Safe Zones for Percutaneous Carpal Tunnel Release

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KEYWORDS

• Safe zone • Carpal tunnel release • Ultrasound • Percutaneous • Carpal tunnel syndrome

KEY POINTS

- Percutaneous carpal tunnel release is a trend that can be safely done under ultrasound guidance in strict accordance with the concepts of “safe zones.”
- Using static bony landmarks, the transverse safe zone refers to the area between the median nerve and the hamate hook, and the longitudinal safe zone starts from 5 mm distal to the metacarpal metadiaphyseal junction to the 5 mm proximal to the midlunate within the transverse safe zone.
- Sometimes, anatomic variations such as the ulnar neurovascular bundle radial to the hamate hook and anomalous collateral vessels exist within the defined safe zones.
- Using the hydrodissection technique, the safety of the safe zones possible may be regained in cases with anatomic variations.

INTRODUCTION

Carpal tunnel syndrome (CTS) is one of the most common nerve entrapment syndromes.[1] Surgical carpal tunnel release (CTR) is recommended after failed conservative treatments. Open CTR is an effective technique using either a limited or a mini-incision.[2] The smaller incision has shown earlier functional recovery.[2,3] However, there is a concern that the procedure will be undergone blindly using a mini-approach. Endoscopic CTR (ECTR) provides clinical superiority to open CTR but invites a significant risk of nerve neuropraxia[4,5] that might be related to median nerve irritation or increased carpal tunnel pressure during blind insertion of the trocar.[5,6] In efforts to use real-time, continuous monitoring throughout the minimally invasive procedure, an ultrasound-guided CTR (UCTR) technique was developed. Different approaches and techniques proposed by several teams have reported clinically effective and safe outcomes.[3,7–19]

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Even though CTR is an effective procedure in open, endoscopic, or ultrasound-guided methods,[4,15] complications are present and potentially devasting. Most complications come from intraoperative technique errors,[20] especially in UCTR and ECTR approaches. UCTR requires substantial surgical experience and familiarity with the ultrasound-guided injection technique. Ultrasound provides real-time, dynamic monitoring,[21,22] but the view is still limited and interfered with by metal surgical instruments. Understanding the "safe zones" is essential to performing percutaneous CTR safely. This article provides a review of the anatomy of the safe zone and the UCTR techniques that can be used to prevent intraoperative complications.

SAFE ZONES IN ULTRASOUND-GUIDED CARPAL TUNNEL RELEASE

Related Anatomy

The carpal tunnel is defined by the carpal bone dorsally and the transverse carpal ligament (TCL) volarly. TCL is started proximally from the scaphoid to the pisiform and distally from the trapezium to the hamate hook.[23] The structures within the carpal tunnel are composed of both superficial and deep flexor tendons, the flexor pollicis longus tendon, and a median nerve that is the most volar structure (**Fig. 1**A, C). Around the carpal tunnel, the median nerve gives off 2 branches, the palmar cutaneous branch (sensory branch) and the thenar motor branch, which have the potential to be injured during CTR.[20] Although there are no major vessels except an anomalous median artery traveling with the median nerve within the carpal tunnel,[20] the ulnar artery and nerve run closely to the TCL and should be handled with caution during surgical release. Furthermore, the superficial palmar arch (SPA), a transverse anastomosis between the ulnar and superficial radial arteries, lies approximately 5 mm distal to the distal edge of the TCL[24] (**Fig. 1**B, D). One must be careful not to injure the SPA during distal release in an antegrade fashion or during palmar entry using a retrograde release.

Transverse Safe Zone

To avoid the violation of branches of the median nerve around the carpal tunnel, which usually arise from the radial side of the median nerve, the area between the median nerve and ulnar neurovascular structure is regarded as a "safe zone" for surgical release because there are no major neurovascular structures within this area (see **Fig. 1**A). This concept was first proposed by Nakamichi and colleagues in 1997 and has been applied in ultrasound-assisted CTR for 50 hands in 50 patients without any complications.[7] However, the width of the safe zone proposed by Nakamichi and colleagues varied with the individual, where a safe zone that is too narrow (≤3 mm) compromises the safety of surgical release.[25] However, we proposed the concept of a "transverse safe zone" using the static bony landmark, the hamate hook, instead of the ulnar neurovascular bundle, which is relatively mobile (see **Fig. 1**C). We defined the distance between the hamate hook and median nerve as the transverse safe zone. In a cadaver study, the width of the transverse safe zone was 5 mm on average (ranging from 4 to 8 mm), thus allowing insertion of surgical instruments and supporting the possibility of UCTR.[26] Currently, both the distances from ulnar artery and the hamate hook to median nerve, representing the working space for release instruments and the space for instrument insertion, respectively, should be preoperatively examined to evaluate the transverse safe zone. In most patients, the ulnar artery is ulnar to the hamate hook, but it is sometimes above or radial to the hook of the hamate,[20] which narrows the transverse safe zone. In our practice, the hydrodissection technique discussed later in this work is the preferred technique to perform UTCR safely in patients with a narrow transverse safe zone.

