



The safety and accuracy of various carpal tunnel injection techniques

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Abstract

Purpose Carpal tunnel (CT) syndrome continues to be a commonly treated hand pathology. We aimed to evaluate several CT injection techniques for (1) spatial accuracy within the CT and (2) risk of median nerve (MN) injury. Our purpose was to evaluate for any significant differences in accuracy of needle placement within the carpal tunnel and final distance between the needle tip and the MN with each technique.

Methods Fifteen fresh frozen cadaveric arms were used for this study. Six different injection techniques for CT injection were performed on each specimen, including palmaris longus, ulnar to flexor carpi radialis, trans-flexor carpi radialis, volar radial, volar ulnar, and direct through the palm techniques. After needle placement, a standard open CT release was performed to assess for accuracy of placement within the CT and measure needle position in relation to the MN and other anatomic structures.

Results Accurate intra-CT needle placement was seen in 91% of injections. While there was no significant difference between injection techniques for distance to nearest tendon ($p=0.1531$), the trans-flexor carpi radialis (tFCR), volar radial (VR), and volar ulnar (VU) techniques consistently provided the greatest intra-CT distance from needle tip to median nerve ($p=0.0019$). The least incidence of intraneural needle placement was found with the tFCR and VR approaches.

Conclusion All six injection techniques reliably enter the CT space. The lowest risk to the MN was found with tFCR and VR techniques, and we recommend these techniques for safe and effective needle placement to avoid iatrogenic intraneural injection.

Level of evidence Level V: Cadaveric Study.

Keywords Carpal tunnel syndrome · Corticosteroid injection · Median nerve

Introduction

Corticosteroid injections are widely used as a conservative treatment option for carpal tunnel syndrome (CTS) [1–5]. While there is dispute over the long-term benefits of corticosteroid injections for CTS, they remain an acceptable treatment option for patients who desire to delay surgical intervention and are looking for short term symptom relief. [6, 7] In addition, a favorable response to steroid injection has been shown to be predictive of surgical outcomes [1, 8]. One of the most devastating complications of CT injections is intraneural injury [3, 9–15]. Mackinnon et al. have highlighted the safety of multiple corticosteroids injections with respect to peri-neural injections. Dexamethasone has been found to be the least neurotoxic, though all steroids are neurotoxic when injected in an intra-fascicular fashion [16]. While several in-office techniques for CT injection have been described, the safest zone for injection placement remains

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controversial [3, 17–22]. Ultrasound-guided injections have been proposed; however, the use of sonography has not been shown to improve CT injection accuracy or patient outcomes [23, 24].

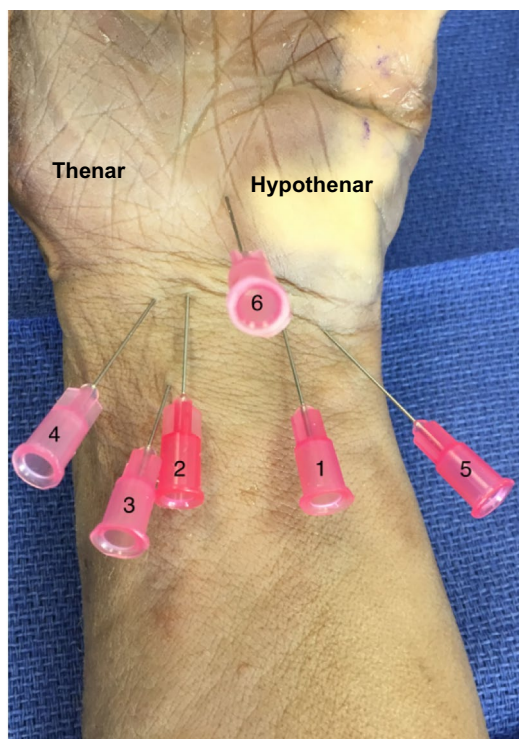
Our aim of this study was to evaluate six previously described CT injection techniques for any significant differences in accuracy within the CT as well as risk of injury to the MN in cadaveric specimens.

