The Accuracy of Common Hand Injections With and Without Ultrasound: An Anatomical Study

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Abstract

Background: The aim of the study is to determine the accuracy of hand injections with and without the aid of ultrasound (U/S) into the carpal tunnel, thumb carpometacarpal (CMC) joint, first dorsal compartment (DC) and the radiocarpal (RC) joint. **Methods:** Four participants of various level of experience injected the carpal tunnel, thumb CMC, first DC, and RC joint into 40 fresh frozen cadaver specimens with blue dye and radiographic contrast. Participants 1 and 2 were injected without U/S guidance, and participants 3 and 4 were injected with U/S guidance. A successful injection was determined by both fluoroscopy and dissection/direct observation. Additional information was recorded for each injection such as median nerve infiltration and evidence of thumb CMC arthrosis. **Results:** The overall accuracy for carpal tunnel, thumb CMC, first DC, and RC injections were 95%, 63%, 90%, and 90%, respectively. Success was compared with and without U/S guidance. Success rates were similar for each injection site, except the thumb CMC joint, where U/S participants had 25% higher accuracy. In the setting of thumb CMC arthrosis, the incidence of success was 38% for participants with no U/S aid and 72% for participants with U/S aid. There was a significant difference between participants who used U/S with the participant with more U/S experience being more successful. **Conclusion:** Carpal tunnel, first DC, and RC injections had an accuracy of greater than 90%. Thumb CMC injections have a lower accuracy (63%) and one can improve accuracy with U/S. The accuracy of U/S-guided injections is dependent on the user and their experience.

Keywords: carpal tunnel, De Quervain, radiocarpal, thumb carpometacarpal

Introduction

Carpal tunnel syndrome, basilar thumb arthritis, De Quervain's tenosynovitis, and radiocarpal (RC) arthritis are common conditions treated with corticosteroid injections. A recent analysis showed that 68% of reimbursements come from the hand surgeon's office setting.¹ There have been a few studies examining the accuracy of these injections.^{1,13,18} The use of ultrasound (U/S)-assisted injections has become popular and has been shown to be efficacious.^{2,8,12,17} The purpose of our study is to determine the accuracy of injections with and without the aid of U/S into the carpal tunnel, thumb carpometacarpal (CMC) joint, first dorsal compartment (DC), and the RC joint.

Materials and Methods

Forty upper extremity fresh frozen cadavers were obtained from the University of Cincinnati Body Donation program with the support of a grant from the University of Cincinnati Orthopaedic Research and Education Foundation. Three

hand fellowship-trained surgeons and 1 hand surgery physician assistant (PA) were chosen to inject the carpal tunnel, thumb CMC joint, first DC, and RC joint. Participants had various levels of training. Participant 1 had more than 5 years of experience, participant 2 had less than 5 years of practice, and participant 3 had over 5 years of experience and has been using U/S for more than 1 year. Participant 4 is a PA with has been in working with a hand surgeon for 5 years and has been using U/S for 1 year.

The carpal tunnel and RC joint were injected with a 1 mL of commercially available blue dye and 1 mL of radiopaque contrast. The thumb CMC joint and first DC were injected

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Figure 1. Anteroposterior (a) and lateral (b) views of a successful carpal tunnel injection.

with a combination of 0.5 mL of blue dye and 0.5-mL-radiopaque contrast.

The carpal tunnel was injected via a standard fashion in the distal forearm staying ulnar to the palmaris longus. The thumb CMC joint was injected dorsally. The first DC was injected at the radial styloid in a retrograde direction. The RC joint was injected at the soft spot 1 cm distal to Lister's tubercle. All injections were performed using a 1½-inch 25-gauge needle. Participants 1 and 2 used palpation and landmarks to guide their injection. Participants 3 and 4 had the assistance of U/S.

To establish a control, a cadaver was dissected using $\times 3.5$ loupe magnification down to the structure to be injected. Under direct visualization, each structure was injected with the dye-contrast mixture. The control arm was then imaged, and 3 views of the hand and wrist were saved. These fluoroscopic images would serve as control images. Figures 1 and 2 demonstrate a fluoroscopically successful carpal tunnel and first CMC injection. Next, each structure was dissected and released or opened. Photos were taken of the dissected structure. These photos would serve as the control images for a successful injection. Figures 3 and 4 demonstrate a successful first DC and RC joint injection on anatomic dissection.

Each participant injected the carpal tunnel, thumb CMC joint, first DC, and RC joint in 10 fresh frozen cadaver arms. Immediately after the injections, 3 views of the hand were obtained with fluoroscopy. The images were compared with the control fluoroscopic image. If the images were similar to the control images, the injection was defined as fluoroscopically successful image. Next, each cadaver was dissected to inspect for the location of the blue dye. If the dissection appeared similar to the control dissection photo, the injection was defined as a successful injection.

Additional information was recorded for each injection. The blue dye location for carpal tunnel injections was noted

Figure 2. Radiograph demonstrating a successful thumb carpometacarpal injection.

