Open Carpal Tunnel Release

Craig M. Rodner and Julia Katarincic

Summary: Open release of the transverse carpal ligament (TCL) has been the gold standard surgical treatment for patients with carpal tunnel syndrome over the past 50 years. Transecting the TCL with a scalpel under direct vision produces reliable symptom relief in the vast majority of cases. However, despite the clinical success of this technique, transient post-operative “pillar pain,” scar tenderness, or weakness are known to occur in some patients. Key Words: Carpal tunnel syndrome—Open carpal tunnel release.

Carpal Tunnel Syndrome (CTS) is the most common compression neuropathy of the upper extremity. The first described case of median neuropathy at the wrist, by Sir James Paget in 1854, involved a patient who had a rope tied tightly around his wrist and had such unrelenting pain and parasthesias subsequently that he required an amputation. In 1913, Marie and Foix performed an autopsy on a patient with bilateral thenar muscle atrophy and found bilateral median neuromas just proximal to the transverse carpal ligament (TCL). Based on this pathologic finding, they were the first authors to suggest therapeutic sectioning of the TCL to decompress the median nerve. In 1938, the neurologist Moersch coined the term “carpal tunnel syndrome,” but it was not until years later, with George Phalen’s monumental work in the 1950s, 1960s, and 1970s, that CTS became a well defined clinical entity. In his reviews of hundreds of hands afflicted with a similar constellation of symptoms, Phalen concluded that “the median nerve is easily compressed by any condition that increases the volume of the structures within the carpal tunnel.” For the past 40 years, transecting the TCL under direct visualization (an open carpal tunnel release) has been accepted as a reliable treatment for patients with CTS refractory to non-operative measures.

This chapter will focus on the technique involved in performing an open carpal tunnel release (OCTR). Any such discussion must begin with a thorough understanding of the pertinent anatomy of the surgical area.

ANATOMY

The carpal tunnel is a well-defined, inelastic channel located in the volar wrist. It is oval in shape and extends from the distal volar wrist crease to the mid-palm, just proximal to the superficial palmar arch. The carpal tunnel is bordered ulnarly by the hook of the hamate, triquetrum, and pisiform, radially by the trapezium, scaphoid, and flexor carpi radialis retinaculum, dorsally by the concave arch of the carpal bones and metacarpal bases of the central rays, and anteriorly by the transverse carpal ligament (TCL). The TCL measures 1 to 3 mm in thickness throughout its length and is 3 to 4 cm wide. Nine extrinsic flexor tendons pass through the carpal tunnel (flexor digitorum profundus, flexor digitorum superficialis, and the flexor pollicis longus), along with the median nerve that typically lies volar and radial to the tendons. The palmar cutaneous branch of the median nerve (PCBMN) originates from the volar-radial portion of the median nerve approximately 5 cm proximal to the wrist crease. It travels with its parent nerve for a distance of 2 cm, before branching off in between the flexor carpi radialis and palmaris longus. One centimeter proximal to the wrist crease the PCBMN penetrates the antebrachial fascia into the subcutaneous layer to provide sensation to the proximal radial palmar skin. At the distal end of the carpal tunnel, the median nerve typically
divides into 6 branches: a motor nerve, three proper digital nerves, and two common digital nerves. The motor branch innervates the radial lumbricals and the thenar intrinsic musculature (the opponens pollicis, the abductor pollicis brevis, and superficial portion of the flexor pollicis brevis). The variation in the anatomic path of the motor branch of the median nerve is well documented. Most of the time (46–90%), the recurrent motor nerve is “extra-ligamentous” and branches off distal to the TCL. Less commonly, the motor nerve is “sub-ligamentous” and branches off beneath the TCL, travels in a distal direction, and then exits the carpal tunnel distal to the TCL. The least common, but most concerning, route for the motor branch to take has been dubbed “trans-ligamentous,” describing a motor branch which penetrates the TCL on its exit from the carpal tunnel. It is important to keep in mind that there are other, less common, branching variations of the recurrent motor nerve, such as coming off of the ulnar portion of the parent nerve or exiting “extra-ligamentously” but then, as it becomes recurrent, laying down on top of the TCL before it travels radially into the thenar muscles. Another less common variation of median nerve anatomy at the wrist is that the main nerve trunk may be bifid, divided by an anomalous muscle or a persistent median artery. Sensory variations in median innervation are common, although typically it supplies sensation to the radial three and a half fingers, mostly on the volar surface of the hand. The presence of transverse communicating branches between the common digital nerves of the third and fourth web spaces may help explain the variability between individuals in their sensory innervation of the small, ring, and middle fingers.