Methods

Approval was obtained from our Institutional Review Board to perform this de-identified cadaveric study. A power analysis was performed prior to cadaveric specimen collection to determine adequate sample size to detect a difference in needle placement between the six study groups. The study was powered to detect a meaningful difference of 20% between the groups. A total of 15 specimens achieved 82% power to reject the null hypothesis that no difference exists in the distance between the needle and median nerve with a significance of 0.05 (alpha), using a priori power analysis with a beta of 0.2 and an effect size of 0.4.

Fifteen fresh frozen cadaveric arms that had not undergone any previous dissections were used for this study. Only cadavers with a palmaris longus tendon were utilized. Six injection techniques for CT injection were performed on each specimen. These included the following techniques: palmaris longus (PL) technique—placed at the proximal wrist flexion crease just ulnar to palmaris longus tendon aimed distally 30 degrees from horizontal plane; ulnar to flexor carpi radialis (uFCR) technique—placed at the proximal wrist flexion crease just ulnar to FCR tendon aimed distally 30 degrees from the horizontal plane; trans-FCR (tFCR) technique—placed 1 cm proximal to the to the proximal wrist flexion crease and aimed distally at 45 degrees from horizontal through the FCR tendon; volar radial (VR) technique—placed at the proximal wrist flexion crease, 33% inset from volar radial side of wrist and aimed toward the CT, volar ulnar (VU) technique—placed at the proximal wrist flexion crease, 33% inset from volar ulnar side of wrist and aimed toward the CT; direct through the palm (DIR) technique—placed directly perpendicular through the palm in line with ring finger radial border (Fig. 1). To simulate an in-office CT injection, 23-gauge needles were utilized on all specimens. The depth of each injection relied on haptic feedback from penetration of the transverse carpal ligament. All injections were performed by a single orthopedic hand and upper extremity fellow.

Following needle placement, an extensile open CT release was performed to identify needle location and measure distances between each needle tip and other anatomic structures. Measurements were obtained using a small



1 = palmaris longus; 2 = ulnar to flexor carpi radialis; 3 = through the flexor carpi radialis; 4 = volar radial; 5 = volar ulnar; 6 = direct through the palm.

Fig. 1 Cadaveric specimen with inserted needles using the 6 investigated injection techniques for CT injections

mechanical caliper. All needles piercing a structure were recorded as having 0-mm separation from that structure. The primary outcome measure was the location accuracy of the needle tips within the CT. Secondary outcome measures included: intraneural MN needle placement and distance between each needle to the MN and from the nearest tendon. The CT injection techniques chosen for this study are based on the available literature supporting their use [3, 17–23]. The six injection techniques are outlined in Table 1 and Fig. 1. Extreme care was taken with each dissection to avoid displacement of the needle tip locations to ensure accurate measurements. We found that the surrounding soft tissue maintained each needle in a consistent position throughout dissection. In addition, the transverse carpal ligament was held in its original position with pick-ups, maintaining light tension during measurements to ensure the transverse carpal ligament was in its native location for accurate needle measurement.

All continuous data were tested for normal distribution by the Shapiro–Wilk *W* test. Because the data sets of two technique groups were found to be nonparametric, values are reported with the median and corresponding interquartile range (IQR). Measurement comparisons across all groups were made using the Kruskal–Wallis test by ranks (*H* test).

Table 1 Description of the six carpal tunnel injection techniques

Technique	Needle insertion landmark	Needle direction
1 (PL)	Proximal wrist flexion crease just ulnar to palmaris longus (PL) tendon	Distally at 30 degrees to horizontal plane
2 (uFCR)	Proximal wrist flexion crease just ulnar to flexor carpi radialis (uFCR) tendon	Distally at 30 degrees to horizontal plane
3 (tFCR)	1 cm proximal to proximal wrist flexion crease, through FCR tendon	Distally at 45 degrees to horizontal plane
4 (VR)	Proximal wrist flexion crease, 33% inset from volar radial side of wrist	Aimed towards CT
5 (VU)	Proximal wrist flexion crease, 33% inset from volar ulnar side of wrist	Aimed toward CT
6 (DIR)	Direct through the palm, in the incision approach area for open CT release, in line with ring finger radial border	Perpendicular to skin

