SCIENTIFIC/CLINICAL ARTICLES

A Walk through the Anatomy of the Hand and Forearm

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Editors' Note: This article appears in a modified presentation format, allowing the reader to embark on a personal journey through the surgical dissection of the hand.

To study anatomy, we must first learn to be observers. We must learn to see and interpret the meaning of the variations of what we observe. The first thing we can observe is the skin, its texture and color and the lines in the skin, as well as its moisture. Skin is that marvelous structure that covers the anatomy. It takes the shape dictated by its underlying parts, folds when necessary as joints flex, and stretches when necessary. When distorted by tension or traction, it returns to its original shape when released. It provides us with information about temperature (of the skin and that which it touches), texture, hardness, or softness, and, when sensitive, it gives us information about the shape of the object it touches. It even provides its own moisture to aid in grasping, and its own oil (eccrine glands) to help keep it waterproof.

The usual greeting of a handshake at meeting someone does not require much conscious thought, but is the result of a series of complex movements involving many of the muscles of the hand and forearm and upper arm. There is interaction involving contraction and relaxation of the muscles of the entire upper extremity. There is also an involvement of the head and neck and facial muscles, and there is usually speech along with the movement of the upper extremity. This complex interaction involves the intrinsic muscles of the hand, the extrinsic finger muscles, the wrist stabilizers, and the muscles of the upper arm and the shoulder. There is contraction of some muscles, relaxation of others, and all of this to place the hand in a position to shake another hand. The prime importance of the movements of the hand, however, is that they constitute the precision adjustment mechanism of the upper extremity, in contrast to the more coarse movements of the rest of the upper extremity.

Hand therapists, and all others entrusted with the restoration of function to the injured or abnormal hand, must have a basic knowledge of the anatomy of the hand and forearm.[1] Traditionally this has meant study of the anatomy of the cadaver, which is the oldest and best recorded source of all knowledge of the human body. With today's modern technology this may mean studying anatomy by viewing video dissections or three-dimensional computer studies, as well as by performing actual dissections of a hand and forearm. All of this knowledge, however, is not enough *if we do not* understand the functional needs of living and a patient's needs in his or her everyday living environment.

EXAMINATION OF THE HAND

The initial examination of the hand begins with a handshake. Just from looking at the hand, its extension of thumb and fingers, its fat, and its full first dorsal interosseous muscle (and other thenar and hypothenar muscles), it can be seen that the median, ulnar, and radial nerves are all working. When you look at the hand, you examine the creases and whether they are in their right place. You first look for the thenar crease and then for the transverse crease—whether it goes up in between the index finger and the long finger. If, as you look at the hand, you don't see a flexion crease, that means that the joint has not been moving (Fig. 1).

The lines of the hand have become significant and can be shown to be related to some genetic variations, such as Down's syndrome. The variations in the fingerprints have been the standard of identifying people for many years. (This is now giving way to DNA identification.) The absence of flexion creases

This article was excerpted in part from dissection presentations given by the author in Carville teaching seminar videos. Parts of this article were adapted, with permission, from Riordan DC: Functional anatomy of the hand and forearm. Orthop Clin North Am 5:199–203, 1974. The author has expanded on the previous article here.

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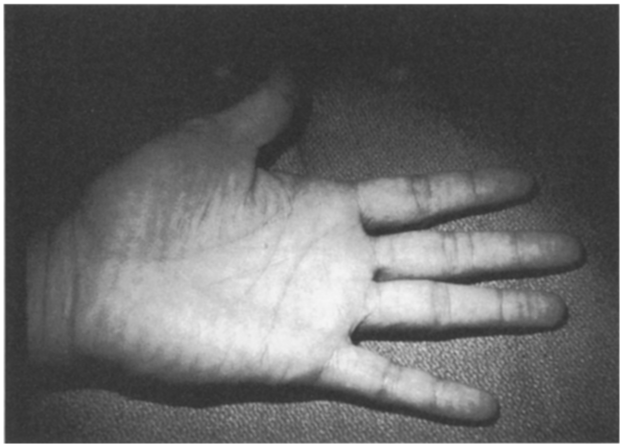


FIGURE 1. A hand with flexion creases. Where there is no flexion, there are no creases.

in the fingers of newborns or adults can be an indicator that the flexors are absent or not working. The study of the lines of the hand has therefore been of interest to not only the hand surgeon, but also to the geneticist and to those studying palmistry, as well as jurisprudence. A study of these skin lines (dermatoglyphics) falls into three groups: (1) The coarse lines of the hand and wrist and the palm of the hand represent the flexion folds or skin joints, and are really lines of skin stasis. These are lines where there is little movement, and these lines are tethered by fibrous bands to the deeper structures. (2) The complicated system of troughs and crests is arranged in whorls, loops, and arches called papillary ridges, seen best in the tips of the fingers and the hypothenar eminence. (3) The tension lines, or Langer's lines, are distributed everywhere and run in different directions. They were actually first described by Dupuytren but were reported by Langer and therefore were given his name. Incisions made in the direction of these lines produce the least amount of scarring when used during surgery.

The papillary ridges are arranged predominantly in transverse or oblique directions, except at the fingertips. Here they are arranged concentrically in whorls. Each person has an individual set of fingerprints that are not duplicated in another person and that can be classified and used in identification. In the interdigital clefts, the papillary ridges are arranged vertically, and in the palm of the hand, obliquely. These areas are endowed with fat pads of a special type. These are in a relatively fixed position, being held by fibrous bands to deeper tissues, yet they are flexible enough to allow the hand to fit the shape of the object they are in contact with and will usually return to their original shape when pressure is released. This ability is called "turgor" and may be altered by some physical illnesses. These specialized pads are the areas where much pressure is applied in the firm gripping or grasping of objects. Areas not involved in such pressure are devoid of not only those fat pads, but also of the papillary ridges. The same findings exist on the plantar aspect of the feet.

The fat pads have the most nerve endings and, in the skin, have the papillary ridges. The sensitivity at the tips of the fingers is extreme in the normal hand and gives us the "tactile gnosis" that gives us a third dimension. The fingertips are truly the "eyes of the hand." The presence of the sweat glands and oil glands is the cause of the papillary ridges and the valleys in between and aids in gripping objects by providing an undulating surface. The moderate amount of moisture provided by the sweat glands also aids adhesion of the skin to objects being grasped. One can realize that the fingertip may not be moist by observing someone "wetting" the tips of the fingers in turning pages, throwing a ball, gripping a hammer handle, and other similar functions in which a nonslip grip is desired.

The dry, smooth hand of a patient who has a peripheral nerve lesion due to disease or injury is an excellent example of the failure of this function. Witness the difficulty these patients have in grasping round or smooth articles, especially when the articles are not anchored and are free to move. The longer a nerve lesion exists, the more atrophied the papillary ridges become so that the fingerprints are eventually lost. The skin of the hand feels as smooth as glass in addition to being dry.

There are many sweat glands in the body, but they are not arranged in papillary ridges except in the hands and feet. In other parts of the body, sweating is part of the mechanism of heat or temperature control. In the hands, the sweat glands have the additional function of aiding in adhesion in grasping or touching.

There are many opinions as to why the ridges of the fingers are different on the tips of the fingers. Grasping is affected by the index finger and thumb. Some of the ridges are always at right angles to those of the opposing digit, which probably aids in grasping and holding the object.