Bordered on all sides by either bone or thick ligament, the carpal tunnel can truly be regarded as a closed compartment with a normal internal milieu and pressure. Any increase in the size of the structures within the carpal tunnel or decrease in the volume of the carpal tunnel may cause the internal pressure in this closed compartment to exceed the tolerance of the median nerve and lead to the symptoms of CTS. Although it is unclear whether these symptoms are the direct result of mechanical compression or relative ischemia of the median nerve, there is no doubt that resting carpal tunnel pressures are higher in patients with CTS (30 mm Hg) than without (2.5 mm to 10 mm Hg).

Before deciding on which type of treatment is most appropriate for a patient with hand pain and numbness, it is first important to make a correct diagnosis through a thorough history and physical examination.

### DIAGNOSIS

An essential part of making the diagnosis of CTS is taking a thorough history. Although one patient with CTS may complain of throbbing pain as the chief complaint, another may complain of nighttime tingling and no pain at all. Whereas no one sign or symptom is unto itself pathognomonic, the classic clinical presentation of CTS includes pain and paraesthesias in the median nerve sensory distribution of the hand, often worse at nighttime and exacerbated by activities which require a fixed position of the wrist. Patients may describe difficulty with opening jars, holding a phone or hairbrush, driving a car, or sleeping. Although sensory symptoms are most common, weakness may become more pronounced over time.

It is important to recall that numbness and tingling in the radial three fingers does not necessarily mean the patient has a median neuropathy at the wrist. Such symptoms can commonly result from cervical spondylosis, disc protrusion, or both. Therefore, evaluation of any patient with these symptoms must involve a complete examination of the cervical spine and upper extremity to rule-out a more proximal lesion (such as a C5-6 or C6-7 radiculopathy, brachial plexopathy of the upper trunk or lateral cord, or a pronator syndrome). Although sensory complaints are the hallmark of CTS, the incidence of abnormal findings on an objective sensory examination may be low. The sensory examination of the involved hand may include both threshold tests (monofilament or vibrometry) and innervation density tests (two-point discrimination), with the former being more consistent and reliable in diagnosing CTS than the latter. There are several specific provocative tests which have been well described to elicit the symptoms of CTS and suggest its diagnosis, including Tinel’s sign, Phalen’s sign, and the more recently described carpal tunnel compression test, or Durkan’s sign. A positive Tinel’s sign is defined by a reproduction of symptoms with tapping over the TCL and a positive Phalen’s sign is defined by a reproduction of symptoms with maximal flexion of the patient’s wrist for 60 seconds. A positive Durkan’s sign is reproduction of symptoms with direct pressure of the volar wrist. None of these provocative tests are requisites for making the diagnosis of CTS, as their sensitivities and specificities have varied widely in the literature. Abnormalities in the motor examination are rare and usually occur only after significant sensory loss. Weakness of the abductor pollicis brevis (APB) is the most sensitive motor sign for CTS. Thenar atrophy is a rare finding and may be present in severe, chronic cases of CTS.
Electrodiagnostic testing is commonly performed in the evaluation of CTS and includes both nerve conduction velocity (NCV) and electromyography (EMG). Normal NCV values vary, but are generally thought to be a distal motor latency of less than 4.5 msec and a distal sensory latency of less than 3.5 msec. EMG of the thenar intrinsic musculature can be used to evaluate the severity or chronicity of median nerve dysfunction. It is important to note that while electrodiagnostic testing represents an important diagnostic tool, negative results do not absolutely exclude the diagnosis of CTS.

