12 Open Techniques for Carpal Tunnel Release

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Introduction/History

The first recorded open carpal tunnel release surgery was described by Dr. Learmonth in 1933 [1]. In his landmark paper, he described two cases of median neuropathy treated by dividing the transverse carpal ligament. Twelve years later, Cannon and Love published their review of 38 surgical releases of the transverse carpal ligament [2]. Along with the promising results of this first series of surgically treated carpal tunnel syndrome, the paper gave us the first accurate illustration of the anatomy and a depiction of carpal tunnel release surgery. In 1966, Phalen cemented carpal tunnel syndrome as a treatable condition with excellent operative outcomes in his series of 354 successful operations [3].

Since the work of these pioneers, our understanding of the anatomy and pathophysiology of carpal tunnel surgery has improved, but the general principles of treating carpal tunnel syndrome have remained the same. The surgical incision has evolved from transverse, zigzags, oblique, and curved incisions [3, 4] to the "mini" and standard longitudinal incisions currently utilized today. Initially, extensive debridement including extensive neurolysis and synovectomy of flexor tendons within the canal was performed along with the release of the transverse carpal ligament. Today, those adjunct procedures have largely been abandoned due to complications such as neuromas, paresthesias, and skin adhesions [5, 6].

Despite the fact that the use of endoscopic carpal tunnel surgery has increased dramatically since its introduction in the late 1980s, open carpal tunnel release surgery remains the gold standard and the most commonly performed procedure to treat carpal tunnel syndrome [7, 8]. Initially, endoscopic carpal tunnel release was proposed as a technique to eliminate pillar pain and get patients back to work earlier. However, endoscopic surgery did not eliminate the issue of pillar pain and no study has shown long-term clinical superiority [9–14] compared to open carpal tunnel surgeries. Additionally, endoscopic techniques have been shown to cause incomplete release of the transverse carpal ligament up to 50% of the time [15]. Although some functional improvement such as grip and pinch strength has been seen early in the post-op period with endoscopic technique compared to open techniques, these benefits disappear by 3 and 6 months [16]. Overall, with questionable long-term clinical significance and the added complications related to the limited visualization in endoscopic tech-

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niques including iatrogenic nerve injury and incomplete release, open carpal tunnel release surgery remains the preferred treatment for idiopathic carpal tunnel syndrome.

Anatomy

A strong knowledge of the anatomical structures of the carpal tunnel and its surrounding structures is essential to avoid complications and iatrogenic injuries. The carpal tunnel is an oval-shaped channel on the volar aspect of the wrist. It is bordered ulnarly by the hook of the hamate; radially by the trapezium, scaphoid, and flexor carpi radialis retinaculum; dorsally by the arch of the carpal bones; and volarly by the transverse carpal ligament (Fig. 12.1). The transverse carpal ligament is 1–3 mm thick and 3–4 cm wide as it crosses transversely over the carpal tunnel. Within the carpal tunnel, there are nine extrinsic flexor tendons from three muscles (flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus) and the median nerve. The median nerve sits on the volar and radial aspect of the carpal tunnel just ulnar to the flexor pollicis longus tendon.

Prior to entering the carpal tunnel, the median nerve gives off its palmar cutaneous branch. The palmar cutaneous branch of the median nerve branches off from the median nerve from the radial aspect of the nerve 6–11 cm proximal to the distal wrist crease [17]. It travels distally together with the median nerve then passes volar to the carpal ligament to the undersurface of the palmar aponeurosis where it then divides into branches to the palmar skin supplying sensation to the radial and lateral aspect of the palm at the base of the thumb.

After the median nerve exits the carpal tunnel, the median nerve gives off its terminal branches including the recurrent motor branch and common digital nerves. The recurrent motor branch of the medial nerve typically wraps around the transverse carpal ligament to innervate most of the thenar muscles (abductor pollicis brevis, the superficial head of the flexor pollicis brevis, and opponens pollicis). The terminal branches of the median nerve divide into the digital nerves that provide sensation to the thumb, index, middle, and radial half of the ring finger (Fig. 12.2).

Outside of the carpal tunnel, it is important to be aware of the other important neurovascular structures in the vicinity of the palmar wrist. The ulnar nerve passes superficial and ulnar to