The skin of the hand on the dorsal side has very few fibrous septa and is quite mobile. A surgeon may be tempted to borrow some of this skin for skin flaps, but it would be a mistake because when you flex the fingers, the skin is completely taken up in flexion. When a tight fist is fully made, there is no excess skin at all. The skin on the dorsum of the hand, for the most part, is not used in skin transfers, with a few exceptions where skin is transferred locally.

The reason one often sees a lot of swelling on the dorsum of the hand is because there are no attachments from the dorsal fascia of the hand to the underlying structures of the hand. A probe passed under the fascia of the dorsal aspect of the hand can pass freely around the dorsal aspect of the hand. If the hand undergoes any swelling, most of it is seen on the dorsum rather than on the site of injury. In the dorsal venous system, the longitudinal veins are the ones that are important. Surgeons, when they have to tie off some of these, do so on the cross-communicators and leave the longitudinal ones alone because they are the venous return of the hand.

The palmar skin is only mildly mobile and is relatively fixed by the vertical septa that anchor it to the deeper structures. When the palmar skin is replaced by a flap from another area of the body, the

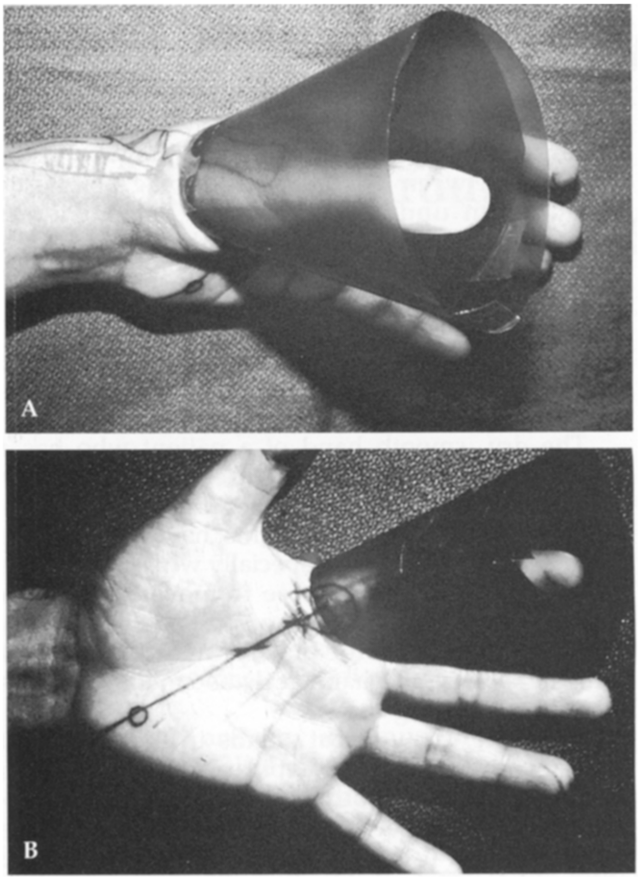


FIGURE 2. *(***A***) Thumb and (***B***) index finger range of motion describe an inverted cone.*

absence of these vertical septa results in the looseness of the flap skin, making it difficult to hold articles in the fingers or palm. The hypothenar fat pad is a bit more mobile than the finger or metacarpal fat pads, but has the unique ability to be stabilized by the palmaris brevis muscle, and with the motion of the thenar eminence and hypothenar eminence can form a cup or a concave surface, making it possible to hold water or take change. The skin lines of the hand represent lines of stasis and are devoid of much fat. They are anchored to the underlying fascia, and this allows the fat pads to remain in position during flexion. The effectiveness of the grip would be impaired if the above anatomy were different.

The palmar fascia is also an important stabilizing factor for the skin of the hand. The palmar fascia is fan shaped, with most of the fibers oriented longitudinally. It is continuous medially and laterally, with the fascia covering the thenar and hypothenar muscles. The transverse fasciculi of the palmar fascia are at the base of the fingers (natatory ligaments) and at the metacarpal heads. The transverse fasciculi, along with the longitudinal of the palmar aponeurosis, anchor the overlying skin. In the areas where the aponeurosis does not exist, the underlying fat pad bulges upward, creating the fat pads between the metacarpal heads. These are best observed when the fingers are adducted together, and may represent an atavistic feature related to the walking pads of quadruped mammals.

If you ask a patient to extend his or her fingers, you can see the extensor tendons. It is important to note whether there is any hyperextension at the middle joint. The amount of hyperextension dictates where a surgeon should insert a tendon transfer, or at least where not to insert the transfer. If you ask patients to flex the tips of their fingers independently, only those who can hyperextend their middle joints and can lock their middle joints in extension can independently flex their profundi because of their common origin up in the forearm.

When a patient extends his or her fingers, the metacarpal arch can be seen, with the first and fifth metacarpals being the most palmar and the second the third being the most dorsal. If intrinsic muscles are present when a fist is made, the fourth and fifth metacarpals further descend toward the palm. The index finger also descends toward the palm a little on most people. The fourth and fifth metacarpals will not be migrating anteriorly during a fist if the intrinsic muscles innervated by the ulnar nerve are not present.

The third metacarpal is the base of the metacarpal arch. The third metacarpal is relatively nonmobile and is dorsal in relation to the other metacarpals. There is usually very little motion between the third metacarpal base and the distal row of carpal bones.

The fourth metacarpal is mobile. When a push is made on it in a dorsal direction, the metacarpal can move dorsally. The little finger is the most mobile. When it goes up into dorsiflexion position, it drags the fourth metacarpal with it because of the ligamentous structures on the palmar side.

If you ask a patient to make a fist and he or she can make a tight fist and put his or her fingertips on the distal flexion crease of the palm, he or she has full flexion range of motion.

The range of motion of the thumb can be likened to that of an inverted cone with the base apex toward the radius. The index finger circumducts and describes a cone in a similar fashion, but not quite as much as the thumb (Fig. 2).

There are other things to observe when you look at the hand. In Figure 3 the approximate positions of the radius and ulna bones, the proximal row of carpal bones, and the first metacarpal of the thumb

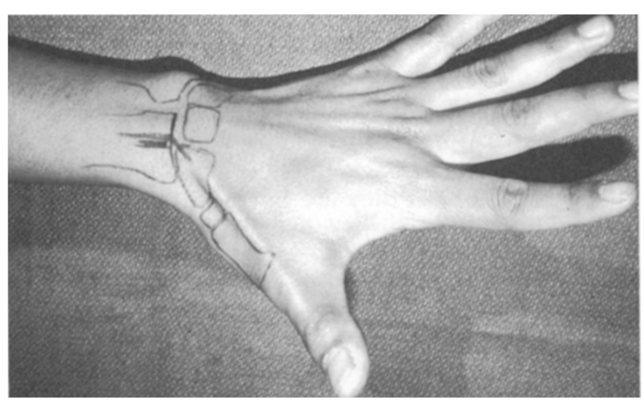


FIGURE 3. *The positions of the radius and ulna bones, the proximal row of carpal bones, the first metacarpal of the thumb and the trapezium beneath, and Lister's tubercle.*

