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REVIEW ARTICLE

Ultrasound-guided interventions in primary carpal tunnel syndrome: perineural injection to thread carpal tunnel release

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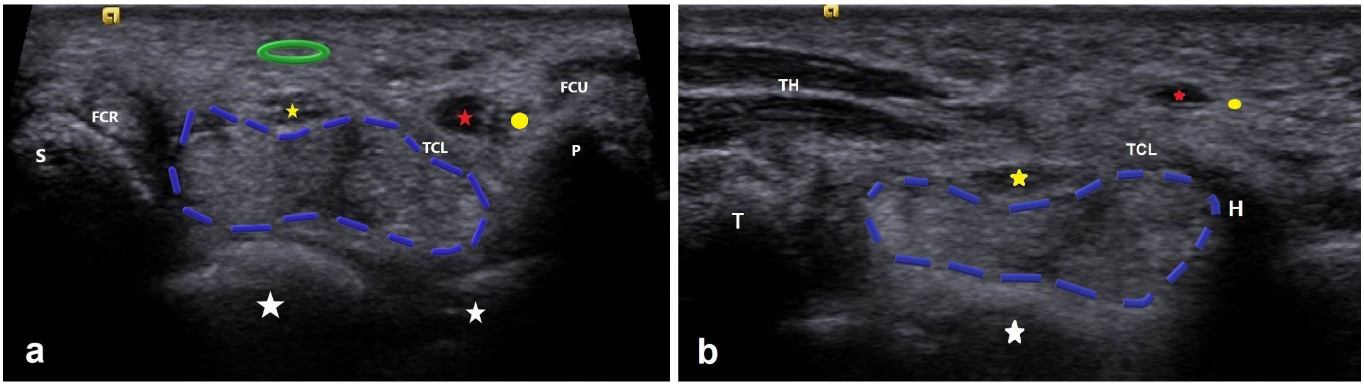
ABSTRACT:

Carpal tunnel syndrome (CTS), the most common entrapment neuropathy, is compression of the median nerve deep to transverse carpal ligament at wrist. Ultrasonography and electrophysiological study are complementary in the diagnosis and grading of CTS in appropriate clinical settings. The initial management of patients with CTS is conservative with medical therapy and splinting. However, surgical interventions are indicated in patients in whom medical management has failed. With evolution of the concept of safe zone on ultrasonography and identification of the sonoanatomical landmarks of carpal tunnel in greater detail, Ultrasonography-guided interventions are safer and preferred over surgical management in CTS. The primary ultrasonography-guided interventions include perineural injection, perineural hydrodissection and ultrasonography-guided release of transverse carpal ligament. This review article presents the principles of ultrasonography-guided perineural injection, perineural hydrodissection in CTS, the merits and demerits of injectant used in perineural injection/ hydrodissection, and percutaneous ultrasonography-guided thread release of transverse carpal ligament utilizing the concept of safe zone of the ultrasonography-guided interventions for CTS.

INTRODUCTION

Carpal tunnel syndrome (CTS), the most common form of entrapment neuropathy, refers to a clinical syndrome resulting from compression of the median nerve within carpal tunnel.[1] The carpal tunnel is located at the base of palm, distal to the distal skin crease at wrist joint. It is bounded dorsally by carpal bones and on the palmar aspect by transverse carpal ligament (TCL), creating a fibro-osseous tunnel through which median nerve and finger flexor tendons passes from forearm to hand.[1,2] Clinical findings and electrophysiological study (EPS) are commonly used for the diagnosis of CTS. However, the diagnostic accuracy of ultrasonography closely correlates with EPS in the diagnosis of CTS.[3,4] The assessment of median nerve dimension, its anatomical variants, TCL, status of flexor tendons within the carpal tunnel, joint spaces within the carpal tunnel, and dynamic assessment by ultrasonography help us to understand the cause–effect relationship in CTS. Thus, ultrasonography has become the mainstay diagnostic modality for the diagnosis and grading of clinically suspected CTS, and also to decide its management protocol.[5] The management protocol of CTS includes initial conservative means with the use of the medicines and splinting. In failed conservative cases with persistent meralgia, and/or motor weakness, surgical management is indicated. Ultrasonography-guided interventions offer a viable, and minimally invasive alternative to the surgical management with merits of no scar of the surgery, safer procedure with direct visualization of the key anatomical structures and anatomical variants within the carpal tunnel and completion of the procedure in out-patient department. These advantages lead to a better cosmetic result with no significant postintervention sequelae and rapid resumption of the daily activities.[6,7] The interventional management of the CTS extends from ultrasonography-guided perineural injection and hydrodissection through the safe zone; taking advantage of pharmaceutical effect of injectant

Figure 1. (a, b) Transverse ultrasonography images of the carpal tunnel at proximal (a) and distal (b) carpal rows. TCL forms the roof of carpal tunnel extending between scaphoid (s) and pisiform (p) at proximal level and between trapezium (t) and hook of hamate (h) at distal level. The carpal bones (white asterisk) form the floor of carpal tunnel. The major content of carpal tunnel is flexor tendons and its synovial sheaths (area under dashed blue lines). Median nerve (yellow asterisk) is superficial in location within carpal tunnel. FCR and FCU tendons are outside the carpal tunnel at corners attached to scaphoid (s) and pisiform (p) respectively. At proximal level, the ulnar nerve (yellow dot) and ulnar artery (red asterisk) lies radial to pisiform within guyon's canal, while at distal level ulnar nerve (yellow dot) and artery (red asterisk) are volar to the hook of hamate. The thin tendon of palmaris longus (green circle) passes outside the carpal tunnel at the level of median nerve. THs covers the radial corner of distal carpal tunnel. FCR, flexor carpi radialis; FCU, Flexor carpi ulnaris; TCL, transverse carpal ligament; TH, thenar muscle.



and mechanical separation of median nerve from the TCL; to ultrasonography-guided release of the TCL by the thread.