NONOPERATIVE TREATMENT

Once the diagnosis is made, nonsurgical therapies are usually tried first in cases of mild and moderate CTS. Such measures are aimed at alleviating mechanical compression of the median nerve at the level of the wrist and treating any contributing underlying causes. Nighttime wrist splinting in the neutral position is the mainstay of conservative treatment as neutral positioning of the wrist has been shown to minimize intra-tunnel pressures. Oral medications, such as nonsteroidal anti-inflammatories (NSAIDs), diuretics, and vitamin B6 may play a role in the nonoperative management of CTS, although they have never been rigorously studied in the literature. Steroid medication is sometimes used in the treatment of CTS and has been shown to reduce hallmark symptoms versus placebo both when taken orally and when injected directly into the carpal tunnel, although their benefits appear more short-term than those of surgical TCL release. There are several other nonsurgical modalities proposed for treating mild CTS, such as ultrasound, iontophoresis, and various exercises (such as tendon and nerve gliding and even yoga).

OPEN CARPAL TUNNEL RELEASE

Surgical management of patients with CTS is indicated if symptoms persist despite nonoperative treatment. It may also be indicated in patients who present initially with advanced findings, such as constant finger numbness, thenar weakness or atrophy, or with electrodiagnostic evidence of thenar denervation. As demonstrated by the breadth of chapters in this publication, there have been several different approaches to decompressing the carpal tunnel over the years, from OCTR, to more limited-open approaches using commercially available products, to endoscopic techniques. Described by Sir James Learmonth in 1933, OCTR has become the gold standard surgical treatment for patients with CTS. It has produced uniformly excellent results with high patient satisfaction and a low complication rate. Some investigators, however, have suggested that OCTR is associated with a high enough incidence of postoperative palmar discomfort, scar tenderness, and weakness that endoscopic release should be considered as a viable alternative. No matter the operative method, transecting the TCL is the essential step in each of them to increase the volume and decrease the pressure around the median nerve in the carpal tunnel. Indeed, magnetic resonance images (MRI) studies have shown that transecting the TCL causes a 24% increase in the volume of the carpal tunnel, as it changes from an oval to more circular cross-section, and shifts the median nerve anteriorly by 3.5 mm. Although several different methods have been successfully used to achieve this end, transecting the TCL with a scalpel under direct visualization (OCTR) remains the mainstay of surgical management.

TECHNIQUE

OCTR affords the surgeon full inspection of the TCL, the possible presence of an “intra-ligamentous” motor nerve branch to the thenar muscles, and the contents of the carpal tunnel. The length of the incision that is made during an OCTR depends on both patient and surgeon factors. Traditionally, OCTR was done through a relatively large 4 to 5 cm longitudinal incision extending from Kaplan’s cardinal line distally to beyond the wrist crease proximally. Over time, this incision has been minimized in general, and most hand surgeons today perform primary OCTRs through a 2 to 4 cm incision, which ends approximately 2 cm distal to the wrist crease. Regardless of the length of incision, each OCTR should proceed through the same reproducible steps: 1) Set-up; 2) skin incision; 3) Palmar fascial incision; 4) TCL release; and 5) postoperative care. We shall discuss each of these in turn.

Set-Up

The patient is brought to the operating room and a tourniquet is placed on his or her forearm to minimize intra-operative bleeding. Anesthesia choice is surgeon dependent and local, regional, or general anesthesia may all be used. We prefer local analgesia with conscious sedation. After administration of conscious sedation (commonly a mixture of versed and propofol), we infiltrate the carpal tunnel and surrounding subcutaneous tissue with a mixture of 10 ml of bupivacaine and lidocaine.
Skin Incision

After washing and draping the extremity, a longitudinal incision placed along the axis of the radial border of the ring finger, approximately 2 mm ulnar to the thenar crease, is generally regarded as the safest location for an OCTR incision. Most hand surgeons avoid transverse palmar incisions because of inadequate exposure and potential injury to the palmar cutaneous nerve branch of the median nerve. The standard longitudinal incision begins distally at Kaplan’s cardinal line (which is a line drawn obliquely from the apex of the inter-digital fold between the thumb and index finger distally, toward the ulnar side of the palm parallel to the proximal palmar crease, and passing 4–5 mm distal to the pisiform) and is extended 2 to 4 cm proximally toward the wrist crease (Fig. 1). Extending the incision proximal to the wrist crease is generally not required in a primary OCTR.