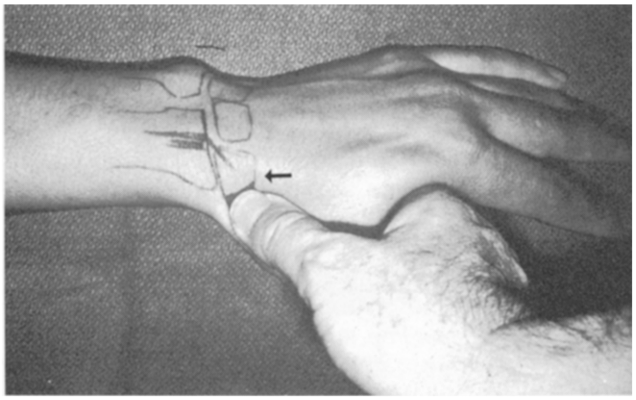


FIGURE 4. Pressure over the scaphoid bone. The arrow points to the radial aspect of the scaphoid.

and the trapezium beneath are marked. You can see the extensors of the fingers. Where the extensor pollicis longus tendon goes around Lister's tubercle and makes its change in its line of pull has also been marked. This is important for a therapist to note if asked by a surgeon to start active exercise for a patient who has had a fracture of the distal radius such as a Colles' fracture. If a finger is placed over Lister's tubercle and crepitation can be felt when the patient extends and flexes his or her thumb, it means that the fracture line went through that little bony tunnel and that the patient is going to rupture the extensor pollicis longus tendon. The surgeon should be informed so that the motion can be stopped before the tendon becomes ruptured.

If you ask a patient to fully flex his or her thumb and he or she can do so without any trouble, you know that the flexor pollicis longus tendon is working, the intrinsic muscles of the thumb are working, and there is a free sliding extensor mechanism. But if he or she complains of pain on the radial side of the wrist, there is probably a stenosing tenosynovitis or de Quervain's disease. When a patient extends his or her thumb, usually there is no pain in this region (if he or she has a problem). It is when he or she goes into flexion at all joints of the hand that there is pain on ulnar deviation of the wrist.

Sometimes a patient will complain of pain at the base of the thumb and we have to determine whether it is in the joint between the first metacarpal and the trapezium, or in the next proximal joint, or in the bone (scaphoid). If a patient has point tenderness in this region, he or she may have a fracture of the scaphoid, which has been diagnosed as a "sprain of the wrist" (Fig. 4).

When a patient complains of pain in the center of the wrist and you are pressing on the lunate bone, it is possible that he or she could have Kienböck's disease or some fracture. One of the tests that usually produces pain if a problem is at the location of the lunate is to block the middle joint of the middle finger in extension and give a smart thump with your thumb or other hand to the end of that finger while keeping it from flexing. The force of that thump will be transmitted and the patient will complain of pain at the center of the wrist (lunate position) (Fig. 5).

If a patient complains of pain on the ulnar side of the hand, check for mobility between the radius and ulna, or for mobility between the carpus and distal ulna. Or, if there is point tenderness over the distal ulna, there may be torn fibrocartilage, or a torn ligament of the ulnar side of the wrist.

INTERNAL ANATOMY

The Hand

If you dissect the skin off of the palm, you can see the attachments between the palmar fascia and the skin. Those who treat Dupuytren's contracture can see the little dimples or indentations of the skin caused by contracture of these tiny bands that go between the deep surface of the skin and the superficial surface of the palmar fascia (Fig. 6).

If you lift up the palmar fascia and look at its deep surface, you can see septa from the deep surface that run down to the metacarpals. They separate the neurovascular bundles from the flexor tendons and interosseous muscles so that each unit runs in its own little tunnel.

The synovial sheath of the flexor tendons to the little finger runs out to the tip, as a general rule. But, on the index, long, and ring fingers, that synovial lining stops just proximal to the metacarpal head; on the thumb, it runs down all the way to above the wrist, so that there are actually two separate and complete tunnels. This becomes important in infec-

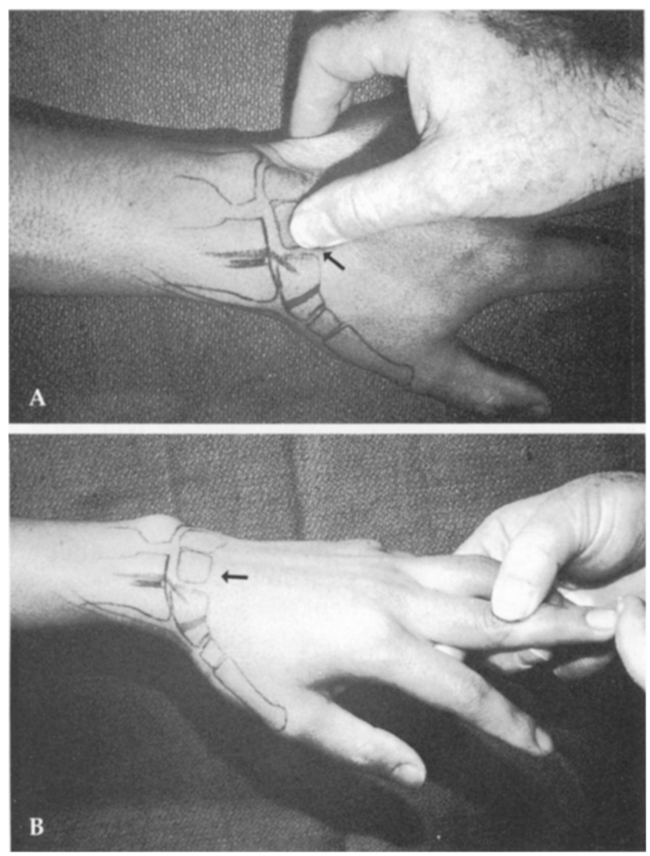


*FIGURE 5. (**A**) Pressure over the lunate bone. (**B**) Transfer of force from a thump on the middle finger to the lunate bone. Arrows point to the lunate.*

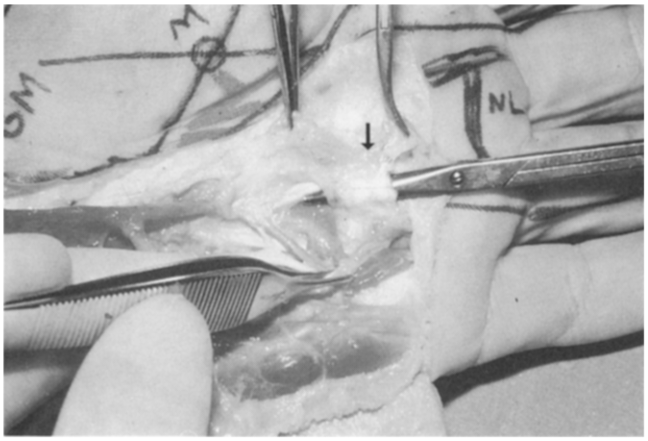


FIGURE 6. *Palmar fascia and septum on the ulnar side of the flexor digitorum tendon of the ring finger. GM = greater multangular; M = motor nerve median; NL = natatory ligament. The arrow points to the transverse fibers.*

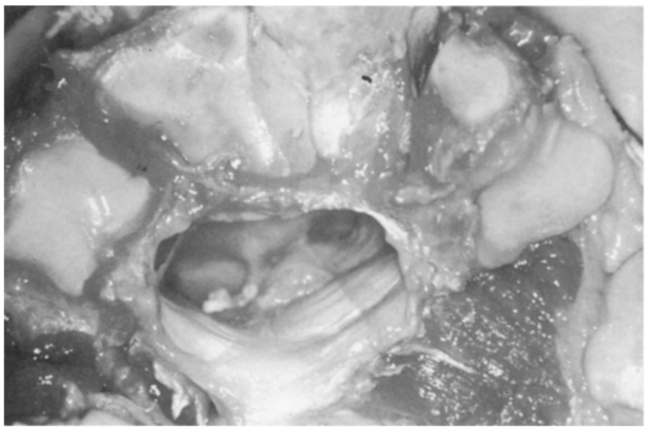


FIGURE 7. *A cross-sectional view of the volar carpal ligament and the carpal tunnel with the finger flexors removed.*

tions of the hand. If there is an infection on the thumb and you squeeze the bulbous thumb, you will sometimes see it expand on the little finger. This means there is a cross connection between the synovial lining of the thumb flexor pollicis and of the other flexors in the palm and out to the little finger. If there is an infection on the index, long, or ring finger and you squeeze a pulpy mass, it will not go any place else because it is usually limited at the metacarpal head area.