Longitudinal Safe Zone

During UCRT, an in-plane ultrasound monitor is recommended during the surgical release. In either an antegrade or a retrograde fashion, the longitudinal ultrasound imaging within the transverse safe zone is the major guidance during the entire procedure. In this imaging, there should be no major neurovascular structures above or beneath the TCL (see **Fig. 1**B, D). Therefore, the longitudinal safe zone makes it possible to prevent injury to the SPA, usually more than 5 mm distal to distal edge of the TCL and makes it possible to avoid incomplete release of the TCL. Even though the TCL can be comprehensively identified using recently developed high-frequency linear transducers (>13 MHz),[15] the introduction of a metal surgical instrument interferes with vision below the instrument. Furthermore, in the UCTR developmental period, a high-frequency transducer with a power of more than 13 MHz was not available.[7,11,25–27] In our previous cadaver study, static bony landmarks that can be easily identified using common high-frequency transducers correspond well to the actual location of the TCL and the SPA. Under longitudinal US imaging, the proximal edge of the TCL is very close to the midpoint of the

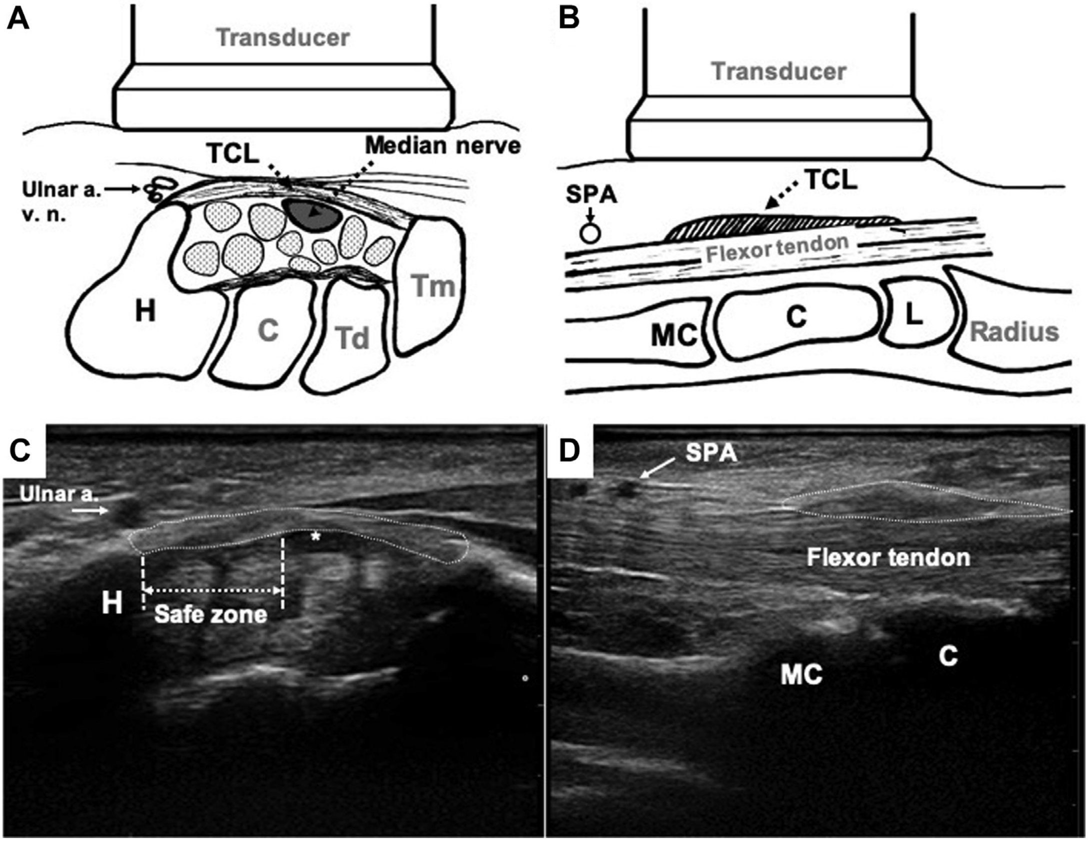

Fig. 1. Illustrations and ultrasound images of the transverse (*A*, *C*) and longitudinal (*B*, *D*) safe zones. The area circled by the broken line includes the TCL; *, the median nerve; a., artery; C, capitate; H, hamate; L, lunate; MC, metacarpal; n., nerve; Td, trapezoid; Tm, trapezium; SPA, superficial palmar artery; v., vein.

longitudinal axis of the lunate, and the distal edge of the TCL is very close to the metadiaphyseal junction of the metacarpal bone (see Fig. 1B). The differences between the bony landmarks under US imaging and the actual edge of the TCL are within 2 mm, which is virtually negligible in clinical practice.[26] The distance between the actual SPA to the actual distal edge of TCL is 11 mm (ranging from 6 to 16 mm),[26] following previous findings.[24] Therefore, we recommend that the CTR start from the metadiaphyseal junction of the metacarpal bone distally to the midpoint of the longitudinal axis of the lunate proximally[26] and should distally extend no further than 5 mm distal to the metacarpal metadiaphyseal junction.[11]

Other Considerations