When planning this incision, care should be taken to stay radial to the hook of the hamate. This may help avoid the occurrence of palmar scar over the hamate hook, as well as minimize injury to the ulnar neurovascular bundle. Making sure that the incision does not project significantly more radially than the inter-thenar depression is important in avoiding injury to the palmar cutaneous branch of the median nerve (PCBMN). However, ulnar cutaneous nerves reside in this very region and it is important to recognize, particularly in dealing with post-operative cases of peri-incisional “pillar” pain, that there is no true inter-nervous sensory plane in the palm. It is important to note that if the PCBMN is cut during the procedure, it is preferable to dissect it proximally and section it at its origin from the median nerve rather than to repair it; as repair usually results in a bothersome neuroma.

Palmar Fascial Incision

After the skin is incised longitudinally, two retractors are placed perpendicular to the incision, exposing a layer of subcutaneous fat. A ragnell retractor is then placed parallel to the incision at its proximal margin and sweeps this layer of fat proximally, exposing the longitudinally oriented fibers of the palmar fascia. Under direct visualization, a scalpel is used to incise in the midline of the palmar fascia fibers. It is important to incise the palmar fascia the full length of the skin incision so as to maximize visualization of the deeper structures. After picking up each edge of the incised palmar fascia with forceps, the 2 retractors are then placed deep to the fascial edges and, by retracting perpendicular to the incision, the transverse fibers of the TCL are revealed. It is important to note that this approach is in close proximity to the ulnar tunnel at the wrist (Guyon’s canal) and, with more superficial dissection ulnar to the hamate, the ulnar nerve may be decompressed if its release is indicated.

TCL Release

With the longitudinal fibers of the palmar fascia being pulled perpendicular to the incision, the transverse fibers of the TCL should be clearly visualized. If these fibers are obscured in any way, better visualization must be obtained before moving on to transecting the ligament. Using a sponge to clean off any fascial remnants from these fibers can be helpful. Sometimes a palmaris brevis muscle belly may be present at this level, lying between the palmar fascia and the TCL. It is helpful to note that whenever a palmaris brevis is encountered, the TCL is found deep to it and can be exposed by sharply elevating the palmaris brevis muscle fibers off of the TCL, often in...
a radial-ward direction. Directly visualizing the TCL must be achieved before transecting it during an OCTR, so as not to injure an “intra-ligamentous” motor branch of the median nerve. Once visualized, the TCL is divided longitudinally along its ulnar aspect from distal to proximal. A ragnell retractor is placed proximally and then distally at the apices of the incision to facilitate exposure of the proximal and distal margins of the TCL as it is being transected (Fig. 2). Staying near the TCL’s ulnar attachment keeps the plane of ligament transection, except for anomalous cases, safely away from the recurrent motor branch of the median nerve. Although the ulnar neurovascular bundle typically resides ulnar to the hamate hook in Guyon’s canal, the surgeon must be aware that it can be located radial to the hook in some instances. The distal end of the TCL is marked by the bed of adipose tissue surrounding the superficial palmar arterial arch. Proximally, the TCL is incised under direct visualization to the level of its confluence with the antebrachial fascia at the wrist crease. If the antebrachial fascia appears to be particularly thickened, which may be the case in patients with connective tissue disease, it may be helpful to release this tissue. Minimizing superficial proximal dissection may decrease postoperative forearm pain.