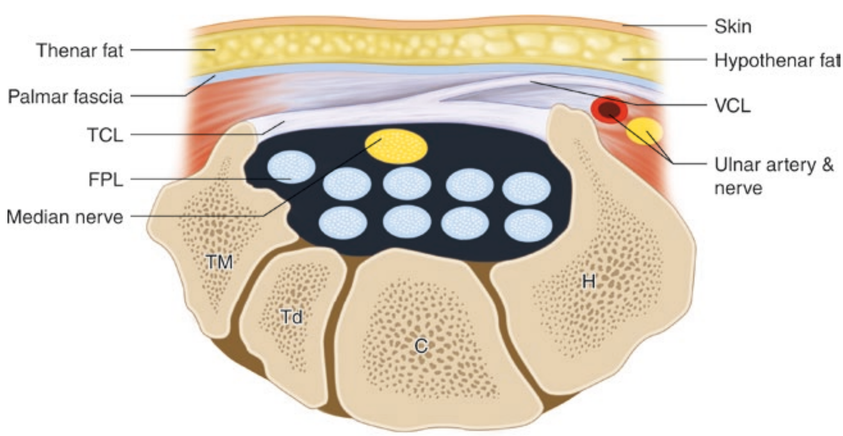

Fig. 12.1 Anatomy of carpal tunnel

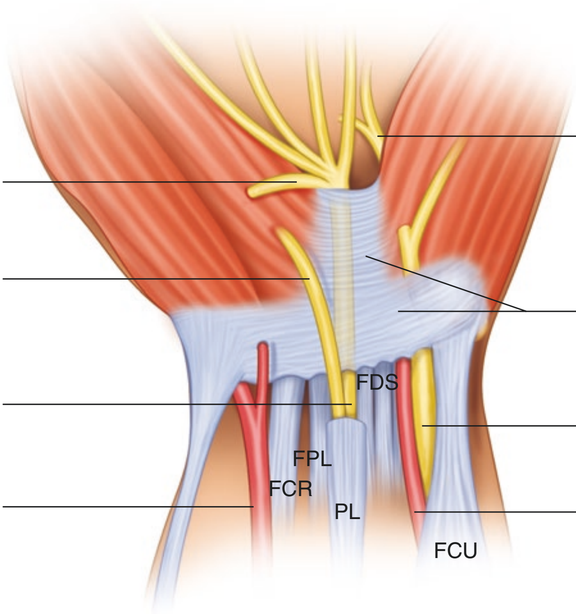

Fig. 12.2 The palmar cutaneous branch of the median nerve lies radial to the median nerve and ulnar to the flexor carpi radialis tendon. The motor branch of the median nerve branches off of the median nerve after the carpal tunnel in most cases

the transverse carpal ligament. It bifurcates into sensory and deep motor branches in Guyon's canal. Its sensory branches provide sensation to the ulnar aspect of the hand, the small finger, and the ulnar aspect of the ring finger. The deep motor branches innervate the interosseous muscles, the third and fourth lumbricals, the hypothenar muscles, the adductor pollicis, and the medial head of the flexor pollicis brevis. Both the radial and ulnar arteries provide arterial supply to the hand. In most cases (88%), the dominant blood supply to the hand is from the ulnar artery via the superficial arch. The other 12% of the time the dominant blood supply is from the deep palmar arch as a continuation of the radial artery. The deep palmar arch anastomoses with the deep branch of the ulnar artery. It lies 1 cm proximal to the superficial arch, and its location can be estimated by drawing Kaplan's cardinal line (a line drawn from the distal edge of the abducted thumb to the hook of the hamate). The deep palmar arch is approximately one finger breadth superficial from that line (Fig. 12.3).

Anatomical Variations

After the median nerve exits the carpal tunnel, it divides into its many terminal branches. There are numerous anatomical variations of the branching of the median nerve that the operating surgeon should be aware of. In 1977, Lanz dissected 246 cadaver hands and found 29 variations of the median nerve that he categorized into four groups [18]. Group I consisted of variations of the recurrent motor branch which was initially subdivided into three described variations: extraligamentous, subligamentous, and transligamentous [19]. The extraligamentous