Theoretically, surgical release can be performed safely after recognizing the transverse and longitudinal safe zones using ultrasound imaging. However, some anomalous anatomic variations exist in clinical practice. For example, there are sometimes visible collateral vessels above the TCL underneath the view of the longitudinal safe zone in patients receiving hemodialysis using the ipsilateral arteriovenous fistula. Previous traumatic or surgical insults may lead to similar anomalous collateral vessels. The hydrodissection technique can push the collateral vessels away from the defined longitudinal safe zone. If the safe zones cannot be guaranteed in either the transverse or the longitudinal view, we suggest that the UCTR should be converted to the open procedure. Another rare variation of the thenar motor branch of median nerve, type IC proposed by Lanz,[28] may challenge the concept of safe zones. However, up to the present time, there has been no such complication reported in the literature or in our practice using UCTR.

TECHNIQUES USED IN ULTRASOUND-GUIDED CARPAL TUNNEL RELEASE

Various UCTR techniques have been reported by several teams.[3,7–9,11–16,18,27] Here, we mainly describe our technique and briefly introduce other methods proposed by other teams. We usually perform UCTR in an operating theater for outpatients using only local anesthesia. We do not recommend the application of a tourniquet, which would mask the identification of safe zones.

Ultrasound Examination

In this example, high-frequency linear transducers were used (6–13 MHz; SonoSite, Bothell, WA, USA; or 4.2–13.0 MHz; GE Healthcare, Madison, WI, USA). The patient was prepared in the supine position with the affected hand and wrist sterilized and draped. The wrist was kept in an extended position at around 15° to 20° with padding (Fig. 2B). Other settings were the same as in our previous study.[11,12] After recognizing the median nerve, flexors tendons, TCL, ulnar artery, and targeted bony landmarks, including the hamate hook, the lunate, the third metacarpal, and the capitate, longitudinal imaging was initially conducted along the median nerve and centered at the capitate. Then, the transducer was moved parallel to the ulnar side until the hamate hook was visible. The space between the median nerve and the hamate hook was the defined “transverse safe zone”[11,12,26] (see Fig. 1A, C). In this step, confirming if the ulnar artery or any pulsatile anomalous vessels are present in this area is crucial. If the transverse safe zone was determined to be “safe” (no ulnar artery, other pulsatile vessels, or visible nerve branches), the transducer was turned into the longitudinal view and held directly next to the hamate hook and centered on the capitate. In this view, the targeted bony landmarks, including the midportion of lunate and the metacarpal metadiaphyseal junction, were confirmed to represent the proximal and distal edges of the TCL, the target for the release. This view was the defined “longitudinal safe zone”[11,12,26] (see Fig. 1B, D). It was also necessary to ensure that the SPA was not within the longitudinal safe zone.