SONO-ANATOMICAL LANDMARKS IN RELATION TO INTERVENTIONS IN CARPAL TUNNEL

The carpal tunnel is a tightly packed fibro-osseous tunnel on the volar aspect of wrist through which nine flexor tendons along with their synovial sheaths (two digital flexor tendons for each of the medial four fingers, and one flexor pollicis longus tendon for the thumb) and the most superficial median nerve traverses. The broad transverse carpal ligament (3–4 cm wide) is attached to scaphoid and pisiform bones in proximal carpal row, and to trapezium and hook of hamate bones in the distal carpal row. Ulnar nerve, ulnar artery and veins pass outside the carpal tunnel through Guyon's canal. At proximal carpal row, the ulnar artery lies on the radial aspect of pisiform, while at distal carpal row, the ulnar artery is on the volar aspect of hook of hamate. Palmaris longus tendon, flexor carpi radialis and flexor carpi ulnaris tendons are outside the carpal tunnel on palmar, radial and ulnar aspects respectively (Figure 1).[1,2] The anatomical variants that need consideration in lieu of CTS are persistent median artery and reverse palmaris longus tendon. Persistent median artery, an anatomical variant is a branch of ulnar artery and accompanies median nerve which may be bifid (Figure 2). The bifid medial nerve, and thrombosis of persistent median artery are predisposing factors for CTS.[8,9] Out of the many variations in palmaris longus, two of the variation require attention that predispose to CTS. In some patients, palmaris longus tendon may pass through the carpal tunnel and in few of the patients there is reversal of the palmaris longus with proximal position of the tendon at elbow and the muscle belly is in distal position at wrist (Figure 3). In patients with reversed palmaris longus, the muscle may pass through the carpal tunnel and may be a causative factor in the development of CTS.[2,10]

Safe zone of carpal tunnel is anatomical the segment that is relatively devoid of major neurovascular bundles (ulnar nerve, ulnar artery, superficial palmar arch) suitable for safe ultrasonography-guided interventions. The transverse safe zone is defined as the space between the ulnar border of median nerve and the radial border of ulnar artery. The longitudinal safe zone is defined as the space between the distal extent of transverse carpal ligament and superficial palmar arch. The ultrasonography-guided interventions for CTS can safely be performed by following the needle trajectory through these safe zones.[11,12]

ULTRASONOGRAPHY DIAGNOSTIC CRITERIA AND GRADING OF CTS

Traditionally, the diagnosis of carpal tunnel syndrome is established by the history, clinical symptoms, and physical examination. These include history of symptoms (*i.e.* pain, numbness, tingling, burning in hand in the distribution of median nerve),

Figure 2. Transverse Doppler ultrasonography image of the wrist in a patient presented with carpal tunnel syndrome demonstrate persistent median artery showing color flow on doppler passing midway between two halves of bifid median nerve (yellow asterisk).

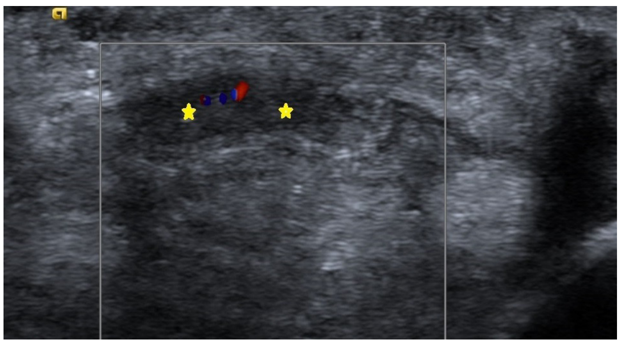
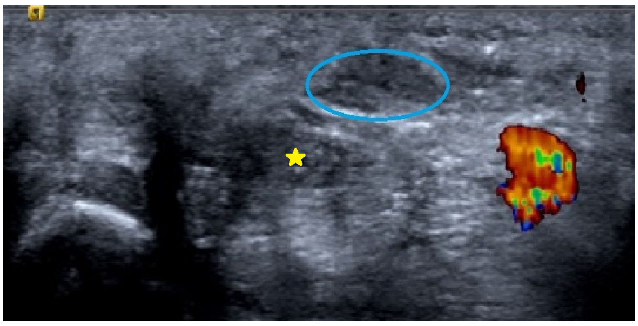


Figure 3. Transverse Doppler ultrasonography image of wrist in a patient presented with carpal tunnel syndrome demonstrate reverse palmaris longus, muscular component at proximal carpal level (blue circle), outside the carpal tunnel. Doppler color flow seen in ulnar vessels. Yellow asterisk: Median nerve.



provocative factors (sleep, repetitive movement of the wrist), mitigating factors (shaking the hands, changes in hand posture), and clinical findings (provocative tests, sensory abnormality in median nerve distribution, weakness or atrophy in the thenar region of the hand).[1,13] However, there can be significant overlap between the characteristic patients of CTS with other neurological disorders, thus, diagnostic tests of ultrasonography and EPS are imperative.[13,14]

EPS are useful for the definition of site and quantitative assessment of nerve physiology (*i.e.* conduction slowing) along the course of a nerve which helps in differentiation of a localized problem such as CTS, from generalized peripheral neuropathies, or nerve entrapment at another site (*i.e.* at the elbow). However, there is variable accuracy of EPS to differentiate between primary and secondary CTS.[3,4]

The potential of ultrasonography for qualitative and quantitative assessment of median nerve at carpal tunnel, to rule out secondary compression of median nerve due to flexor tenosynovitis or carpal joint pathologies, and to demonstrate the predisposing anatomical variants makes it suitable investigation modality for the evaluation of patients with suspected CTS.[1,5]