Table 2 Summary of data collected from carpal tunnel injections using six techniques

Technique	% In CT	% In MN	Median distance to MN (mm)	Median distance to nearest tendon (mm)
1 (PL)	75	20	5	8
2 (uFCR)	87	13	7	8
3 (tFCR)	100	0	8	6
4 (VR)	93	0	8	4
5 (VU)	87	7	8	4
6 (DIR)	100	27	2	5

n = 15 arms

Avg average; CT carpal tunnel; DIR direct through the palm; MN median nerve. PL palmaris longus; tFCR trans-flexor carpi radialis; uFCR ulnar to flexor carpi radialis; VR volar radial; VU volar ulnar

Post hoc individual pair comparisons between technique groups were made using the Wilcoxon rank sum test, and the Hodges–Lehmann estimator was used to calculate the median difference, 95% confidence interval (CI), and *p* values. A *p* value < 0.05 was considered statistically significant.

Results

A summary of outcomes for each injection technique is reported in Table 2. In total, 82 of 90 injections (91%) were successfully placed in the CT. Accuracy was lowest with the PL technique and highest in the tFCR and DIR techniques. Ten of ninety injections (11%) were intraneural (Fig. 2). Intraneural injections were most commonly observed with the PL and DIR techniques, 20 and 27%, respectively. Figure 3 demonstrates the median and interquartile range of each injection technique with respect to distance from the MN. There was a significant difference in injection techniques with respect to distance to the MN (*p* = 0.002). Post hoc analysis identified that the tFCR, VR, and VU techniques were all found to have a greater distance to the MN than both the PL (*p* = 0.030) and DIR (*p* = 0.003) techniques.



Fig. 2 Dissected carpal tunnel with intraneural placement of a 23 gauge needle using technique 6 (DIR). MN median nerve

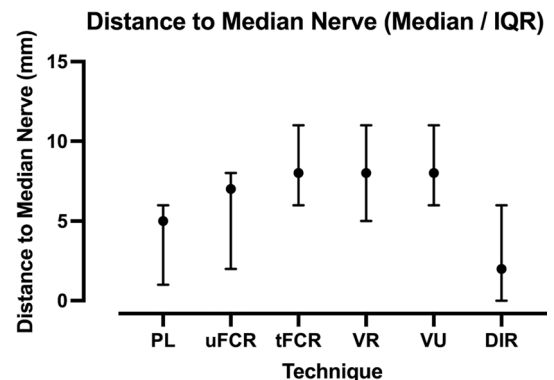


Fig. 3 Median and interquartile range of needle distance to median nerve (mm)

There was no significant difference in injection techniques with respect to distance to nearest tendon ($p=0.205$).

Discussion

Carpal tunnel injections are commonly performed in clinical hand surgery practice. Overall, these injections are safe with minimal risk of complications; however, devastating consequences can occur with intraneural median nerve injection, including persistent paresthesias, weakness, pain [9–12]. Numerous injection techniques have been described in the literature based on anatomical landmarks to maximize accuracy and minimize complications; however, the optimal technique remains unknown (Table 3).

Green et al. performed 756 simulated CT injections by 31 hand fellows immediately prior to open carpal tunnel release utilizing the PL technique. They reported 75.7% intra-carpal tunnel accuracy as well as an 8.7% rate of intraneural median nerve injection. [3, 25]. Their intra-CT accuracy mirrored our own results of 75%; however, we had a significantly higher rate of intraneural injection (20%) utilizing this technique. The accuracy of injections per fellow ranged from 53 to 100% with only 3 fellows correctly placed the needle 100% of the time, underscoring the variability in needle placement with this technique. Wood et al. noted that the CT was missed in 2 of 26 (8%) of cases when using the same PL technique [13]. In a cadaveric study, MacLennan et al. reported a rate of 27% intraneural injection rate using the same technique compared to a 7% intraneural injection rate using the uFCR technique. However, they found that the uFCR technique consistently put the palmar cutaneous branch of the MN at risk. [18] In our series, we did not have any instances of intraneural injection through the palmar cutaneous branch of the MN with the uFCR technique,

though anecdotally it was noted to be adjacent to the uFCR needle during dissection in several of the cadavers.