Entry

After confirming the safe zones, the UCTR was done using an in-plane wrist crease entry. We prefer the following instruments in this order: 21- and

Fig. 2. Instruments used for ultrasound-guided carpal tunnel release in our practice: 5-mL syringe with 21-gauge needle, 18-gauge needle, and Ti-Chi hook knife set including a probe and a hook knife (*A*). Pictures taken during the clinical procedure (*B*) and postoperatively (*C*).

18-gauge needles, and Ti-Chi hook knife set (Aplus, Taipei, Taiwan) including a probe and a hook knife designed for UCTR (Fig. 2A, B). Palmar entry is another choice proposed by Nakamichi and colleagues[3,7] However, there are concerns related to the risk of damaging the SPA and sensitivity to a surgical scar on the palm as compared with one at the wrist crease.

Hydrodissection

The procedure began with infiltration using 1% lidocaine in a 5-mL syringe with a 21-gauge needle under the view of the longitudinal safe zone. With the exception of the entry, the infiltration, which usually requires 2 to 3 mL lidocaine, into the space between the TCL and the subcutaneous tissue is done from the entry to 5 mm distal to the metacarpal metadiaphyseal junction. When the local anesthetic fills and expands the targeted space, this is called hydrodissection (Fig. 3A, C). This procedure facilitated introducing the probe and the release instrument in the optimal position. When the ulnar artery or anomalous vessels were present within the transverse safe zone, this technique also provided a safe route for UCTR using a certain amount of lidocaine (usually an additional 2–3 mL) to push the pulsatile vessel(s) away from this area. In such a clinical scenario, the effect of hydrodissection only lasts a few minutes, and the subsequent procedures must be completed within this period. This technique is demanding and requires substantial training.

Carpal Tunnel Release

After an 18-gauge needle was used to dilate the entry, the custom-made probe followed the track created by the hydrodissection. The probe plays 2 roles during a UCTR conducted in this manner: (1) it facilitates and confirms that the track is smooth for the later releasing instrument used in the safe zones (Fig. 3B, D) and (2) confirms the release is complete at the end of the procedure (Fig. 4B, D, E, F). After reconfirming that no pulsatile vessels or median nerves were present along the created tract (also within the 2 safe zones), the hook knife was then introduced along the track superficial to the TCL to distally reach the level of

