] that extends between its transverse and oblique heads of origin, and the deep branch of the ulnar nerve passes deep to that arch. Because the nerve is superficial to the base of the third metacarpal, it passes through a kind of tunnel as it enters the adductor pollicis muscle. The nerve is thought to be vulnerable to chronic external compression where it passes through this tunnel.

MUSCULOCUTANEOUS NERVE

The musculocutaneous nerve is the continuation of the lateral cord of the brachial plexus ([Figure 1](#)). It begins in the axilla and inclines immediately laterally toward the coracobrachialis muscle, which it pierces and supplies. It then continues its oblique course through the arm between the brachialis and biceps brachii muscles, which it also supplies. In the cubital fossa, just lateral to the tendon of the biceps brachii and medial to the brachioradialis muscle, it enters the subcutaneous tissue by passing through the investing (brachial) fascia. Its name changes to the lateral antebrachial cutaneous nerve, and it descends along the lateral aspect of the forearm to provide the cutaneous innervation to that area. Even though reports of musculocutaneous nerve entrapment are rare, there are two points at which the nerve appears vulnerable.

PEP: The most likely point of entrapment proximal to the elbow is the *coracobrachialis muscle*[71,72] ([Figure 1](#)) itself or perhaps just distal to that muscle. Because the nerve passes through the muscle and the muscular symptoms usually include only the biceps brachii and brachialis, the coracobrachialis muscle seems the likely cause. Even though the initial course of the musculocutaneous is quite variable, it tends to be more variable when an occasional variant muscle slip, a third head of the biceps brachii, is present. Perhaps there is a relationship between the nerve's vulnerability to entrapment in this area and the presence of that variation.

PEP: The *lateral antebrachial cutaneous nerve*[73,74] seems to be vulnerable where it passes between

the tendon of the biceps brachii and the brachioradialis muscle then immediately pierces the investing fascia. It can be affected by external forces that compress the nerve against the biceps tendon. There are also reports indicating its vulnerability during repetitive and forceful upper-limb exercise.

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