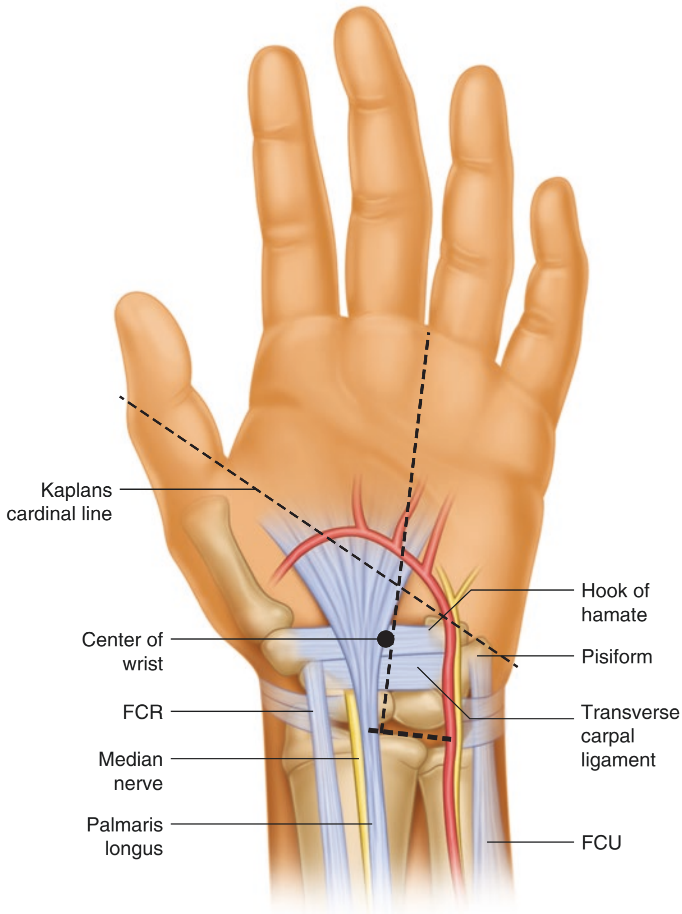

Fig. 12.3 Volar Wrist Anatomy

pattern is found in the majority of people and is therefore considered normal anatomy. In this pattern, the recurrent motor branch arises from the median nerve distal to the transverse carpal ligament to innervate the thenar muscles. In the subligamentous variation, the recurrent motor branch leaves the nerve within the carpal tunnel and bends around it at the distal aspect of the retinaculum. The transligamentous variation branches off within the tunnel and penetrates directly through the transverse carpal ligament before innervating the thenar muscles. This last transligamentous variation is of particular importance due to the compression within the retinacular fibers or iatrogenic injury from a retinaculum release. There have been reports of more rare patterns of the recurrent branch including where the branch takes off from an ulnar and anterior location [20] or branches that have a course superficial to the transverse carpal ligament [21]. However, further studies have confirmed that an extraligamentous pattern is found in 80–90% of cases [22–24] (Fig. 12.4).

The other median nerve groups described by Lanz include accessory branches of the median nerve at the distal carpal tunnel (Group II) found in 7.2% of cases, a high division of the median nerve at the level of the forearm (Group III) found in 2.8% of cases, and accessory branches of the median nerve branching proximal to the carpal tunnel (Group IV) found in 1.6% of cases. The majority of these branches leave the median nerve radially. Therefore, at surgery the nerve should be approached from the ulnar side to

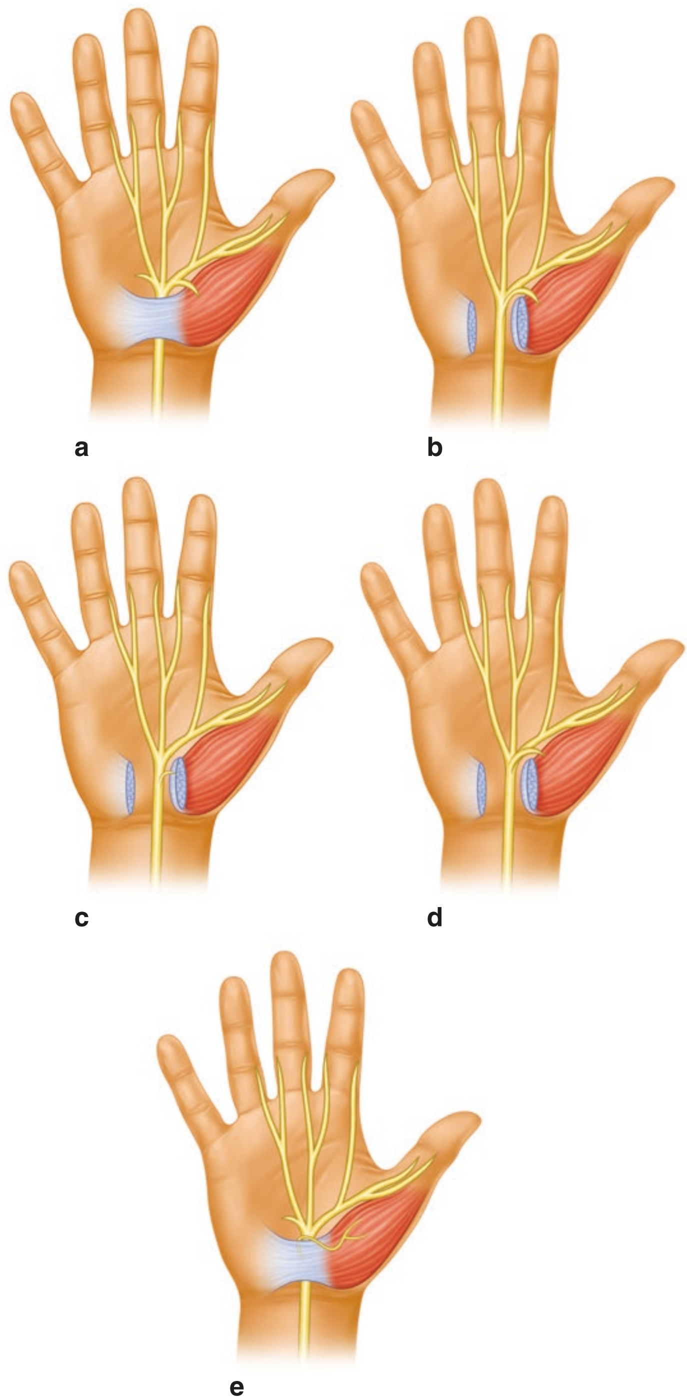

Fig. 12.4 Group I: Variations of the recurrent motor branch of the median nerve: Extraligamentous (**a**), subligamentous (**b**), intraligamentous (**c**), branch from ulnar aspect (**d**), and traversing over transverse carpal ligament (**e**)

minimize injury to the nerve or its branches. However, rare variations of branches dividing from the ulnar side of the median nerve [18] or a bifid median nerve where the nerve is seen in two distinct compartments within the carpal tunnel [25, 26] have been described.