At the site of maximum compression of median nerve, it gets flattened and proximal to this region the nerve become swollen because of vasocongestion with increase in endoneurial fluid and localized edema.[15] Therefore, cross-sectional area (CSA) of the median nerve at carpal tunnel inlet, is the most commonly applied criterion for diagnosing CTS on ultrasound. The cross-sectional area of the median nerve at the inlet of carpal tunnel more than 15 mm^2 is considered diagnostic for CTS. If CSA of the median nerve is between 10 and 14 mm^2 at the level of inlet of the carpal tunnel, then additional criteria of CSA at the level of pronator quadratus in distal forearm is measured. If the difference between CSA of the median nerve at pronator quadratus and inlet of carpal tunnel is more than 2 mm^2, then it is considered diagnostic of CTS. In patients with bifid median nerve a difference of 4 mm^2 is considered significant.[16,17]

Evidence from the literature have shown that ultrasonography directly correlates with EPS and even allows to estimate the severity of CTS.[3,4,18] El Miedany et al recommended cut-off points of median nerve CSA to discriminate between different grades of CTS severity and its correlation with EPS (Table 1).[4] This was also supported by Karadag et al who found high concordance of ultrasonography with EPS defining CTS severity.[18]

The five-step approach for sonographic evaluation of the median nerve in CTS include:

(1) To recognize the anatomical variants: bifid median nerve, persistent median artery and reverse palmaris longus around the wrist joint.
(2) To rule out the secondary causes of CTS: flexor tenosynovitis, carpal arthropathy, any space occupying lesion in carpal tunnel.
(3) To characterize the morphological alteration of the median nerve secondary to compression within the carpal tunnel: CSA at carpal tunnel inlet, hourglass shape of median nerve in longitudinal view and hypoechogenic nerve.
(4) To grade the severity of CTS based on CSA of the median nerve at carpal tunnel inlet.
(5) To discuss the management protocol with physician to correlate ultrasonography-grading of CTS with clinical symptoms.

ULTRASONOGRAPHY-GUIDED INTERVENTIONAL MANAGEMENT OF CTS

Uultrasonography-guided intervention is indicated in patients having failed conservative management. There is a consensus among the experts from different medical specialities that instructions (advice to limit full extension/flexion of the wrist, reduce heavy work activities, and avoid repetitive movements) should always be combined with any form of treatment for CTS which includes perineural interventions and release of TCL. Therapeutic preferences for patients with CTS symptoms depend on the severity and duration of symptoms, and grade of CTS

Table 1. Grading of carpal tunnel syndrome: based ultrasonography and electrophysiological study[4]

Grade of CTS	Ultrasonography (CSA of median nerve)	Electrophysiological study
Mild CTS	10–13 mm^2	Abnormal SNCV, Normal DML
Moderate CTS	13–15 mm^2	Abnormal SNCV, Abnormal DML
Severe CTS	> 15 mm^2	Absent SNCV, Abnormal DML

CSA, cross-sectional area; CTS, carpal tunnel syndrome; DML, distal motor latency; SNCV, sensory nerve conduction velocity.

based on CSA of the median nerve measured by ultrasonography at carpal tunnel inlet.[19]

(1) The primary indication for perineural intervention (injection/hydrodissection) of the median nerve is mild to moderate CTS with mean nerve diameter 10–14 mm^2 and reduced sensation in distribution of the affected nerve but no motor weakness.
(2) The main indication for carpal tunnel release is severe CTS (CSA >15 mm^2) with absent sensation or motor weakness/ thenar muscle atrophy.

Ultrasonography-guided perineural injection in CTS

As compared to the landmark based blind injections, ultrasonography-guided perineural injections are more accurate, effective and is associated with less iatrogenic injuries.[20]

Injectant for perineural injection in CTS

The aim of perineural injection is to obtain a combination of anti-inflammatory effect on perineural and neurogenic edema (pharmaceutical effect) with adhesiolysis of the median nerve from underlying subsynovial tissue and overlying TCL (mechanical hydrodissection effect). The most commonly used injectant solution for perineural injection includes corticosteroid diluted with local anaesthetic agent (2 ml of triamcinolone acetonide/ methyl prednisolone and 2 ml of 1% lidocaine).[21,22] Corticosteroid is a potent anti-inflammatory agent. It reduces perineural inflammation, nerve edema and causes suppression of nociceptive discharge of nerve.[21] However, being a low volume injection, perineural steroid has more of pharmaceutical effect than mechanical dissection between nerve and TCL. Side-effects include local depigmentation, thenar muscle atrophy. Rarely, neurotoxicity resulting from intraneural injection may occur which has been linked to the preservative methylparaben.[23] The therapeutic effect of corticosteroid persists for 4–6 months. However, in 20–34% of cases, the effect extends beyond 9–12 month, that is attributed to spontaneous resolution of CTS.[21,22,24] Due to short-term effect of perineural steroid injection, some patients cannot avoid surgery or may require multiple injections.[25,26]

First described by John Lyftogt in 2007 to treat neuropathic pain by injecting 5% dextrose.[27] Perineural injection of 10 ml of 5% dextrose for treatment of CTS is supported by many literatures.[28–31] 5% dextrose is isotonic to normal saline, thus non-irritant to the nerve. 5% dextrose reduces neurogenic inflammation via inhibition of capsaicin-sensitive receptors (*e.g.* transient receptor potential vanilloid receptor-1) to stop the secretion of both substance-P and calcitonin gene-related peptide, which are known to induce pain and swelling of the nerve and/or surrounding tissue (pharmaceutical effect). High volume of the injectant also acts as an efficient media for nerve hydrodissection (mechanical effect) between median nerve and TCL.[28,31] Evidence from the literatures have shown that the therapeutic effect of perineural 5% dextrose persist longer than perineural corticosteroid.[29,30]