At the wrist there is what some call the superficial wrist ligament. To me, this is a thickening of the forearm fascia as it runs down and overlays the actual volar carpal ligament. The size of the volar carpal ligament, like the size of the dorsal carpal ligament, varies from patient to patient. It is usually a fairly thick, dense structure and a surgeon opens it from the ulnar side. I think that direct vision is good when doing carpal tunnel surgery (Fig. 7).

Under the volar carpal ligament of the hand, the median nerve is the most superficial structure. In Guyon's canal the ulnar nerve with sensory and motor branches and the ulnar artery are found. There is usually a cross connection between the median nerve and the common digital branch of the ulnar nerve to the long and ring fingers. There is a motor branch of the deep ulnar nerve to the thenar eminence.

The flexor tendons are layered above the wrist. The superficialis tendons to the long and ring fingers are in the top layer, the superficialis tendons of the little and index fingers are in the middle layer, and all of the profundi are lined up in a row in the deep layer. The flexor pollicis longus is separate. After the flexor tendons come out of the carpal tunnel, they are stacked up one on top of the other where they go to each finger. The superficialis tendons are superficially in a line, and the profundi are deeper in a line.

The annular ligamentous sheaths of the tendons are not the synovial sheaths of the tendons, but are the fibro-osseous structures that keep the tendons in their place. The fingers and thumb have these fibrous flexor sheaths called the annular ligaments, which run transversely over the tendons (Fig. 8). These have thick and thin parts. They are thin where they fold up when the fingers flex and are thick over the middle part of the proximal phalanx out to just proximal to the joint. These are known as the A1, A2, A3, and A4 pulleys and the intervening pulleys are known as the cruiciate pulleys. These act as pulleys

FIGURE 8. *The annular ligamentous sheath over the flexor tendons.*

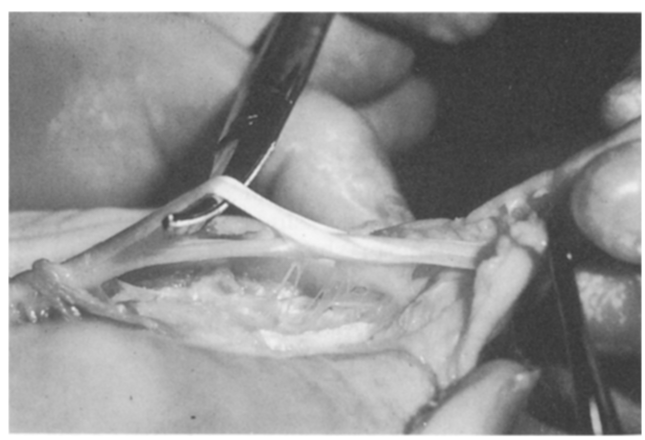


FIGURE 9. *The profundus tendon passing through the superficialis tendon slips at the level of the proximal interphalangeal joint. The vincula attachments supply blood.*

FIGURE 10. The dorsal carpal ligament (arrow) and the extensor mechanism of the fingers as it narrows down on the metacarpophalangeal joint.

and keep the tendons from bow stringing when tension is applied. They are extremely important for the balance of the fingers. Imbalance of the finger is produced when they are removed surgically or by injury. In the areas of the tendons covered by the annular ligaments, a thin synovial membrane provides lubrication to the tendons to make it easier to glide in the constricted spaces.

With the annular ligaments removed, the profundus can be seen at the point it passes through the superficialis split attachment at the proximal interphalangeal joint. The vincula attachments provide blood suply to the tendons (Fig. 9).

The dorsal carpal ligament is the only area on the dorsum of the hand where the extensor tendons have synovium on them to lubricate the tendons as they go through the fibro-osseous tunnel (Fig. 10). When treating rheumatoid patients, these tunnels should be palpated when flexing and extending the fingers. Tenosynovitis and raw bone, perhaps raw carpal bone, is going to wear away the tendons and cause them to rupture. There is a lot of variation in how the dorsal carpal ligament runs. Most of the time it is transparent and wide, although it can be more narrow. If you make a cross-section of the wrist at the level of the distal radius and ulna, you can see that the abductor and extensor tendons of the wrist, the extensor pollicis longus, the common extensors, the extensor digiti quinti, and the extensor ulnaris all run in fibro-osseous tunnels. Fractures of any of the bones here make these tendons under the ligament pretty vulnerable for destruction.

The extensor tendons narrow down over each metacarpal head, and have a broad expansion on the sides of the finger (Fig. 10). There is a central slip and two oblique fibers on both sides joined by the interosseous tendon from the interosseous muscle (with a thin, filmy membrane between the two). They run across and join the extensor mechanism. They form a so-called lateral band on the lateral side of the middle joint, which must be volar to the axis of motion to allow full flexion. In Figure 11A, we have pulled the oblique fibers out on both sides so that the direction they run can be seen. You can see the central slip going to its bony insertion on the base of the middle phalanx, the lateral band from the radial and ulnar sides, and the two run together. The fibers are actually crisscrossing distally as they go to their insertion on the distal phalanx. Some of the fibers from the radial side cross over to the ulnar side and some of the fibers on the ulnar side cross over to the radial side, and the insertion is made up of both tendons. Since there is no live muscle, it can be seen with the finger in extension. There is slack in the extensor tendon, but there is a little bulge that is the tubercle on the base of the middle phalanx, into which the central slip of the extensor tendon inserts.