Abnormalities within the tunnel are not limited to the median nerve. Anomalies of the tendons are rare, although elongated or additional muscle bellies of flexor digitorum superficialis have been described [27–32]. Women have been found to have elongated bellies of flexor digitorum superficialis and profundus extending into the carpal tunnel more often than men [33]. The osseous anatomy of the tunnel has also been associated with an increased risk of carpal tunnel syndrome. Hypoplastic variants of the hook of the hamate have been found to be more common in a group with carpal tunnel syndrome than in a group without carpal tunnel syndrome [34].

Surgical Technique

An open carpal tunnel release allows excellent visualization of the transverse carpal ligament and the contents of the carpal tunnel. Most open carpal tunnel releases today are performed through a "mini-open" surgical approach [7], but many are still performed through a standard open technique. The decision of the type of approach is dependent on the patient, surgeon preference, and the visualization in the OR. Regardless of the length of the incision, all open carpal tunnel releases follow the same basic steps: setup and anesthesia, skin incision, palmar fascia incision, transverse carpal ligament release, carpal tunnel inspection, and closure.

Setup and Anesthesia

Carpal tunnel surgery begins with the selection of the appropriate surgical setting and anesthesia for the patient. Options for anesthesia include full sedation/general anesthesia, conscious sedation with local anesthesia, intravenous regional anesthesia (Bier block), or "wide-awake anesthesia" [35, 36]. The type of anesthesia used is a multifactorial decision involving the surgeon preferences, patient factors including potential comorbidities, availability of facilities, and experience of the anesthesia and surgical staff. According to a recent survey of hand surgeons, most surgeons use intravenous sedation with local anesthesia (43%), followed by a Bier block (18%) and general anesthesia (11%) [7].

Elective carpal tunnel surgery does not require local or systemic antibiotics. Numerous studies support low infection rates in the hand without the use of perioperative antibiotics. Multicenter studies evaluating elective soft tissue hand surgery [37] and specifically elective carpal tunnel surgery [38] have shown no statistical difference in infection rates with or without preoperative antibiotics. The overall infection rate is very low, and even in high-risk populations such as diabetic patients, antibiotic use did not decrease the rates of infection.

A tourniquet can greatly aid the surgery by minimizing bleeding and providing excellent visualization of the surgical field. The decision of whether or not to use a tourniquet is dependent on the surgeon's preference and the clinical situation. A tourniquet can cause pain and may be contraindicated in patients with fistulas or who are at increased risk for clot formation. If a tourniquet is used, regional anesthesia blocks or a double tourniquet can be used and changed at 10 min so that the patient does not experience pain. If a tourniquet is not used, adding to epinephrine to the local anesthetic can provide sufficient vasoconstriction to maintain a dry surgical field [39, 40].

The patient is placed supine with his or her arm on a hand table. After appropriately cleansing the extremity, the wrist is prepared for surgery. Often a "lead hand" is helpful in positioning the hand. The appropriate anatomy and surgical landmarks are identified and labelled including Kaplan's line as described previously in this chapter. The appropriate surgical instruments are collected and placed on the surgical field.

Skin Incision

The skin incision in an open carpal tunnel release surgery is placed longitudinally over the ulnar aspect of the carpal tunnel as identified by its anatomical landmarks. The incision should avoid crossing the distal wrist crease at a right angle as it may result in a hypertrophic and painful scar. The incision is oriented longitudinally to avoid the potential injury to the palmar cutaneous nerve branch and has better exposure compared to a transverse incision [41].

For a primary carpal tunnel surgery, the mini-open technique is the preferred approach. A longer, standard open skin incision is indicated in patients who require more proximal exposure or exploration of the canal such as in patients with gout or amyloidosis. An incision started as a mini-open incision may be extended to a standard incision based on the need for additional visualization or exposure.

Standard Open Skin Incision

The standard longitudinal incision is a straight or curvilinear (parallel to the thenar crease) incision at the base of the palm. The straight incision begins distally at the Kaplan cardinal line and extends proximally toward the distal wrist crease along an axis defined by the radial aspect of the ring finger for approximately 3–4 cm (Figs. 12.5a and 12.6a). It should pass 3–5 mm ulnar to the thenar crease in most patients. If a curvilinear incision is desired, it should be parallel and ulnar to the thenar crease. The incision should avoid crossing the distal wrist crease to prevent a painful hypertrophic scar. However, if more exposure is needed proximally, the incision can be extended in a zigzag fashion across the wrist in an ulnar direction (Fig. 12.5a).