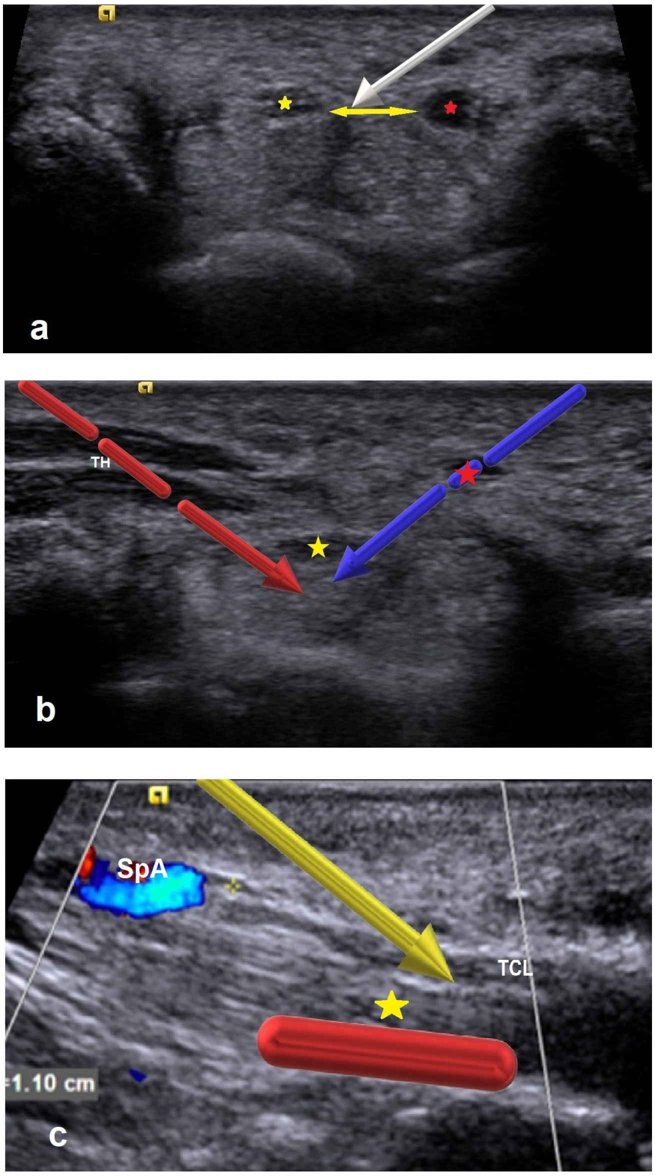
Approach for perineural injection in CTS

(1) **Transverse ulnar approach at proximal carpal row:** The needle is introduced in-plane along ulnar to radial direction at the level of proximal carpal row, superficial to Guyon's canal, to puncture TCL so that the needle tip can be advanced to perineural plane of the median nerve. This approach is easier to learn, allows better visualization of carpal tunnel content, and enables accurate perineural injection by avoiding neurovascular structures, therefore, is the preferred technique. This approach follows the trajectory along safe transverse zone and both deep and superficial surface of medial nerve can be targeted with precision.[11,12,32] At distal carpal row, ulnar artery is on the volar aspect of hook of hamate, that may be injured along the trajectory of needle (Figure 4a and b).[11,32]
(2) **Transverse radial approach:** The needle is introduced in-plane along radial to ulnar direction, then proceeds above the flexor carpi radialis tendon, and punctures the TCL so that the needle tip can be advanced adjacent to the median nerve. This approach may cause injury to thenar muscle, so considered least preferred technique (Figure 4b).[11,32]
(3) **Longitudinal approach:** In the longitudinal approach, the transducer is positioned parallel to the median nerve at distal wrist so that the median nerve is seen beneath TCL from the carpal tunnel inlet to the carpal tunnel outlet. This approach follows the trajectory along safe longitudinal zone concept (Figure 4c).[11,33] However, it is difficult to reach beneath the median nerve through this approach.
(4) **Combined transverse ulnar and longitudinal proximal to distal approach:** The carpal tunnel at distal carpal row is narrower than proximal carpal row. Perineural injection of low volume of steroid injectant (4 ml) through transverse ulnar approach at proximal carpal row, sometimes fails to hydrodissect the perineural segment of the narrower distal carpal row. Thus, a combined perineural hydrodissection using high volume (10 ml) 5% dextrose injection utilizing the merits of both transverse ulnar approach and longitudinal approach is advocated.[24,28,31]

Basic principles and procedure of perineural injection in CTS

(1) Targeting the median nerve in short axis at the level of proximal carpal row from ulnar-side and respecting the principle of transverse safe zone. The TSZ is the avascular zone between the ulnar margin of median nerve and radial margin of ulnar neurovascular bundle (Figure 4a).[11,12]
(2) In patients of CTS, the width of transverse safe zone is reduced as compared to healthy subject. Thus, to avoid injury to the ulnar neurovascular bundle, the width of transverse safe zone is increased by injection of 2–3 ml 1% lidocaine in the plane superficial to TCL (Figure 5).[11]
(3) Targeting the needle position in adventitial gliding layer which is extrinsic to epineurium: Injection into this adventitial layer is desirable and confirmed at ultrasonography by circumneural spread of the injectant.[5]
(4) The injection is first performed in posterior perineural space with bevel of the needle facing upwards followed by the injection in anterior perineural space with bevel of the needle facing downwards. The position of bevel during perineural injection/hydrodissection keeps needle tip away from nerve, thus avoid iatrogenic nerve injury, and propels the injectant around the nerve (Figure 6).[5]

Figure 4. (a,b,c) Transverse ultrasonography images of the carpal tunnel at proximal level (a), distal level (b), and longitudinal doppler ultrasonography image of distal carpal tunnel and palm (c). At proximal level (a), transverse safe zone for needle trajectory to carpal tunnel (solid white arrow) is the space (double headed yellow arrow) between ulnar artery (red asterisk) and median nerve (yellow asterisk). At distal level (b), needle trajectory into carpal tunnel from ulnar side (solid blue arrow) can cause ulnar artery (red asterisk) injury, while needle trajectory into carpal tunnel from radial side (solid red arrow) passes through thenar muscle (TH). Longitudinal safe zone for needle trajectory (solid yellow arrow) to carpal tunnel is the space between SpA arch and TCL as demonstrated in fig."c". Note is made that in distal longitudinal view (c), needle trajectory beneath median nerve (solid red band) may pass through median nerve (yellow asterisk) and can cause its injury. SpA, superficial palmar; TCL, transverse carpal ligament.