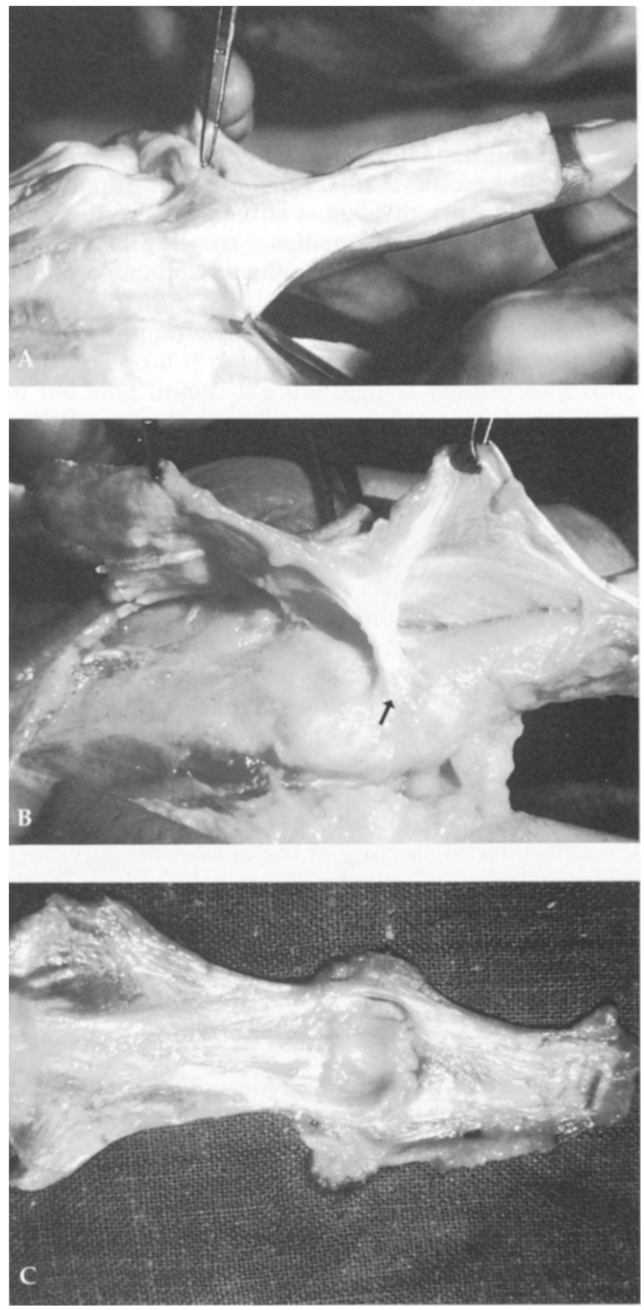


FIGURE 11. (**A**) *The lateral band with oblique fibers pulled out so that the direction they run can be seen. Fibers crisscross distally as they go to insertion on the distal phalanx.* (**B**) *Lifted up extensor mechanism over the proximal phalanx (arrow).* (**C**) *Removal and reverse of the extensor mechanism.*

If we lift up the extensor mechanism over the proximal phalanx and view the metacarpal head, we can see that there is nothing holding the tendon down against the bone. It is check reined by the broad fan-shaped, umbrella-like structure that completely encircles the joint capsule and the flexor mechanism, so that there is no true bony attachment with Sharpey's fibers on the proximal phalanx of the extensor mechanism. Many textbooks say that there are (Fig. 11B).

You cannot pull the extensor mechanism off of the finger unless you sharply dissect the Sharpey's fibers of the central slip on the middle phalanx and the Sharpey's fibers at the distal phalanx as the tendon goes to its distal insertion.

If we look at the removed extensor mechanism by itself, it can be seen more clearly how the extensor tendon from the metacarpal head level divides into three parts—a central slip going to the middle phalanx and the two lateral bands (oblique fibers) going to join and become the lateral band. If the specimen is placed on an x-ray box, you can see by the illumination the different densities—some parts are very thin and can be torn easily whereas other parts are thick (Fig. 11C).

The Forearm

The fascia of the forearm is similar to a stocking on a lady's leg. It's an all encompassing thing that helps keep the shape, but it moves with the shape of the contents underneath it. It has a function to offer resistance to the tendency for a muscle to expand when it contracts to do its work.

Each muscle group on the dorsal side of the forearm is separated by fascia or septum. This means that if you have any injury that causes swelling on the dorsum of the forearm, it is easy to get a compartment syndrome. Extension of the arm, of the elbow, of the wrist, and of the fingers, but not of the intrinsic muscles, is supplied by the radial nerve on the dorsum.

If we start dissecting at the elbow, the top most superficial muscle is the brachioradialis, which is the big thin but broad muscle that attaches anywhere from two to three inches above the lateral condyle and takes its origin on the humerus bone. It is a broad, flat muscle that runs down the radial aspect of the forearm. It is a flexor of the elbow and it acts as a stabilizer. It has its insertion on the distal radius. You can palpate the muscle if you put your left hand on top of your right wrist and thumb and flex your elbow against resistance.

When we open the fascia of the arm on the dorsal ulnar side, we observe the extensor carpi ulnaris. It has a large tendon, and it inserts to the base of the fifth metacarpal. It is an ulnar deviator of the hand and a wrist extensor. The dorsal carpal ligament is what is necessary for it to have an effect as an ulnar deviator.

If we open the fascia of the extensor muscle group of the fingers, we see three or four muscle groups. On the most ulnar side are two tendons over the dorsal of the hand; this single tendon usually divides somewhere under the dorsal carpal ligament and becomes two tendons, an anatomic finding only occasionally absent. It is an extensor of the proximal phalanx, of the little finger.

The next group of muscles are the communis tendons to the long, ring, and index fingers. If they are pulled individually by virtue of the juncturae, the pull on one will effect a pull on the two adjacent fingers because these are "y" shaped and bifurcating. This is especially true on the communis to the ring finger. There is a lot of variation in the communis to the ring finger. It may have a completely independent tendon going to the ring finger, or it may have several. It can go in a "y" shape to the little finger, and sometimes it goes in a "y" shape to the long finger. There are usually always two tendons to the index finger. The communis of the index finger is almost always connected at least by a very thin juncturae tendinum to the communis of the long finger. The most ulnar of these two, the extensor indicis proprius, I have never seen absent. That comes from the deeper layer of muscle in the forearm. It passes underneath the juncturae from the index communis to the communis of the long finger. The indicis proprius inserts on the ulnar side of dead center of the second metacarpal head, so that it is not only an extensor of the index finger, but also an ulnar deviator.

In the next deeper layer to the radial side in this dorsal compartment is the extensor pollicis longus. It makes a considerable angle as it goes under the dorsal carpal ligament. And it goes around the small bony prominence known as Lister's tubercle. This little pulley system has its own separate compartment in the dorsal compartment of the wrist, the third compartment. This is necessary for it to change its angle and approach the thumb, and it is the extensor of the distal joint of the thumb.

There is a group known as the "outcroppers," which are the abductor pollicis longus and the extensor pollicis brevis tendons going to the thumb; they abduct and extend the thumb. There are usually multiple tendons of the abductor pollicus longus. These two muscles pass over the extensor carpi radialis brevis and the extensor carpi radialis longus.

Both of the radial wrist extensors take their origin just above the humerus for the longus, and at the lateral epicondyle and just below it for the extensor carpi radialis brevis. The extensor carpi radialis brevis inserts into the third metacarpal base, and is the only true central wrist extensor. Because it approaches at a slight angle, it extends the wrist and slightly radially deviates the wrist because it is slightly off center to the ulnar side, especially if the wrist is in ulnar deviation.

The extensor carpi radialis longus passes underneath the dorsal carpal ligament through the same compartment, with the extensor carpi radialis brevis, as it goes to its insertion on the second metacarpal. It inserts on the radial side. It is so far to the radial side that it is a strong radial deviator of the wrist and only actually extends the wrist if the wrist is in flexion. It will bring the wrist to neutral position and to

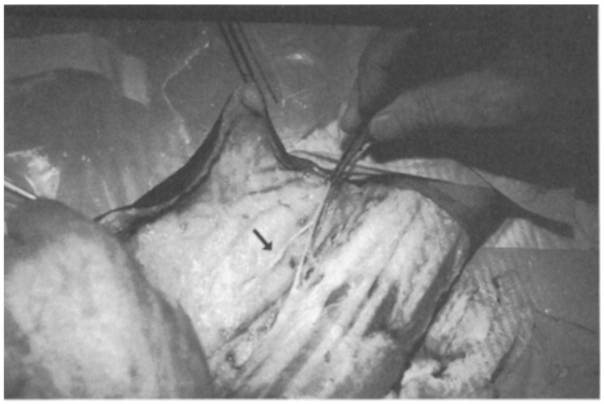


FIGURE 12. The superficial branch of the radial nerve at the forearm. Volar view of the forearm with an arrow pointing to the superficial radial nerve.

radial deviation. In rheumatoid surgery, sometimes the dorsal carpal ligament is removed and placed underneath the tendons to give a new bed for the tendons to run on so they do not rupture. I think it is very important that when a surgeon removes that ligament he or she leaves the proximal portion so that there is some sort of a pulley that remains to prevent the tendons from bow stringing. It would be easy for them to drift to the ulnar side because that is the tendency in rheumatoid arthritis, if you do not leave that portion of the ligament. It is very important that you leave the forearm fascia, since it acts as a secondary ligament and prevents some of the bow stringing.