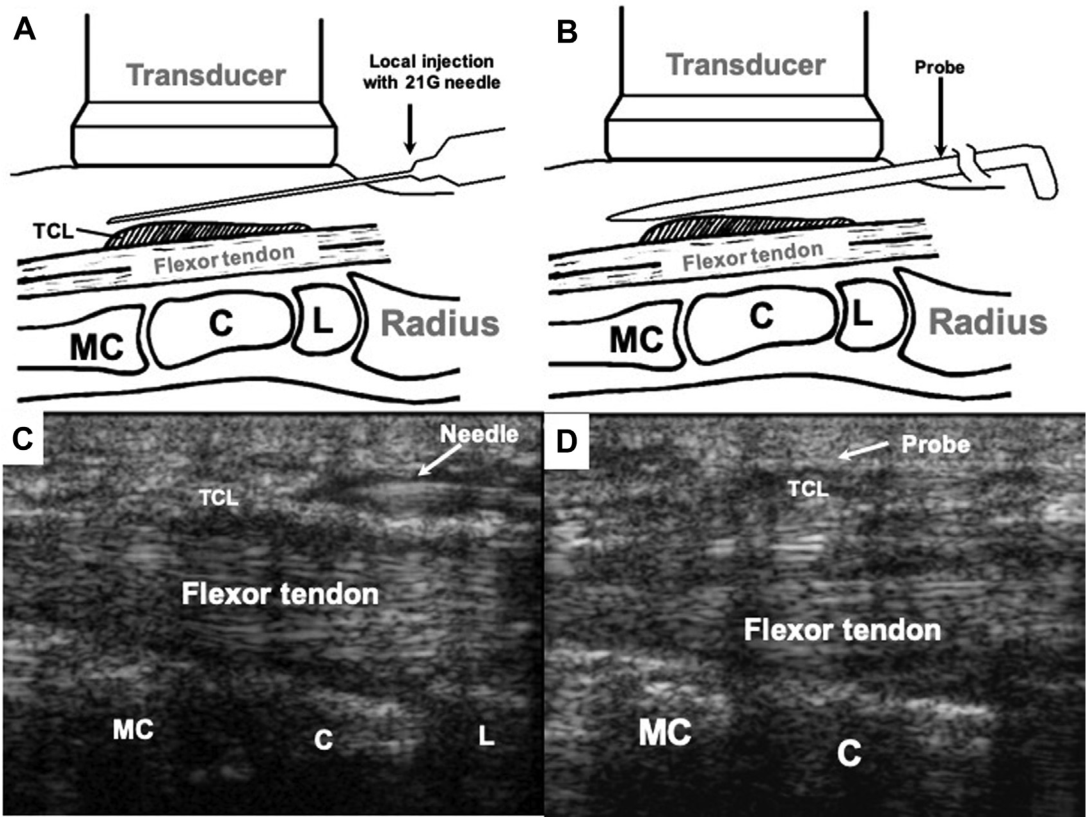

Fig. 3. Hydrodissection using 1% lidocaine was carried out along the space between the subcutaneous tissue and the TCL within the safe zones (*A*, *C*). The probe was introduced to confirm that the tract created by the hydrodissection was smooth for the hook knife following late (*B*, *D*). C, capitate; L, lunate; MC, metacarpal.

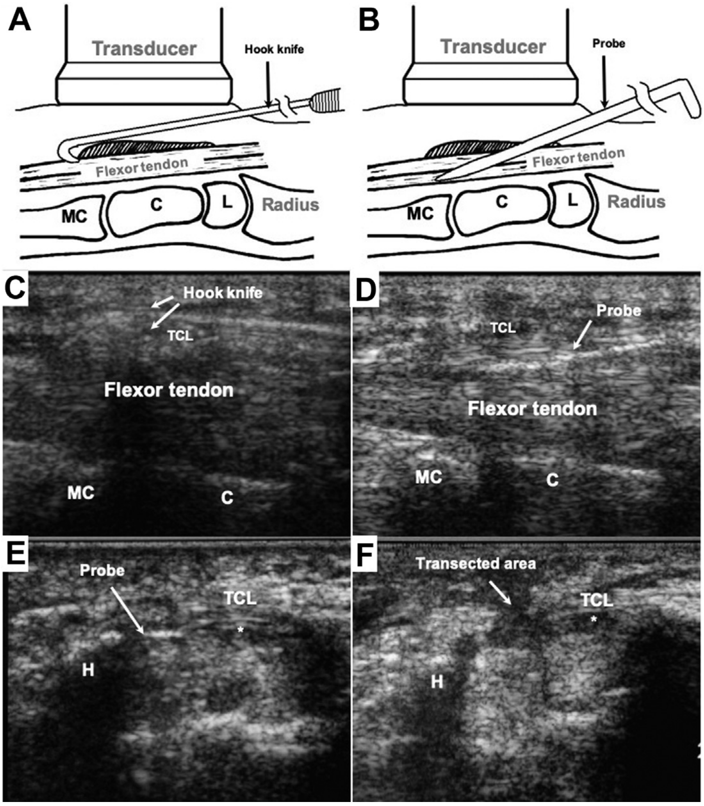

Fig. 4. The hook knife was advanced within the safe zones until it was 5 mm distal to the metacarpal metadiaphyseal junction, hooked onto the TCL, and withdrawn backward until it was 5 mm proximal to the midlunate (*A*, *C*). The probe was used to confirm adequate release, defined as unhindered movement of the probe from the subcutaneous space into the carpal tunnel (*B*, *D*, *E*). The transected area of the TCL was clearly visible in the transverse view (*F*). C, capitate; H, hamate; *, median nerve.

the metacarpal metadiaphyseal junction (Fig. 4A, C). In some cases, the junction between the distal edge of the TCL and the palmar fascia became thickened and required simultaneous release. However, the hook knife should not be advanced further than 5 mm distal to the metacarpal metadiaphyseal junction (within the longitudinal safe zone). Once the distal targeted area for release was reached, the hook knife was rotated downward to ensure that the blade was perpendicular to and hooked onto the TCL. CTR was carried out by pulling the knife retrogradely until the midlunate and extended proximally no further than 5 mm, if necessary.

Typically, the choices of the release instruments are subject to the surgeon's preferences and include hook knives with various designs,[3,10–12,16] the 18-gauge needle,[8] the scalpel blade,[14] the Gigli saw,[13] or specially-designed instruments, such as the basket punch,[7] the Kemis knife[15] and the Manos system.[9] When considering the SPA distal to the longitudinal safe zone and avoiding turning the knife around within the carpal tunnel, we prefer the retrograde release using a hook knife and the approach superficial to the TCL (outside the carpal tunnel).