(5) Longitudinal injection targeting the anterior perineural space of median nerve in long axis on the volar aspect of wrist from distal to proximal approach along longitudinal safe zone.[11,12] The needle is placed in potential space between the superficial surface of median nerve and TCL (Figure 7).

(6) Avoiding inadvertent intraneuronal injection by initial use of low volume injection at a lower pressure: On real time sonography, intraneural injection shows nerve expansion with fascicular separation or change in echotexture which requires immediate repositioning of the needle before administering any further injectant.[5]

Uultrasonography-guided thread carpal tunnel release (TCTR) in CTS

Ultrasonography allows the evaluation of carpal tunnel anatomy with a wide and flexible field of view at higher resolution. This has led to the use of ultrasonography-guided percutaneous release of transverse carpal ligament with the help of different cutting devices and thread.[34]

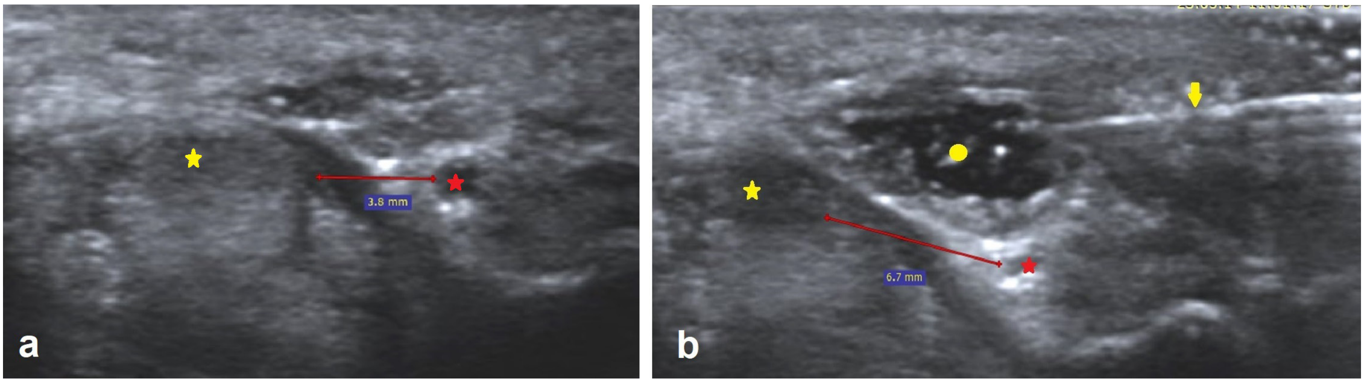
Ultrasonography-guidance allows safe and effective thread carpal tunnel release (TCTR) with only two needle punctures, no incision and therefore early recovery with better strength during the immediate post-operative period. High resolution ultrasonography also allows real-time visualization of the median nerve and its variant anatomy, contents of the carpal tunnel and overlying TCL, minimizing the risk of associated nerve injury. Ultrasonography-guided thread release is performed under local anesthesia with minimal wound problems and cosmetic advantages and thus has better patient acceptability.[35]

The different dividing elements used for ultrasonography-guided release of TCL includes hook knife, angle knife, saw blade, miniscalpal needle (MSN), MANOS, and transverse carpal ligament transection device.[34,36,37]

The ultrasonography-guided MSN release has also been combined with steroid injection, having better therapeutic efficacy as compared to steroid injection alone. The local release of carpal tunnel may lead to better diffusion and absorption of the steroid injected afterwards.[36] Percutaneous ultrasonography-guided MANOS (MANOS CTR™, San Francisco, CA) technique of carpal tunnel release has been successfully performed by surgeons having experience in open CTR and certified in the use of the MANOS device.[37] The major limitation of the percutaneous release with these blades and devices is that they require repetitive cutting motions to divide the TCL, which increases the risk of iatrogenic injuries or incomplete release, especially for patients with a narrow gap between the median nerve and the ulnar artery.[38] However, in transverse carpal ligament transection device, inflation of balloon prior to activation of cutting knife increase the size of transverse safe zone, hence, reduced chances of iatrogenic injury of nerve, or artery.[34]

Thread release of TCL is performed by percutaneous looping of the ligament by medical grade commercial suture under

Figure 5. (a, b) Transverse ultrasonography images of the carpal tunnel at proximal level demonstrate the increase in length of transverse safe zone (thin red line) after injection of 1% lidocaine (yellow dot) in fascial plane superficial to guyon's canal for safe passage of needle to carpal tunnel. (Yellow asterisk: median nerve, red asterisk: ulnar artery, yellow arrow: needle.)



Ultrasonography-guidance.[38,39] Smartwire-01 having thin titanium nitride coating layer has been also used for TCTR. The advantages of Smartwire-01 over commercial medical grade suture are higher visibility on ultrasonography, endurance of higher maximum load due to reinforced loop tensile strength, and adequate elasticity for TCTR.[40]

Major advantages of using thread over cutting devices include placing the loop of thread through the smallest needle punctures at entry and exit points, routing the flexible thread in the form of a loop around TCL allowing precise control of the transaction, and thus, avoiding transaction of the non-targeted tissue lying outside the thread loop.[34,35,38] The return to daily life activities after TCTR is five times faster than open carpal tunnel release and 1.5 times faster than reported for TCL release using a cutting device.[35,39]

Indications

(1) Patients with severe CTS who are not responding to conservative management, or perineural injection.[34,35,38]
(2) CTS patients with thenar muscle atrophy and/or weakness.[34,38,40]

Pre-procedure ultrasonography

(1) To reassess the diagnosis of primary CTS and its severity grading. There must be a consensus with physician regarding correlation between ultrasonography grading of CTS and clinical symptomatology.
(2) To confirm the anatomical eligibility for the procedure. Ulnar path of the recurrent motor or palmar cutaneous branch of median nerve, and longitudinal safe zone of less than 2 mm or transverse safe zone of 0 mm are contraindications for the procedure.[34]
(3) To identify the relevant anatomical landmarks pertaining to intervention: median nerve, flexor tendons, proximal and distal margins of TCL, bony landmarks of pisiform, tubercle of scaphoid, hook of hamate, trapezium, and superficial palmar arterial arch. The third and fourth common digital nerves, Berrettini branch, if exists is also identified.