On the flexor side of the forearm, the volar fascia is equally important. The biceps muscle runs down to flex the elbow. There are main thick fascial fibers at the elbow. The lacertus fibrosis is made of small fine fibers, which are white like string. That is an extension of the fascia and tendon of the biceps, and it runs at right angles to the longitudinal axis of the forearm fascia. It makes your biceps flex not only your elbow because of the bony attachment of the biceps tendon to the radius, but also because of the attachment to the fascia of the flexor muscles of the forearm.

The brachioradialis muscle can also be seen on the volar side because it is a broad muscle that covers part of the flexor radial side of the wrist too. Its insertion is the floor of the first compartment of the dorsal carpal ligament, into the distal radius.

Coming out on the ulnar side of the brachioradialis tendon is the superficial branch of the radial nerve (Fig. 12). This is the only sensory part of the radial nerve to amount to anything. It comes out on the ulnar dorsal side of the brachioradialis tendon, between the extensor carpi radialis longus and the brachioradialis tendons. It usually gives a number of branches to the dorsal aspect of the thumb. They supply the dorsal aspect of the skin of the thumb, the radial half of the wrist, and the proximal phalanx of the index and long fingers on their dorsal side to the proximal interphalangeal joint.

The most radial of the wrist flexors is the flexor carpi radialis. It has a very big tendon that inserts onto the volar side of the base of the second metacarpal. It goes through its own fibro-osseus tunnel in the carpal canal.

Only about four out of five people will have the palmaris longus. It inserts onto the palmer fascia and the base of the palm. It is also a wrist flexor because it is in the center, and it is quite superficial. It has a big moment arm, but it is not a very big muscle. We do use it sometimes as the only wrist flexor when the others have been damaged.

If we move the palmaris longus aside, we see the sublimis tendons, or the superficialis with the new terminology. When the sublimis tendon to the ring finger is flexed, the little finger sometimes flexes too. The synovial sheath covers these two muscles, and even though the superficialis of the little finger is deeper than the superficialis of the ring finger, they work together. Sometimes it is very difficult for a person to separate the superficialis function of the little finger from that of the ring finger, and it is purely because of that synovial attachment.

The superficial palmar branch of the median nerve is usually on the radial side of the palmaris longus tendon. Although it is sometimes shown on the ulnar side by Netter[2] and others, rarely does this actually occur (Fig. 13A).

The superficialis of the index finger is the deep tendon, and it is deeper underneath the superficialis of the long finger. It's the biggest tendon as a rule, and the muscle usually comes down fairly far. This

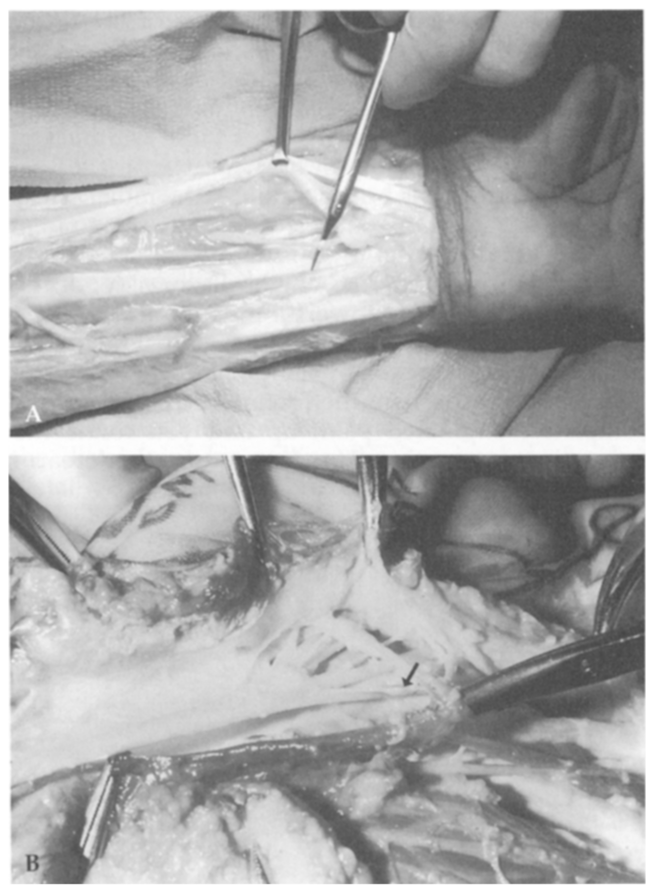


FIGURE 13. *(A) The superficial palmar branch of the median nerve at the forearm. (B) The median nerve, with the carpal tunnel opened, and the anastomotic branch to the ulnar nerve.*

inserts on the middle phalanx of the index finger and flexes the middle joint of the index finger, like the superficiali of the other fingers. It takes about one-half inch of range of motion at the wrist to effect about a 90-degree range of motion at the proximal interphalangeal joint of the index finger. One anatomic structure that should always be considered when we are looking at the superficialis of the index finger is the median nerve.

The median nerve always comes out from beneath the muscle belly of the superficialis of the index finger, on its radial side. The median palmar branch takes off of the median nerve about two to three inches above the flexion crease of the wrist, and supplies a circular area at the base of the thumb.

The flexor carpi ulnaris is also in the superficial layer. It inserts on the pisiform bone and lays directly over the ulnar artery and the ulnar nerve. The flexor carpi ulnaris is a powerful flexor of the wrist. Since it attaches to the pisiform bone, it has a fairly good moment arm; but like the other tendons that are off center, it not only flexes but also ulnarward deviates the wrist.

The ulnar nerve sits on part of the flexor mass in the forearm.[3] At the wrist it sits directly over the ulna and pronator quadratus, which sits underneath and to the radial side of the tendon of the flexor carpi ulnaris (Fig. 14).

As the flexor carpi ulnaris is retracted, some of the muscle bellies of the superficialis tendons can be found. They are attached to the fascia of the flexor ulnaris, so that all of these muscles, whether they are extensors or flexors, originate not only on bone but also have part of their origin on fascia of adjacent muscles. You cannot really dissect these without destroying some of the origin of their attachment.

If you retract the brachioradialis, the radial artery can be seen. The large muscle that is the most radial one that takes its origin from the medial epicondyle and part of the humerus, on the flexor side, is the pronator. It is a very powerful muscle, and it has a nice white tendon that you can see. It wraps over the radius. You can see by its radial dorsal insertion that when you pronate the forearm if the forearm is completely supinated palm up and you rotate the forearm into pronation, it's going to turn the forearm into pronation out of the supinated position, and it can flex the elbow too. It depends on what you do with your triceps whether this is going to actually flex the elbow. When we use this muscle for transfer, we have to make sure that we take the periosteum with it to get enough tendon to work with. The muscle comes right down to the radius, so that even though you have a big tendon, it is not much of a tendon to work with as far as suturing goes.