Dubert and Racasan reported that the MN extends ulnar to the PL tendon in 88% patients, thereby imparting risk of intraneural injection with the PL technique. Thus, they recommended a tFCR injection, but no anatomical study was performed to further evaluate the technique [17, 22]. Fredrick et al. expanded on this, presenting three case reports of intraneural injection utilizing the PL technique. All three patients underwent neurolysis and debridement of the injected material but suffered ongoing functional loss at long term follow up [9]. Kay et al. reported similar findings with the PL technique. In comparison, they recommended the VU technique as the needle is placed deep to the MN and reported on 250 VU injections with no incident of MN injury [26]. Ozturk et al. performed a cadaveric CT injection study utilizing acrylic dye to evaluate the tFCR technique described by Dubert and Racasan in comparison with PL and VU techniques. [21] Performing injections on 50 cadaver wrists, they found a 96% rate of accuracy with no injuries to the MN with the tFCR technique. The two injections that were not within the CT were found to be within the transverse carpal ligament. In comparison, they reported an 82% intra-CT accuracy and a 22% rate of intraneural injection with the PL technique and a 72% intra-carpal tunnel accuracy with no intraneural injections with the VU technique.

Despite these informative studies, a full comparison of the accuracy of these six techniques has not been previously evaluated. The current study demonstrates no significant difference between the six described techniques with regard to proximity to the nearest tendon in the CT. However, the study found a significant increase in distance between needle placement and the MN with the tFCR, VR, and VU techniques suggesting these techniques have the highest safety without compromising accuracy. The safest and most accurate anatomical injection location, defined as the largest

Table 3 Summary comparison of the CT injection techniques in the literature

	<i>n</i>	Cadaveric	Technique	% In CT	% in MN
Green et al. [3]	756	N	PL	75.7%	8.7%
Menge et al [19]	64	Y	VU and VR	100% for VU and VR	0% for VR 6% for VU
MacLennan et al [18]	30	Y	PL, uFCR	100% for PL and uFCR	PL: 27% uFCR: 7%
Ozturk et al [21]	150	Y	PL, VU, tFCR	PL: 82% VU: 72% tFCR: 96%	PL: 19.5% VU: 0% tFCR: 0%
Dubert and Racasan [17]	93	N	PL, tFCR	No comparison study done. Median nerve extended ulnar to the ulnar edge of the PL 88% of the time. Therefore, recommend tFCR technique	

n = number

CT carpal tunnel; DIR direct through the palm; MN median nerve. PL palmaris longus; tFCR trans-flexor carpi radialis; uFCR ulnar to flexor carpi radialis; VR volar radial; VU volar ulnar

measured distance between the needle and the MN and the lowest incidence of intraneural needle placement while achieving near 100% intra-CT needle placement, was found with both the tFCR and VR injection locations.

This study has several limitations. Most significantly, the cadaveric model eliminates the ability to report clinical outcomes following the injection techniques. Further, injections were performed in a single pass without the ability to respond to patient feedback. In the clinic setting, the patient is instructed to report paresthesia of any kind, guiding the clinician during the procedure and helping to avoid iatrogenic nerve injury. While this was not possible in our cadaveric study, case reports in the literature have demonstrated iatrogenic nerve injury in the clinic setting even with patient feedback [9]. Therefore, it is essential to use the safest injection technique available in order to avoid iatrogenic nerve injury, even when patient feedback is available. It should also be noted that we were unable to assess the variability of patient discomfort with these six techniques. Further studies would be needed to confirm the tFCR technique does not cause increased discomfort for the patient.

Ultimately, all six injection techniques reliably enter the carpal tunnel. However, even with patient feedback in the clinic setting, risk of intraneural injection should be avoided at all cost. We therefore recommend injection through a tFCR or VR approach to maximize accuracy of carpal tunnel injection while incurring the lowest risk of injury to the median nerve.

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Declarations

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