After complete release of the TCL, attention is next turned to the course of the motor branch of the median nerve. If a trans-ligamentous route is observed, care should be taken to completely free this branch through further dissection of the ligament. Once the TCL is sectioned, and the motor branch identified, the contents of the carpal tunnel are grossly inspected. The median nerve is typically located volar and radial to the nine extrinsic flexor tendons within the canal and its appearance should be noted by the surgeon. Although there are frequently cases in which the nerve appears quite normal, other times it can have a bluish-red discoloration proximal to the area of compression and/or an edematous “hour-glass” morphology, representing a neuroma-in-continuity. Adjunctive procedures to structures within the carpal tunnel, such as internal median neurolysis or flexor tenosynovectomy, are rarely indicated. Although initially favored by some surgeons to address intra-neural fibrosis in cases of severe CTS, performing a routine median neurolysis or epineuromyotomy during OCTR has repeatedly been shown to offer no advantage over control groups. Similarly, routine flexor tenosynovectomy during OCTR is not advised, as it has been shown to offer no benefit compared with transecting the TCL alone in treating idiopathic CTS. However, there may be a role for tenosynovectomy in patients with concomitant connective tissue disease and accompanying flexor tenosynovitis.

After the TCL is transected along its ulnar border and the median nerve completely decompressed from the distal forearm fascia to the superficial palmar arch, the wound is irrigated and hemostasis achieved. Our incisions are closed with interrupted mattress sutures (4-0 or 5-0 nonabsorbable material) and covered with a soft dressing and compressive wrap, with careful attention paid to not restrict any digital movement (Fig. 3).

**Postoperative Care**

Immediately after the surgery the patient is encouraged to move his or her fingers freely. Light hand use and active digital motion is encouraged during the next 7 to 10 days, until the patient returns to the office for a wound check and suture removal. In our experience, resumption of full activities of daily living and return to work usually occurs within 2 to 6 weeks. Formal rehabilitation programs are not usually necessary. Although there is no evidence to support the use of postoperative splints, some surgeons use them transiently to prevent concomitant wrist and finger flexion that could theoretically sublux the flexor tendons out of the canal. Patients experiencing postoperative “pillar” pain have significantly more difficulty returning to work than the majority of patients after OCTR. “Pillar” pain is best defined as pain in the thenar or hypothenar areas and may be due to a variety of factors: scar sensitivity, neuromas of cutaneous nerve endings, changes in carpal arch dynamics or thenar and hypothenar muscle origins, and/or decreased median nerve gliding. Such patients may benefit from receiving hand therapy (for tendon and nerve gliding) and therapeutic modalities to try to decrease peri-incisional inflammation.

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ALTERNATIVE OPEN TECHNIQUES

While most authors suggest transecting the TCL along its ulnar portion, a radial incision has also been described and deserves mention. Weber and Sanders describe an incision made over the flexor carpi radialis tendon, proximal to the wrist crease. The tendon is then used as a guide to follow distally and dissect the TCL off of its radial insertion. Although not a mainstream approach, this method may be associated with less “pillar” pain than more traditional incisions and may have a role in patients who have CTS and a concomitant distal radius fracture undergoing open reduction and internal fixation via a volar approach.

Another alternative technique for OCTR actually involves preserving the TCL, which has been suggested to maximize postoperative grip strength. By performing a step-cut lengthening of the ligament or reconstructing it with a transposition flap or with palmar fascia, the TCL can be maintained and its theoretically important flexor tendon pulley function preserved. In this way, some authors have suggested that preserving the TCL in a lengthened capacity alleviates CTS symptoms while maximizing postoperative grip strength.

OUTCOMES AND COMPLICATIONS

OCTR has been the mainstay of surgical treatment for CTS over the past several decades and has been shown to produce reliable alleviation of patient symptoms (ranging from 81–98%) with minimal complications. However, there is a group of patients in which there is no period at all after surgery that there is an improvement in preoperative symptoms. Although this may be due to a variety of reasons, it classically suggests the possibility of an incomplete release of the TCL. Incomplete release is associated with because of inadequate visualization and has been suggested to occur more frequently with both transverse and so-called “mini” incisions. Several authors cite the distal retinaculum as the most common site of incomplete release in open surgery. A second reason patients may have a persistence of symptoms after surgery is that they did not actually have CTS in the first place, but rather a more proximal nerve lesion as might be the case with a cervical radiculopathy, brachial plexopathy, or a pronator syndrome. Thirdly, a median neuropathy at the wrist may have in fact been present and fully decompressed, but an occult proximal lesion could explain persistent symptoms by producing a “double crush” phenomenon. Fourth, symptoms may persist when there is an intrinsic neuropathy present, as in advanced cases of CTS with preoperative evidence of thenar denervation or in patients with systemic polyneuropathy, such as patients with diabetes. Fifthly, persistent symptoms may be because of untreated space-occupying lesions in the carpal tunnel, such as a ganglion, other tumor, displaced lunate, inflamed flexor tenosynovium, or a gouty tophus. In these rare circumstances, releasing the TCL is helpful, but may not be sufficient to fully decompress the median nerve. Finally, because of anatomic variation, perineural scar, or surgical error, the median nerve may be iatrogenically injured during the operation, leading to continued symptoms despite surgical release. Although OCTR is a safe, theoretically simple procedure, its potential complications are indeed well documented.