Defining proximal and distal points of TCTR: sonoanatomy and surface marking

In ultrasonography of proximal palm longitudinal view, the convergence of the distal segment of the TCL and the Superficial Palmar Aponeurosis is shaped like a duck's beak (Figure 8). The duck's beak is considered as distal point of TCTR.[35] The proximal point of TCTR is approximately two cm proximal to distal wrist crease, medial to palmaris longus tendon.[35,40]

The pre-procedural surface marking of distal and proximal points of TCTR can also be done to ensure the correct entry and

Figure 6. (a, b) Transverse ultrasonography images of the carpal tunnel at proximal level demonstrate posterior perineural injection with bevel up needle position (a) and anterior perineural injection with bevel down needle position (b). (Yellow asterisk: median nerve, yellow arrow: needle).

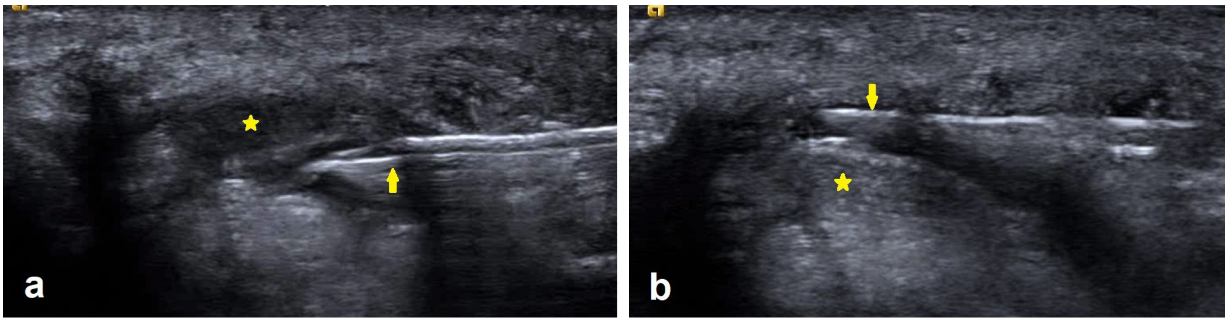
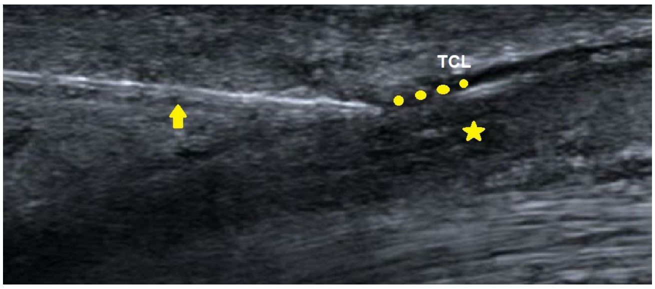


Figure 7. Longitudinal ultrasonography image of the carpal tunnel at distal level demonstrate needle trajectory (yellow arrow) through longitudinal safe zone into the potential space (yellow dots) between TCL and median nerve (yellow asterisk). TCL, transverse carpal ligament.



exit points of needle during TCTR. The crossing point of a line drawn along the centre of middle finger and another horizontal line drawn from the apex of interdigital fold between the thumb and index finger, corresponds sonographically as tip of DB/distal limit of TCL/distal point of TCTR. The proximal point of TCTR is 2 cm proximal to the distal wrist crease, which could be visualized by opposition of the thumb and little finger with slight wrist flexion. The line joinning the distal and proximal release points guides the correct plane of needle during ultrasonography-guided TCTR (Figure 9).[35,39,40]

Approaches of TCTR

(1) Wrist entry-palm exit.
(2) Palm entry-wrist exit.

The authors in the present study used the "Palm entry-wrist exit" approach with needle entry at DB location of palm and exit from the wrist 2 cm proximal to the distal wrist crease, medial to palmaris longus tendon. The major advantage of using this approach over the "Wrist entry-palm exit" approach is the ease of control of curved needle near the entry site which harbours the vital SpA than the exit site and excluding superficial palmar aponeurosis from cutting loop.[41]

Figure 8. Longitudinal ultrasonography image of the carpal tunnel at distal level demonstrate convergence of superficial palmar aponeurosis (dashed yellow line) and transverse carpal ligament (dashed red lines) appear like DB. Deep palmar aponeurosis (dashed blue lines) also converge to distal end of transverse carpal ligament at DB. Superficial palmar arch (red circle) lies in the FP between superficial and deep palmar aponeurosis. DB, duck's beak; FP, fat pad; FT, Flexor tendons.