Checking Release

The TCL is a very dense fibrous tissue that is remarkably resistant during probing and releasing. Therefore, adequate release was confirmed by the unhindered movement of the probe from the subcutaneous space into the carpal tunnel under the ultrasound imaging (see Fig. 4B, D, E). If there was any suspicion of incomplete release, the release procedure was repeated. All the aforementioned procedures were monitored and guided using real-time ultrasound observations.

Postoperative Care

After the operation, the entry wound (usually 1–2 mm) did not require suturing suture (Fig. 2C). It was covered with a dry dressing that could be removed the next day. Immobilization was unnecessary, and patients were encouraged to return to their normal life and work activity as tolerated.

CONTRAINDICATIONS

According to the literature, most authors excluded patients with previous surgeries on the affected hand in the clinical series. However, this does not mean a previous surgery should be a contraindication. Nakamichi and colleagues[7] proposed that once there is a hypertrophic flexor pollicis brevis or palmaris brevis extending into the safe zone in the ultrasound imaging, UCTR should not be performed. Kamel and colleagues[18] reported that when the distance from the median nerve to the ulnar artery is zero, or the distance between the distal edge of the TCL and the SPA is less than 2 mm, they exclude patients for UCTR. We agree that if there are visible neurovascular bundles in the previously defined transverse and longitudinal safe zones, UCTR cannot be performed safely. More specifically, we believe that the 2 zones are dynamic when using the hydrodissection technique. In idiopathic CTS, only an “unsafe” safe zone after hydrodissection is considered to be a contraindication for UCTR. In our early series, patients with recurrent CTS were excluded from UCRT.[11] With more experience, UCRT now is our first choice for idiopathic recurrent CTS due to advantages including minimal invasiveness and the fact that it is highly effective.

COMPLICATIONS

Even though anatomic variation exists, there have been no reports of neurovascular injury or wound complications during UCTR in the literature. In patients on hemodialysis who usually have anomalous collateral vessels in the upper extremities characterized by arteriovenous fistula, primary UCTR was done safely without any complications in 113 consecutive cases using our techniques.[17] In a 2-year follow-up of 641 hands in 376 patients, only 1 patient reported transient nerve palsy and recovered within 6 weeks.[19] Up to the present time, more than 4000 UCTR procedures have been performed by our team. There have been no permanent major neurovascular injuries reported in our records. However, we still emphasize that UCTR should not be done if the transverse and longitudinal safe zones cannot be guaranteed.

SUMMARY

In strict accordance with the concepts of safe zones, UCTR is an effective and reliable procedure for CTS. Substantial experience for ultrasound-guided injection and surgery is essential for safe UCTR.

CLINICS CARE POINTS

- As defined here, safe zone requires the route of release instruments to be away from vital structures including the median nerve and its branches, the ulnar artery, the superficial palmar artery, and other collateral vessels. A preoperative ultrasound examination is essential.
- Using the hydrodissection technique, the safe zones become “dynamic” via pushing undesired vital structures away from the safe zones.
- If the transverse and longitudinal safe zones cannot be guaranteed, the ultrasound-guided carpal tunnel release should not be done.

DISCLOSURE

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REFERENCES

1. Olney RK. Carpal tunnel syndrome: complex issues with a "simple" condition. Neurology 2001;56:1431–2.
2. Cellocco P, Rossi C, Bizzarri F, et al. Mini-open blind procedure versus limited open technique for carpal tunnel release: a 30-month follow-up study. J Hand Surg Am 2005;30:493–9.
3. Nakamichi K, Tachibana S, Yamamoto S, et al. Percutaneous carpal tunnel release compared with mini-open release using ultrasonographic guidance for both techniques. J Hand Surg Am 2010;35:437–45.
4. Sayegh ET, Strauch RJ. Open versus endoscopic carpal tunnel release: a meta-analysis of randomized controlled trials. Clin Orthop Relat Res 2015;473:1120–32.
5. Shin EK. Endoscopic versus open carpal tunnel release. Curr Rev Musculoskelet Med 2019;12:509–14.
6. Petrover D, Richette P. Treatment of carpal tunnel syndrome : from ultrasonography to ultrasound guided carpal tunnel release. Joint Bone Spine 2018;85:545–52.
7. Nakamichi K, Tachibana S. Ultrasonographically assisted carpal tunnel release. J Hand Surg Am 1997;22:853–62.
8. McShane JM, Slaff S, Gold JE, et al. Sonographically guided percutaneous needle release of the carpal tunnel for treatment of carpal tunnel syndrome: preliminary report. J Ultrasound Med 2012;31:1341–9.