Mini-Open Skin Incision

Initially described by Bromley in 1994 [42], the "mini-open" technique has gained rapid popularity and clinical acceptance as a way to minimize incisional pain and scarring while allowing adequate visualization of the carpal tunnel. The skin incision for the mini-open technique begins distally at

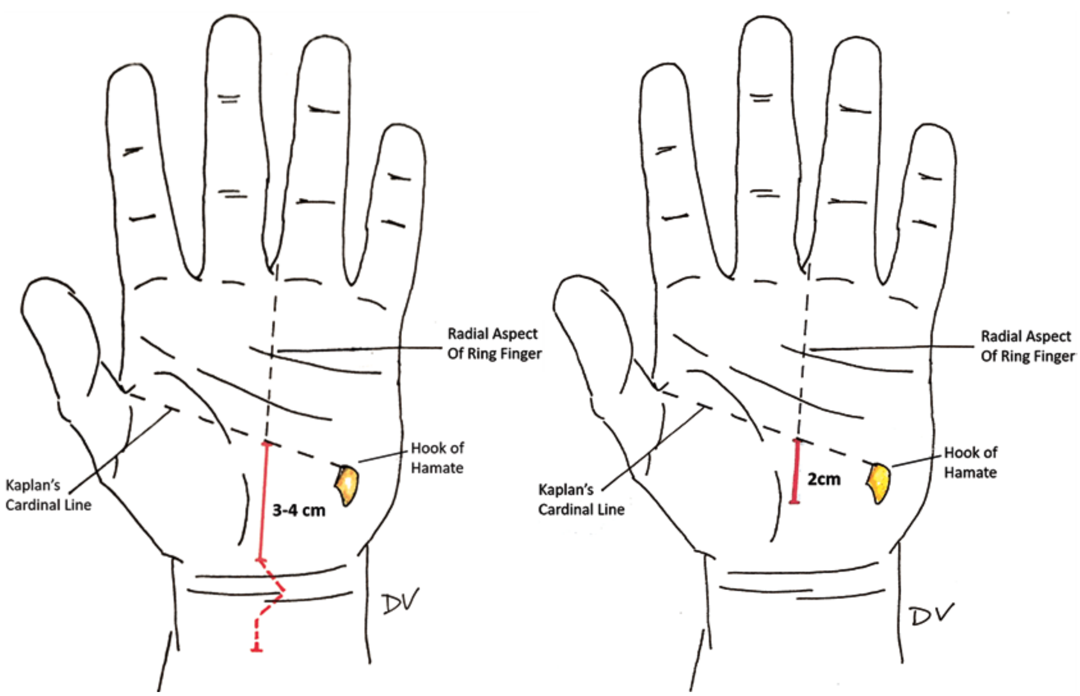

Fig. 12.5 (**a**) Standard open incision with optional extension proximal to wrist crease (*dotted line*) (*left*) and (**b**) mini-open incision (*right*)