In their review of questionnaires sent to members of the American Society for Surgery of the Hand, Palmer et al. gathered data regarding major complications, after

FIG. 3. After the incision is closed, the hand is covered with a soft dressing and compressive wrap, with careful attention paid to not restrict any digital movement.
both endoscopic and open CTR, that had been surgically treated by hand surgeons over a 5-year period.\textsuperscript{54} Although Palmer et al. acknowledge the inherent limitations of a retrospective voluntary study, the data are nonetheless provocative and underscore the fact that this surgery is not without substantial potential risk. There were 283 major complications after OCTR treated by 616 respondents. These complications included 147 median nerve lacerations (23 complete), 29 ulnar nerve lacerations (11 complete), 54 digital nerve lacerations, 34 vessel lacerations (21 superficial palmar arch), and 19 tendon lacerations (13 complete). The incidence of infection after OCTR is generally thought to be less than 1%, with \textit{Staphylococcus} and \textit{Streptococcus} the most common affecting organisms. Most infections are cellulitic in nature and can be treated with oral or parenteral antibiotics, although sometimes incision and drainage can be necessary. Postoperative skin and palmar fascia necrosis is an uncommon, but reported, complication of OCTR and, as with any case of necrotizing fasciitis, should be managed surgically and aggressively.\textsuperscript{25}

It is important to note that, even if the OCTR procedure is performed technically perfectly and even if all preoperative symptoms are relieved, there is a significant group of patients who have postoperative complaints, because of lingering discomfort at the base of the palm in the thenar or hypothenar area (so-called “pillar pain”), scar tenderness, or weakness.\textsuperscript{14,33,34,63} The etiology of postoperative “pillar pain” remains controversial. If its cause is because of alterations in the carpal arch or in the origin of the hypothenar and thenar musculature that occur after transection of the TCL, one would expect “pillar pain” in both endoscopic and open surgery, regardless of the size of the incision.\textsuperscript{28,67} An alternate theory is that violating the palmar skin, cutaneous nerves, and underlying palmar fascia is responsible for this phenomenon; a theory advocated by proponents of endoscopic and mini-open techniques.\textsuperscript{42} Despite its prevalence, postoperative “pillar pain” remains a perplexing problem that has no reliable treatment other than the tincture of time. Povlsen et al. have indeed shown that pain over the thenar and hypothenar eminences improves with time, with 41\% of the patients they reviewed experiencing such pain one month postoperatively, but only 6\% had this pain 1 year after surgery.\textsuperscript{58} Partly because of dissatisfaction with the relatively high incidence of postoperative “pillar pain” and scar tenderness in their patients, many surgeons embraced endoscopy as an attractive alternative to OCTR when instrumentation became commercially available in 1990.\textsuperscript{2,3,10,11,46,50,53,59,61} This technique will be discussed at length elsewhere in this publication.

**CONCLUSION**

Open release of the TCL has been the mainstay of surgical treatment for CTS for the past several decades, producing reliable symptom relief in the vast majority of patients. The nerve is directly visualized so chance of injury should be rare. It is important to note that, even with the most diligent surgical technique, transient postoperative “pillar pain,” scar tenderness, or weakness commonly occur. Using this technique, patients can reliably have good relief of their carpal tunnel symptoms and most return to the majority of activities in about 6 weeks.

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