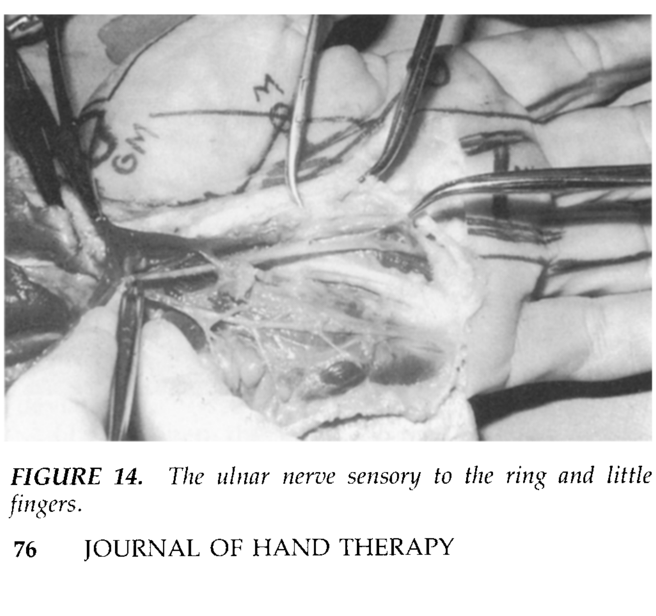


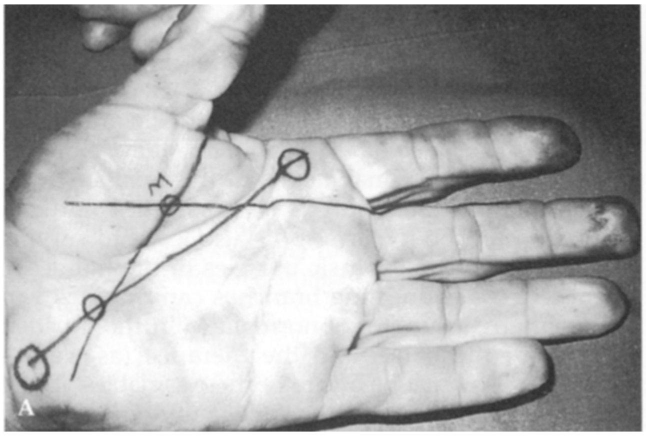
FIGURE 14. The ulnar nerve sensory to the ring and little fingers.

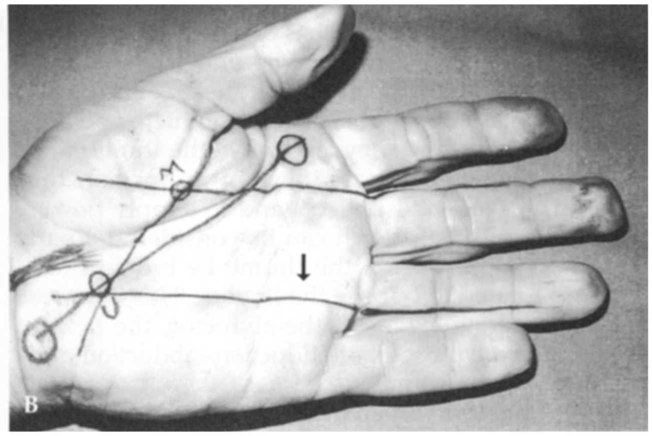
Kaplan[4] has claimed that if you make some lines on the hand, you can define where underlying structures are. I used to make an identification of the pisiform and about an inch distal to that in a line with the second metacarpal head. You could palpate the hook of the hamate. Kaplan's cardinal line was from the volar surface of the thumb in extension to the hook of the hamate. If you draw a line from the radial side of the long finger where it crosses that cardinal line of Kaplan, you locate the motor branch of the median nerve where it enters the thenar muscles (Fig. 15A). There is great variation, but it enters the thenar muscles usually at this point. That does not tell you where it comes off the median nerve. I have seen it come off at the wrist. I have seen it come off in mid palm and not leave the nerve until it reaches that area. I have seen it come off the nerves to the radial side of the index finger and the sensory nerves to the thumb. If a line is drawn on the ulnar side of the ring finger, proximally in that same line, where that crosses the hook of the hamate, the ulnar nerve and its motor branch are going to be just to the ulnar side of the hook of the hamate (Fig. 15B).

Figure 15C adds (1) longitudinal bands (L) of the palmar fascia, and the transverse band (T) of the palmar fascia; (2) the approximate path of the motor branch of the ulnar nerve (U), as it passes to the ulnar side of the hook of the hamate; and (3) the motor branch of the median nerve (M). If you could draw a line in the distal flexion crease of the palm, everything contained within the parallelogram made by those four lines would really be the guts of the hand, consisting of all of the sensory branches and the motor branches and the superficial palmar arch of the hand. If there is a wound through this part of the hand, a lot has been damaged.

HAND MECHANICS

Grasp and pinch are the most important movements of the hand. The intricate and complex movements are required in special skills, such as typing, playing stringed or keyboard instruments, handling tools (large and small), and the many functions of daily living. After injuries, the goal is to restore function, primarily of grasp and pinch. Grasping can be broken down into three phases of action: opening the hand widely, surrounding the object to be grasped with the fingers, and gripping the object between the fingers and the thumb or between the fingers and the palm. This requires, in the normal hand, four main muscle groups to act to carry out these phases of grasp: the wrist extensors, the finger and thumb extensors, the finger and thumb flexors (the digito-





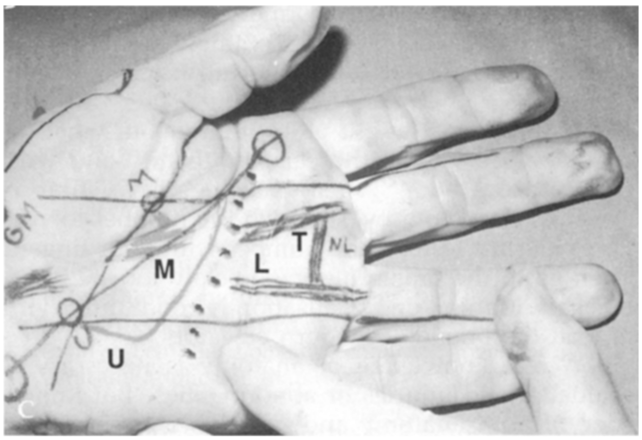


FIGURE 15. Lines of the hand locating surface anatomy. (**A**) *Kaplan's cardinal line with the addition of a line on the radial side of the long finger to locate the motor branch of median nerve (M) where it enters the thenar muscles.* (**B**) *The addition of a line (arrow) on the ulnar side of the ring finger to the intersection of the hook of the hamate bone to locate the ulnar nerve and its motor branch.* (**C**) *The addition of (1) longitudinal (L) and transverse (T) bands of the palmar fascia; (2) the path of the motor branch of the ulnar nerve (U); and (3) the motor branch of the median nerve (M). The addition of a line at the distal flexion crease defines everything within the parallelogram formed as the guts of the hand. The dotted line in the distal palm represents the fourth side of the parallelogram. GM = greater multangular; NL = natatory ligament.*

rum profundi, the flexor superficialis, and the flexor pollicis longus), and the intrinsic muscles of the fingers and the thumb (the interossei and the thenar and hypothenar muscles).