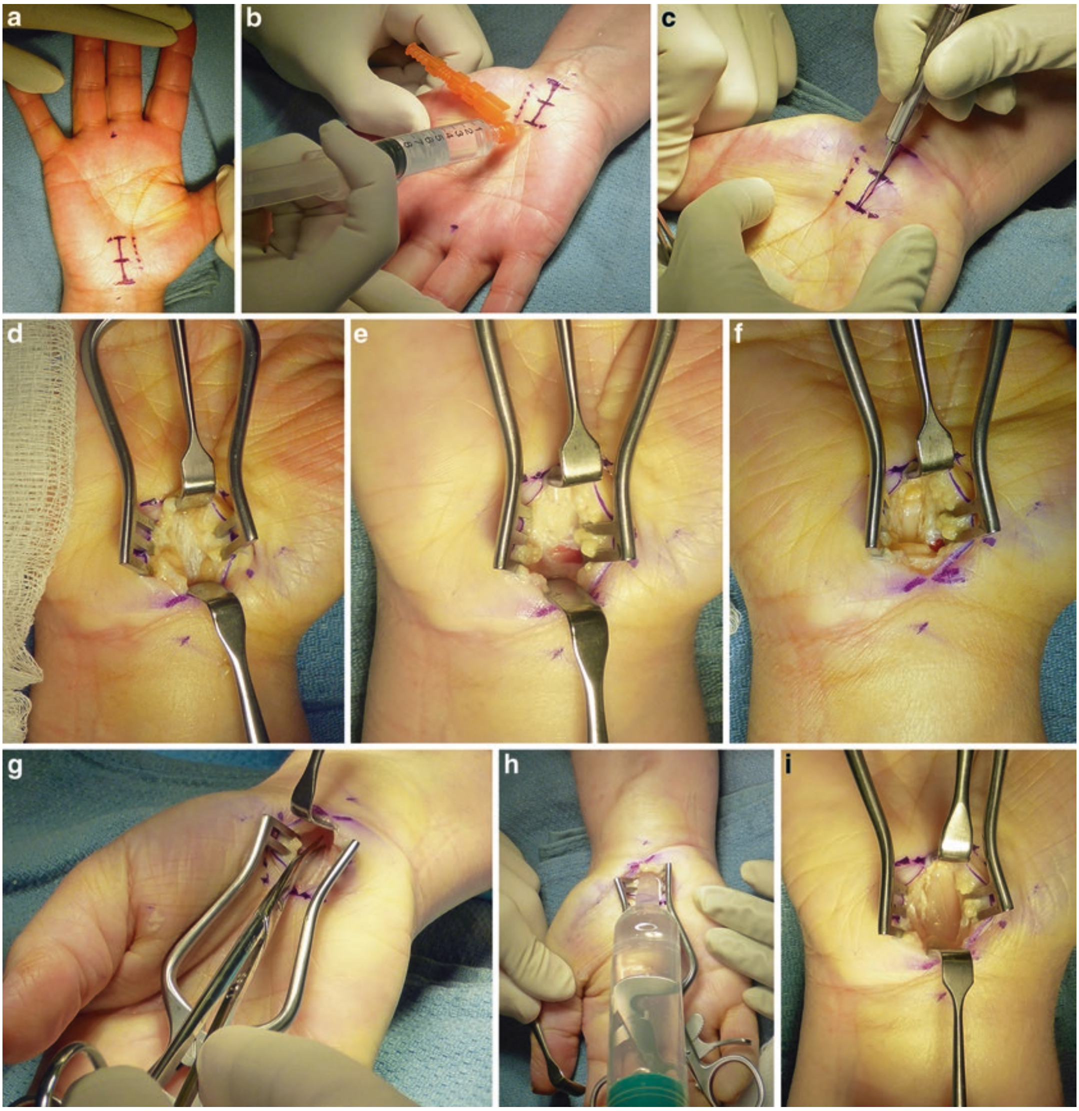

Fig. 12.6 (**a**) The incision of a standard open carpal tunnel release. (**b**) Injection of local anesthesia epinephrine can be used as part of the anesthesia for the procedure or to help with postoperative pain control. Epinephrine can be added to the injection to provide a bloodless field if not using a tourniquet. (**c**) Incision is made with a scalpel through skin and subcutaneous tissue. (**d**) Beneath the subcutaneous fat, the palmar fascia is exposed. The fibers of the palmar fascia run longitudinally and can be distinguished from the fibers of the transverse carpal ligament which run transversely. (**e**) A small incision in the transverse carpal ligament is made exposing the median nerve (seen here at proximal aspect of wound). (**f**) The transverse carpal ligament is transected proximally until the volar fat pad is visible. Dissection distal to this risks injuring the superficial palmar arch. (**g**) The transverse carpal ligament is released proximally using tenotomy scissors and a Ragnell retractor to ensure adequate visualization. (**h**) A bulb syringe can be used to inject saline into the proximal aspect of the incision. A visible collection of fluid underneath the skin indicates adequate release of the antebrachial fascia. (**i**) Excellent exposure of the median nerve after complete release of transverse carpal ligament

the Kaplan cardinal line and extends proximally approximately 2 cm (Fig. 12.5b). The incision should be along the axis of the radial aspect of the ring finger, approximately 3–5 mm ulnar to the thenar crease. If additional exposure is required, the incision can be extended proximally into a more standard open skin incision.

Palmar Fascia Incision

After the skin is incised, a layer of subcutaneous fat is exposed. The subcutaneous fat is bluntly dissected for exposure, being careful to avoid injuring superficial nerves. The palmar cutaneous nerve of the median nerve [4, 43] and occasionally its corollary of the ulnar nerve crosses in this location. Identifying and preserving these cutaneous sensory branches is thought to be the most important step in reducing painful incisional neuromas; however, it has not been shown to improve postoperative scar pain in a recent prospective randomized study [44].

A self-retaining retractor such as an Alm or a small Weitlander retractor and two Ragnell retractors can be placed to aid in visualization being careful to avoid injuring any superficial nerves. Soft tissue dissection through fatty tissue is continued down to expose the palmar fascia (Fig. 12.6d). The fibers of the palmar fascia are oriented longitudinally and should be incised in line with their fibers under direct visualization for the entire length of the skin incision. The retractors are repositioned underneath the palmar fascia, and the transverse carpal ligament is exposed.

Transverse Carpal Ligament Release

Deep to the palmar fascia lies the roof of the carpal tunnel, the transverse carpal ligament (TCL). The TCL must be clearly visible and exposed to avoid injuring an intraligamentous variation of the recurrent motor branch of the median nerve. The TCL should be approached carefully and a small incision should be made with a scalpel or beaver blade (Figs. 12.6e and 12.7a). Once an opening is created, the TCL is divided longitudinally, perpendicular to the orientation of its fibers with a sharp blade or tenotomy scissors. The incision should be near the ulnar aspect of the TCL directed toward the ring finger to avoid the recurrent branch of the median nerve.

The incision is extended distally under direct visualization until the volar fat pad around the superficial arch is encountered (Figs. 12.6f and 12.7b). The volar fat pad is a reliable anatomic landmark that ensures that the ligament has been released completely [45]. The incision is then extended proximally and inspected for complete transection of the ligament. In a mini-open incision, the incision may need to be extended to ensure complete transection of the transverse carpal ligament.

Attention is now directed toward the antebrachial fascia located just proximal to the wrist crease. A release of the antebrachial fascia, particularly in the case of connective disease where the fascia may be thickened, can help prevent recurrence of carpal tunnel syndrome [46]. To release the fascia, the incision may need to be extended if using a mini-open technique. The surgeon will be positioned at the end of the hand table to ensure excellent visualization. The fascia is divided from distal to proximal using a No. 15 blade or tenotomy scissors approximately 2.5 cm proximal to the wrist crease on the ulnar side of the palmaris longus tendon (if present) (Figs. 12.6g and 12.7c). To confirm that the fascia is released, a bulb syringe can be placed in the proximal aspect of the incision and water injected into the distal volar forearm. The water pressure should cause a visible bulge underneath the skin, known as the "Stein sign", confirming that the antebrachial fascia is released (Fig. 12.6h).