9. Markison RE. Percutaneous ultrasound-guided MANOS carpal tunnel release technique. Hand (N Y) 2013;8:445–9.
10. Capa-Grasa A, Rojo-Manaute JM, Rodriguez FC, et al. Ultra minimally invasive sonographically guided carpal tunnel release: an external pilot study. Orthop Traumatol Surg Res 2014;100:287–92.
11. Chern TC, Wu KC, Huang LW, et al. A cadaveric and preliminary clinical study of ultrasonographically assisted percutaneous carpal tunnel release. Ultrasound Med Biol 2014;40:1819–26.
12. Chern TC, Kuo LC, Shao CJ, et al. Ultrasonographically guided percutaneous carpal tunnel release: early clinical experiences and outcomes. Arthroscopy 2015;31:2400–10.
13. Guo D, Tang Y, Ji Y, et al. A non-scalpel technique for minimally invasive surgery: percutaneously looped thread transection of the transverse carpal ligament. Hand (N Y) 2015;10:40–8.
14. Lecoq B, Hanouz N, Morello R, et al. Ultrasound-assisted surgical release of carpal tunnel syndrome: results of a pilot open-label uncontrolled trial conducted outside the operating theatre. Joint Bone Spine 2015;82:442–5.
15. Apard T, Candelier G. Surgical ultrasound-guided carpal tunnel release. Hand Surg Rehabil 2017;36:333–7.
16. Petrover D, Silvera J, De Baere T, et al. Percutaneous ultrasound-guided carpal tunnel release: study upon clinical efficacy and safety. Cardiovasc Intervent Radiol 2017;40:568–75.
17. Wang PH, Li CL, Shao CJ, et al. Ultrasound-guided percutaneous carpal tunnel release in patients on hemodialysis: early experiences and clinical outcomes. Ther Clin Risk Manag 2019;15:711–7.
18. Kamel SI, Freid B, Pomeranz C, et al. Minimally invasive ultrasound-guided carpal tunnel release improves long-term clinical outcomes in carpal tunnel syndrome. AJR Am J Roentgenol 2020;217(2):460–8.
19. Wang PH, Wu PT, Jou IM. Ultrasound-guided percutaneous carpal tunnel release: 2-year follow-up of 641 hands. J Hand Surg Eur 2021;46:305–7.
20. Karl JW, Gancarczyk SM, Strauch RJ. Complications of carpal tunnel release. Orthop Clin North Am 2016;47:425–33.
21. Wu PT, Lin CL, Tai TW, et al. Sonographically assisted percutaneous removal of screws in dynamization of the interlocking intramedullary nail. J Ultrasound Med 2013;32:319–24.
22. Wu PT, Lee JS, Wu KC, et al. Ultrasound-guided percutaneous radiofrequency lesioning when treating recalcitrant plantar fasciitis: clinical results. Ultraschall Med 2016;37:56–62.
23. Cobb TK, Dalley BK, Posteraro RH, et al. Anatomy of the flexor retinaculum. J Hand Surg Am 1993;18:91–9.
24. Rotman MB, Donovan JP. Practical anatomy of the carpal tunnel. Hand Clin 2002;18:219–30.
25. Nakamichi K, Tachibana S. Distance between the median nerve and ulnar neurovascular bundle: clinical significance with ultrasonographically assisted carpal tunnel release. J Hand Surg Am 1998;23:870–4.
26. Chern TC, Jou IM, Chen WC, et al. An ultrasonographic and anatomical study of carpal tunnel, with special emphasis on the safe zones in percutaneous release. J Hand Surg Eur 2009;34:66–71.
27. Rojo-Manaute JM, Capa-Grasa A, Rodriguez-Maruri GE, et al. Ultra-minimally invasive sonographically guided carpal tunnel release: anatomic study of a new technique. J Ultrasound Med 2013;32:131–42.
28. Lanz U. Anatomical variations of the median nerve in the carpal tunnel. J Hand Surg Am 1977;2(1):44–53.