The three wrist extensors (the extensor carpi radialis longus, the extensor carpi radialis brevis, and the extensor carpi ulnaris) stabilize the wrist in the necessary degree of dorsiflexion and in radial or ulnar deviation, depending on the needs. The thumb extensors are the abductor pollicis longus, the extensor pollicis brevis, and the extensor pollicis longus. The finger extensors are the extensor digitorum communis, the extensor indicis proprius, and the extensor digiti quinti proprius. These muscle groups, when unopposed, extend the wrist and the fingers and the thumb at all joints. The finger extensors can secondarily extend the wrist. When the extensors are opposed by the action of the interossei, or when hyperextension of the metacarpophalangeal joint is prevented by an internal or external block, the long extensors then secondarily extend the proximal and distal interphalangeal joints and fully straighten the fingers at the distal two joints. The abductor pollicis longus, the extensor pollicis brevis, and the extensor pollicis longus extend all three joints of the thumb. In addition, the abductor pollicis brevis can also extend the distal phalanx of the thumb. The extensor pollicis longus can also function as a secondary adductor of the thumb, as observed in intrinsic paralysis of the hand (claw hand).

In the second phase of grasp, the fingers have surrounded the object to be grasped, and the finger flexors and intrinsics then come into play. The flexor digitorum longus is primarily a flexor of the distal joint of each finger; this action is also necessary in the third stage of grasp. Secondarily, the profundus also acts on each joint it crosses and therefore flexes, in progression, the proximal interphalangeal joint, the metacarpophalangeal joint, and the wrist joint. The flexor pollicis longus is the only flexor of the distal joint of the thumb, and it also secondarily flexes the metacarpophalangeal joint of the thumb. To a lesser degree, it will also flex the carpometacarpal joint of the thumb.

The lumbrical muscles may help in extending the distal joint by pulling the proximal profundus distally. The interossei are considered "intrinsic muscles." Since the tendons of insertion of the interossei are anterior (palmar) to the axis of motion of the metacarpophalangeal joints and posterior (dorsal) to the axis of motion of the proximal interphalangeal and distal interphalangeal joints, it can be understood how their actions seem paradoxical. By virtue of the position of their tendons, these muscles therefore flex the metacarpophalangeal joints and extend the interphalangeal joints. Since they simultaneously flex the metacarpophalangeal joints and extend the interphalangeal joints, they act during the first phase of grasp by stabilizing the metacarpophalangeal joint, aiding in extension of the interphalangeal joints. They also act in phases 2 and 3 of grasp as the fingers surround an object and grip it firmly. Thus, in the normal hand both the intrinsic muscles and the long extensors are active in extending the interphalangeal joints in phase 1 of grasp. The intrinsic muscles of the thumb (the abductor pollicis brevis, the opponens pollicis, the flexor pollicis brevis, and the adductor pollicis) serve to flex the proximal phalanx and assist in extending the distal phalanx (the abductor pollicis brevis) of the thumb. They also move the thumb into radial abduction or ulnar adduction to position the thumb in phase 1 and phase 2 and to supply power for grasp in phase 3. Pinch can be considered a part of grasp. It requires that the thumb be brought forward and rotated to oppose the fingers. This requires action of the long extensor, the abductor, the flexor, and the intrinsic muscles of adduction–abduction and opposition of the thumb.

Thus, phase 1, opening the hand, can be seen to require both long extensor and intrinsic muscle action. Phase 2, surrounding the object, requires intrinsic action for the most part. Phase 3 requires strong action of the long flexors for the final closing and grasping of the object and also requires action of the intrinsic muscles of the fingers and thumb.

PERIPHERAL NERVES AND HAND FUNCTION

When the therapist is asked to evaluate the hand, preoperatively or postoperatively, it is imperative that the sensory and motor patterns of the median, ulnar, and radial nerves be understood. The superficial branches of the radial nerve and ulnar nerve on the dorsum crisscross, and there can be some variation in innervation on the dorsal aspect of the hand.

There is a variation in the ulnar sensory pattern because of the cross anastomosis of a branch from the ulnar nerve to the median nerve in the palm. This unites the common digital nerves in the third intermetacarpal space. This anastomosis causes a variation in the ulnar sensory pattern of the ring and middle fingers (Fig. 13B).

Variations of the motor nerves of the ulnar and median nerves may also occur in the hand. In the palm, the deep branch of the ulnar nerve supplies all of the muscles of the hypothenar eminence, all of the interossei, the two ulnar lumbricals (of the ring and little fingers), and occasionally the deep head of the flexor digitorum brevis of the thumb. Riche[5] and Cannieu[6] have also described a branch of the ulnar motor nerve to the recurrent motor median branch, so that the deep head of the flexor digitorum brevis may be innervated by both ulnar and median nerves or solely by the abnormal branch of the ulnar nerve.

Variations of the motor nerves in the forearm are seen in several levels. Martin[7] and Gruber[8] have described a branch running from the median nerve proximal in the proximal third of the forearm to the ulnar nerve several inches distally. This leads to a variable motor innervation of the intrinsic muscles of the hand. They also describe, more distally, a branch running from the ulnar nerve to the median nerve in a distal direction, and this occurs in the middle or distal third of the forearm. This also leads to varying innervation of the intrinsic muscles in the hand. All of these cross-connecting branches can produce variable patterns of motor abnormalities in the intrinsic muscles of the hand, and the therapist (as well as the physician) must be aware of these variables. These variations may result in the ulnar nerve innervating all of the intrinsic muscles or sharing equally with the motor median nerve innervating the intrinsic muscles of the hands. Less commonly, the median nerve may innervate all of the intrinsic muscles of the hand.

Moberg[9] has taught us to think about what the eye can "see," what the ear can "hear," and what the hand can "do." A real challenge is to enter an elevator, close your eyes, punch the number to your floor, and try to read the number with your fingers. Then go to the braille numbers below for the blind. It is easy to think one's sensation is good until trying to read the braille of modern elevators.

A real knowledge of anatomy is necessary to evaluate hand injuries or abnormalities. But knowledge of both anatomy and function is essential for the hand therapist to successfully analyze and treat a preoperative or postoperative hand.

REFERENCES

1. Riordan DC: Functional anatomy of the hand and forearm. Orthop Clin North Am 5:199–203, 1974.
2. Netter FH: Ciba Symposium on Surgical Anatomy of the Hand. Ciba-Geigy, 1989.
3. von Lanz, Wachsmuth: Praktische Anatomie. Berlin, Springer-Verlag, 1959, p. 224.
4. Kaplan EB (ed): Functional and Surgical Anatomy of the Hand, 2nd ed. Philadelphia, J.B. Lippincott, 1965.
5. Riche P: Le ners cubitale et les muscle de leminene thenar. Bull Soc Anat Paris 251–252, 1897.
6. Cannieu JMA: Note sur une Anastamose Unter La Branche profunde du, cubital el le mediane. Bull Soc Anat Physiol Bordeaux 18:339–340, 1897.
7. Martin R: Tao om Nervous Almanna Egenskater 1 Manniskans Kropp. Stockholm, Lars Salvius, 1763.
8. Gruber W: Über die verbindung des Nervus medianus mit dem Nervus Ulnaris am Unterarmee des Mensche. Arch Anat 501, 1870.
9. Moberg E: Aspects of sensation in reconstructive surgery of the upper extremity. J Bone Joint Surg Am 46:817, 1964.