Carpal Tunnel Inspection

With the transverse carpal ligament released, the median nerve should be completely exposed (Fig. 12.6i). The carpal tunnel should be examined

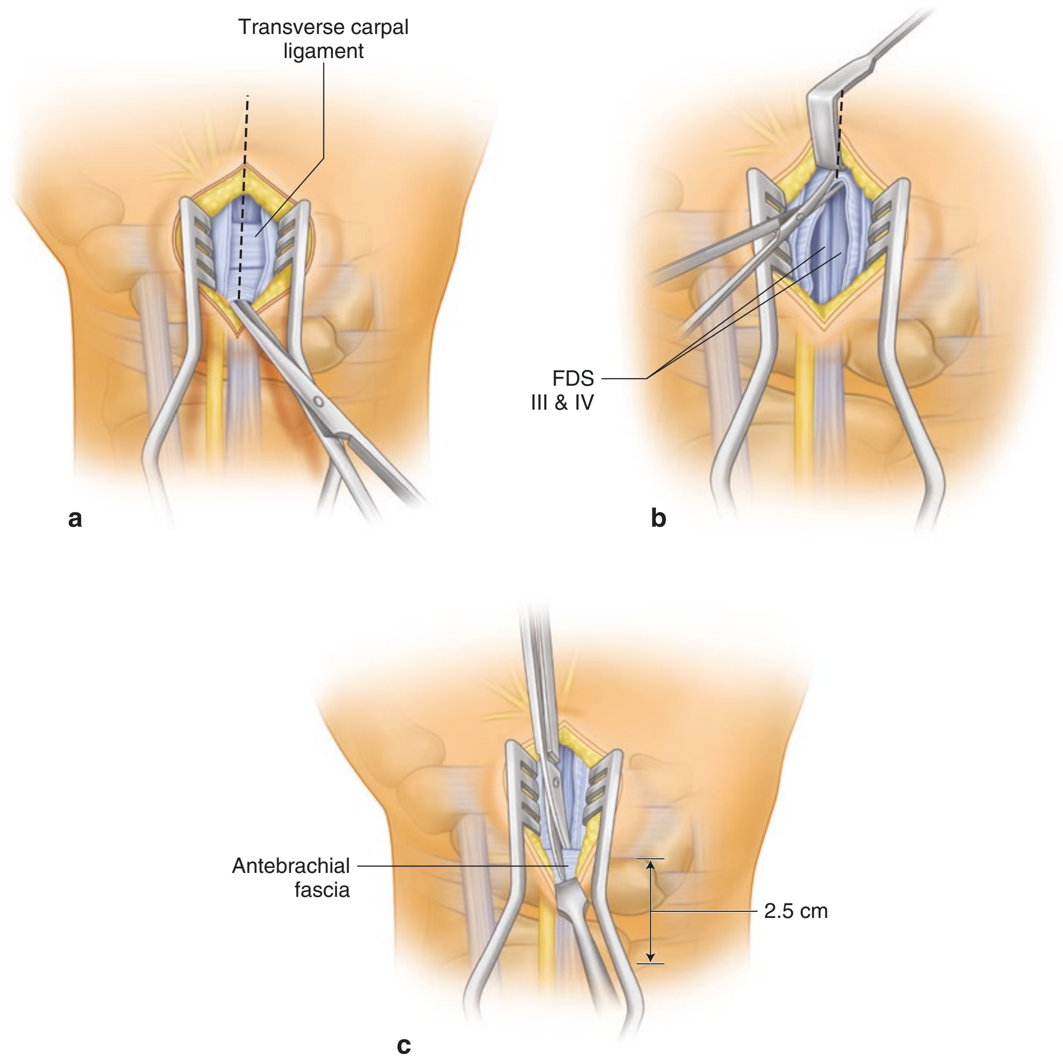

Fig. 12.7 (**a**) Exposure of transverse carpal ligament—modify image to show vertical incision and blade instead of scissors making cut. (**b**) Release of TCL. (**c**) Release of antebrachial fascia

for irregularities of the nerve and surrounding soft tissues such as tumors, aberrant muscles, or thickened synovium. Often this is performed by sliding a smooth instrument, such as a freer elevator, alongside the nerve to unsure that it is free proximally or distally. If an intraligamentous variation of the recurrent motor branch of the median nerve is found, the branch should be carefully released from the transverse carpal ligament. Additional procedures such as internal neurolysis, epineurotomy, and tenosynovectomy are rarely indicated and should not be a routine part of primary carpal tunnel release [47–49].

Closure

After the release has been completed, the tourniquet is deflated, and bipolar electrocautery can be used for hemostasis. The skin is closed with nylon sutures. A long-acting anesthetic (bupivacaine) can be injected into the incision for postoperative comfort. Often this injection is performed prior to the initial incision.