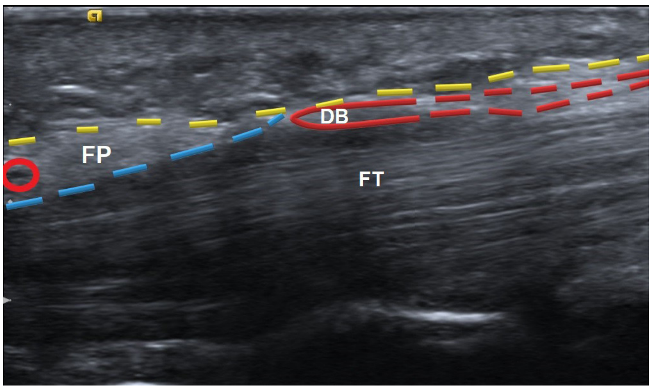
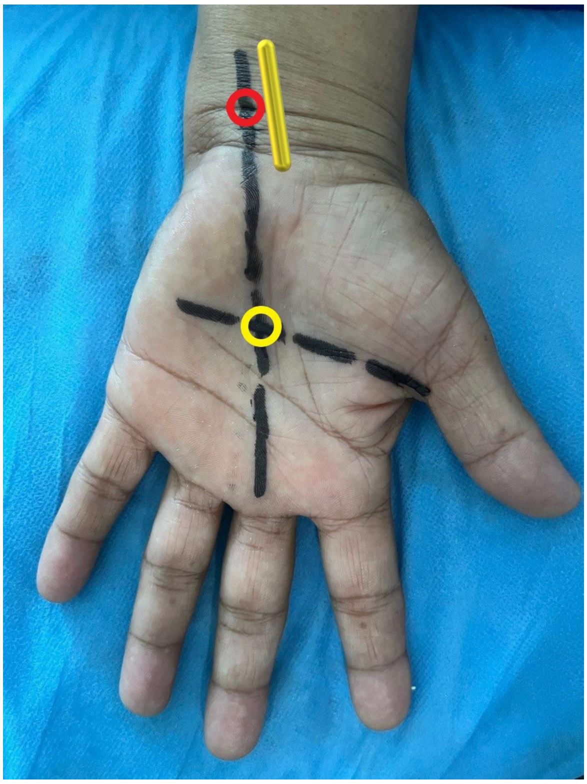


Figure 9. Photograph demonstrating surface marking for proximal and distal points of TCTR. The distal point (yellow circle) of TCTR is the crossing of the line drawn along the centre of middle finger and another line drawn from the apex of the interdigital fold between the thumb and index finger. The proximal point of TCTR (red circle) is approximately 2 cm. proximal to the distal wrist crease, medial to palmaris longus tendon (solid yellow line). TCTR, thread carpal tunnel release.

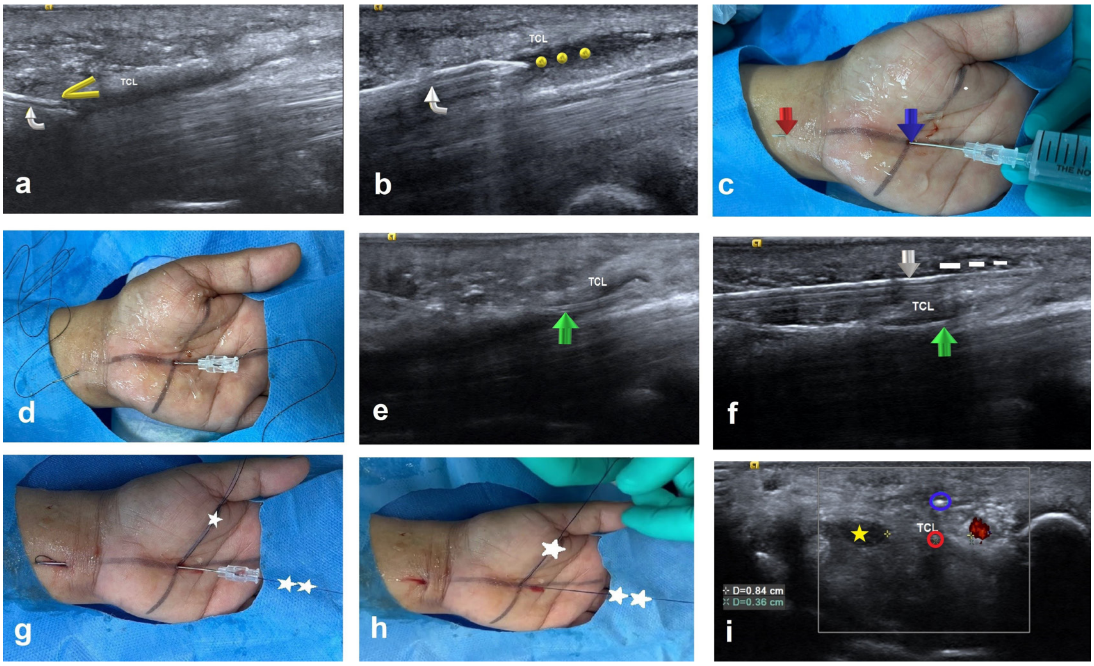


Basic principle and procedure of TCTR

The important steps of release of TCL include looping of the thread through TCL and precise transection of TCL by the thread.[34,38,40,41]

(1) Preparation of the sterile surgical field, covering ultrasonography probe with sterile cover and supporting the affected wrist over a thin pillow.
(2) Two spinal needle (One curved and another straight) technique: Anterior 1/3rd of one spinal needle (18G) is bent to achieve smooth curvature. The other needle is to be kept straight. The curved needle is used to pass beneath TCL, while the straight needle (18G) is used to pass superficial to TCL.
(3) Entry at palm technique: The aforementioned entry point in palm is punctured by the curved needle to reach at the tip of sonographic Duck's beak (Figure 10a).
(4) Hydrodissection of TCL: The curved needle is passed beneath TCL by hydrodissecting the plane between TCL and Flexor digitorum tendon. Hydrodissection is achieved by use of 1% lidocaine solution (Figure 10b).

Figure 10. (a–i) Ultrasonography images at carpal tunnel (a, b, e, f: longitudinal; i: transverse) and photographs (c, d, g, h) demonstrate sequential steps of Palm entry-wrist exit approach of TCTR. a, curved needle trajectory (bent white arrow) along longitudinal safe zone, targeted at Duck's Beak (yellow pointed curved line). Duck's beak is the distal limit of TCL. (b) Hydrodissection (yellow dots) of the plane beneath TCL by curved needle (bent white arrow). (c) Curved needle entry at palm (blue arrow) and exit at wrist (red arrow). (d) Suture was threaded through the needle. (e) After removal of needle, demonstration of suture (green arrow) beneath TCL. (f) Straight needle (white arrow) trajectory superficial to TCL and deep to superficial palmar aponeurosis (dashed white line). Suture (green arrow) is demonstrated deep to TCL. (g) Threading of proximal free end of suture through the straight needle from tip to hub. (h) Loop of suture around TCL. (h) (Single asterisk: Free end of the suture deep to TCL, double asterisks: Free end of the suture superficial to TCL). (i) Position of superficial and deep suture in relation to TCL, median nerve and ulnar artery. TCL, transverse carpal ligament.

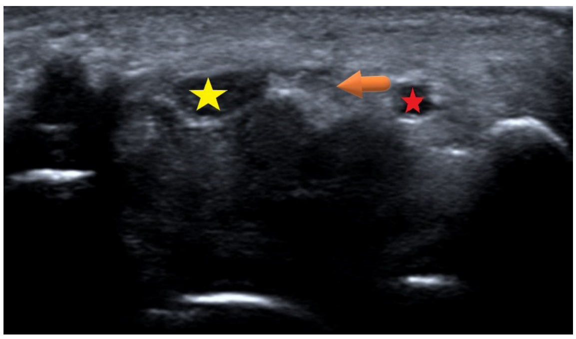


(5) Exit point at wrist: The curved needle is taken out of skin at aforementioned exit point (medial to palmaris longus tendon, 2 cm proximal to distal wrist crease) (Figure 10c).
(6) Threading through curved spinal needle: A medical grade suture is threaded through the spinal needle leaving sufficient length of suture at both entry and exit points (Figure 10d). The spinal needle is then taken out, leaving the suture beneath the TCL (Figure 10e).
(7) Rerouting the straight needle through the same entry and exit points, but, superficial to TCL and hydrodissecting TCL from overlying fascial layer (Figure 10f)
(8) The free proximal end of the thread is passed through needle from tip to hub, and straight spinal needle is taken out. Thus, forming a loop around the TCL (Figure 10g and h).
(9) Confirmation of the desired location of the thread: Evaluation under ultrasonography by gently moving the thread and seeing its relationship with median nerve, ulnar artery and superficial palmar arch (Figure 10i)
(10) Manual release of TCL by alternate pulling of both ends of the thread.
(11) Confirmation of complete release of TCL under ultrasonography (Figure 11).

Outcome of TCTR

Evidence of prior studies have demonstrated the improved clinical outcome of TCTR as compared to open carpal tunnel release and endoscopic carpal tunnel release in terms of symptom relief and functional improvement.[35,38–40] For most patients, the numbness and tingling get relieved in 3–5 h post-procedure and able to use their hands for simple daily activities on the day of procedure. Some may require analgesia on the first night. Most patients become eligible to return to work next day after the procedure.[41] For quantitative assessment, patient-related outcome measures such as the visual analog score, and BCTQ

Figure 11. Transverse ultrasonography images of the carpal tunnel at proximal level demonstrate post TCTR discontinuity in TCL (orange arrow). Yellow asterisk: median nerve, red asterisk: ulnar artery. TCTR, thread carpal tunnel release; TCL, transverse carpal ligament.



(Boston carpal tunnel questionnaire) is commonly used to monitor post-operative recovery and to detect early symptomatic and functional improvement. Significant BCTQ symptom severity improvement is observed in 1 week after TCTR, and BCTQ scores for function become significantly lower in 1–3 weeks. Motor recovery of the thenar muscle, pinch and grip strength are observed after 6 weeks post- TCTR.[39]

Complications of TCTR and measures to minimize

TCTR has potentially a lower risk of neurovascular injury compared to open and endoscopic release due to real-time visualization.[35,38,40,41] However, injury to palmar cutaneous branch of median nerve, third and fourth common digital nerves, Berrettini branch has been reported. The injury can be avoided by pre-procedural ultrasonography to specifically look for ulnar path of palmar cutaneous branch of median nerve and Berrettini branch, if exists.[39] Some patients develop pillar-pain in the thenar and/or hypothenar eminence between 2 and 6 weeks that is worse with pressure or grasping. The cause of pillar pain is unknown but may be due to post-operative swelling or temporary instability of insertions of the thenar and hypothenar musculature on TCL. Nearly, all cases resolve spontaneously in 6–9 months. After TCTR, hypothenar pain that persist may localize to pisotriquetral joint. The pisiform is stabilized by TCL radially and may be destabilized after TCTR in certain patients with pre-existing chondromalacia or subluxation of pisotriquetral joint, causing pain. Patients will experience pain relief with intra-articular anesthetic injection.[42]

Hematoma is a rare complication that can be minimized by discontinuation of antiplatelet before TCTR. The coagulation profile must be normal before performing TCTR.[39] Diabetic patients are prone for post-intervention infection, that can be minimized by avoiding steroid use in TCTR and advise to keep the hands dry after TCTR. Any pre-existing infection must be ruled out by hemogram profile before performing TCTR. In case of oozing from the entry/exit wound, or erythema at post-intervention Day 3, antibiotic coverage is needed. If the oozing and/erythema persist at Day 7, open drainage may be required. Flexor tenosynovitis is a very rare complications of TCTR.[41]

CONCLUSION

Ultrasonography-guided perineural hydrodissection is a preferred treatment for patients with carpal tunnel syndrome where the conservative management has failed. Ultrasonography-guided release of the transverse carpal ligament is a safe, effective and a less invasive alternative to the open and endoscopic release of the TCR in patients with severe CTS or CTS with thenar muscles weakness/atrophy.

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COMPETING INTERESTS

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Nothing to disclose.

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