Postoperative Care

Immediately following surgery, the patient is placed in a soft dressing. Historically, after surgery patients were placed in a splint to protect the wound and prevent the flexor tendons from bow stringing through the now open transverse carpal ligament. However, a recent study found no difference in outcomes between a postoperative light bandage or a bulky dressing with a volar splint left in place for 48 h [50]. Accordingly, only 29% of recently surveyed hand surgeons use a postoperative orthosis, down from 37% 3 years prior [51] and 82% of hand surgeons in 1987 [52].

Patients can be safely discharged without the need for postoperative antibiotics. Postoperative infections from carpal tunnel surgery are rare and are not significantly decreased with the use of antibiotics [37, 38]. After surgery, the patient can remove the dry dressing and shower 3 days postoperatively. Patients should begin range of motion exercises for the elbow, wrist, and digits early in the postoperative period to prevent stiffness. To prevent a painful scar, desensitization techniques, such as percussion or friction massage, and scar massage should be initiated early following surgery.

Surgical sutures are removed at the first follow-up appointment 10–14 days after surgery. At our institution, no specific restrictions are given to the patients postoperatively, and gradual resumption of activity and use of the hand is encouraged. Over the next 4–6 weeks, most patients have resumed normal activities. A final follow-up appointment is scheduled for 6 weeks to evaluate healing and outcomes. Formal rehabilitation programs with physical therapists have not been shown to improve the functional recovery compared to home therapy exercises in all patients [53, 54]. We therefore reserve formal rehabilitation programs only for patients who develop pillar pain or are slow to recover.

Outcomes and Complications

Open carpal tunnel surgery is an extremely effective treatment for carpal tunnel syndrome. Most studies report the long-term symptomatic improvement between 75 and 90% [55–59]. Although carpal tunnel surgery has proven to be safe and reliable, complications do occur. Complications from carpal tunnel surgery can be thought in three different categories: persistent symptoms, recurrent symptoms, and new symptoms.

Persistent Symptoms

The most common complication of carpal tunnel surgery is the persistence of symptoms, occurring in up to 20 percent of patients [60]. There are three primary reasons for persistent symptoms after a carpal tunnel release. The most common reason is incomplete division of the transverse carpal ligament or antebrachial fascia. It has been suggested that surgeries with less visualization such as the mini-open or endoscopic techniques are more susceptible to this type of complication, particularly because the distal retinaculum is the most common site of incomplete release [61, 62]. Inadequate visualization can also lead the surgeon to miss space occupying lesions such as a ganglion or tumor that can compress the nerve and replicate the symptoms of carpal tunnel syndrome.

Another reason for persistent symptoms would be median nerve compression proximal to the wrist. While there may be compression of the nerve at the carpal tunnel, damage to the nerve may occur at an area proximal to the tunnel such as in a cervical radiculopathy, brachial plexopathy, or another lesion such as the “double crush” phenomenon. If there is doubt about the location of the pathology, electrodiagnostic testing should be performed to locate the location of the nerve injury to localize the area of pathology. In some cases, the injury to the nerve is so profound that even if it is fully decompressed, the nerve is unable to recover.

Finally, patients who were diagnosed incorrectly with carpal tunnel syndrome would not improve after carpal tunnel release. If a patient's symptoms do not resolve, an alternate diagnosis should be investigated.

Recurrent Symptoms

Some patients may do well initially after carpal tunnel release, only to have some symptoms return. Recurrent symptoms can be divided into early and late recurrence. Late recurrence occurs years after the initial surgery and may be due to true recurrence of the pathological process causing the compression of the median nerve in the carpal tunnel. Patients with late recurrence require a full repeat work-up for their symptoms.

Early recurrences are symptoms that return weeks to months after the initial procedure. This can occur from excessive scar tissue formation forming around and compressing the median nerve. Techniques and therapy such as minimizing postoperative immobilization and appropriate range-of-motion exercises are vital in minimizing the chance for a painful or hypertrophic scar. Alternatively, symptoms may recur if the median nerve is compressed at a site proximal to the carpal tunnel such as at the antebrachial fascia or in pronator syndrome. The carpal tunnel release may unmask these symptoms of a more proximal injury.

New Symptoms

Even when the median nerve is successfully and fully decompressed at the carpal tunnel, the patient may have other painful symptoms that may occur postoperatively. Complications following open carpal tunnel release include, but are not limited to, iatrogenic injuries to the motor branch and palmar cutaneous branches of the median nerve, neuroma and hematoma formation, palmar arch injuries, tendon adhesions, and pillar pain.

Pillar pain, the term used to describe pain in the thenar or hypothenar area of the palm, in particular is a significant problem in many patients. The exact cause of pillar pain is unknown although some speculate it to be ligamentous or muscular in origin, an alteration in the carpal arch (now that the TCL is released), or due to the violation of the palmar skin, its cutaneous nerves, and palmar fascia [63]. This last theory has led many to attempt to minimize the incision in an effort to decrease pillar pain. Desensitization and nerve gliding exercises can be used to treat pillar pain. Fortunately, pillar pain does seem to improve with time, and only 6% of patients report having this pain 1 year postoperatively [64].

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