Figure 3. Photograph of a successful first dorsal compartment injection on anatomic dissection.

as involving the synovium of the flexor digitorum superficialis (FDS), flexor digitorum profundus (FDP), or both. The median nerve was inspected for any infiltration. Radiographic evidence of thumb CMC arthrosis was noted. Each first DC was inspected for the presence of an extensor pollicis brevis (EPB) subsheath. Also, the abductor pollicis longus and EPB tendons were inspected for the presence of blue dye.

Statistical analysis was performed with SAS 9.3 (Cary, North Carolina). Accuracy of injection and 95% confidence intervals were calculated for participants by injection site.

Figure 4. Photograph of a successful radiocarpal injection on anatomic dissection.

Fisher exact test was used to compare differences in incidence of injection success among participants. Comparisons of participants' overall injection accuracy (combining all sites) were calculated using repeated measures analysis (PROC GLM in SAS), to account for any correlation of data by cadaver arm (same arm injected at 4 sites). Two-tailed *P* values less than .05 were considered significant.

Results

The overall injection accuracies are shown in Table 1. Carpal tunnel injections had an overall accuracy of 95% (38 of 40). Fifteen of the 38 successful carpal tunnel injections (39%) had methylene blue around both FDS and FDP tendons. Nine of the 38 (24%) successful injections had dye in the FDS tendon sheath only, and 14 of the 38 successful injections (37%) had dye in the FDP sheath only. None of the cadavers showed any dye infiltration in the median nerve. A fluoroscopically successful injection correlated with a successful injection in all cadaver specimens except for one.

Thumb CMC injections had an overall accuracy of 63% (25 of 40). Thumb CMC arthrosis was present in 31 of the 40 (78%) cadaver specimens. In cadavers with no thumb CMC arthrosis, the CMC injection accuracy was 78% (7 of 9). Cadavers with thumb CMC arthrosis had CMC injection accuracy of 58% (18 of 31). This difference was not statistically significant. When participants 1 and 2 (no U/S assistance) missed the thumb CMC injection, they injected the scaphotrapezialtrapezoid (STT) joint. Figure 5 demonstrates a missed thumb CMC injection. When participants 3 and 4 (U/S aid) missed their thumb CMC injections, they missed the injection superficial to the thumb CMC joint and trapezium. A fluoroscopically successful thumb CMC injection correlated with a successful injection in all cadaver specimens except for one.

First DC injections had an overall accuracy of 90% (36 of 40). The prevalence of an EPB subsheath was 45% (18 of

40). On dissection of successful injections, the blue dye was found in the abductor pollicis longus (APL) subsheath in 9 of the 36 cadavers (25%), in the EPB compartment in 2 out of the 36 cadavers (6%), and in both APL and EPB in 25 of the 36 cadavers (69%). In cadavers with an EPB subsheath, only 6 out of the 18 cadavers (33%) had dye in both the APL and EPB. Figure 6 demonstrates the first DC with and without an EPB subsheath on U/S. All fluoroscopically successful injections correlated with successful injections on cadaver dissection.

RC injections had an overall accuracy of 90% (36 of 40). In the non-U/S group, the 1 miss was injected into the midcarpal joint. In the U/S group, all 3 misses were superficial to the joint. All fluoroscopically successful injections correlated with successful injection on cadaver dissection.

Table 2 demonstrates the incidence of success with and without U/S. Incidences of success by injection site were similarly high for U/S versus non-U/S participants except for the thumb CMC injection. The incidence of success for thumb CMC injections was higher among the U/S participants (75% vs 50%, *P* value: NS). In the setting of thumb CMC arthrosis, the incidence of success was 38% (5 of 13) for participants with no U/S and 72% (13 of 18) for participants with U/S, this difference approached statistical significance (*P* = .06).

When comparing incidence of success among participants, the incidence of success between participants 1 (78%) and 2 (90%) (no U/S) was not significant. The incidence of success between participants 3 (95%) and 4 (75%) (U/S aid) was significant (*P* value of .02).

Discussion

This study is one of the few studies evaluating the accuracy of common hand injections with and without U/S guidance in a cadaveric model. Our study did not show any statistical significance difference between U/S-guided injection and traditional injection methods. However, in the setting of thumb CMC arthrosis, U/S-guided injections had a higher rate of success that approached statistical significance. Our overall accuracy of thumb CMC injections was 63%, which was similar to Helm et al who reported an accuracy of 58%. In their study, they did not use U/S and injected the thumb CMC based on palpation of landmarks. They confirmed their accuracy with biplanar fluoroscopy.⁵ Moreover, Umphrey et al injected 17 cadavers thumb CMC joints with the aid of U/S and demonstrated an accuracy of 94%.¹⁶ Mandl et al reported an accuracy of 100% (no U/S or fluoroscopic guidance) for thumb CMC injections with moderate to severe thumb CMC arthrosis. Accuracy was confirmed with microbubbles via U/S. They concluded that thumb CMC injections could be injected accurately without the

Table 1. Overall Injection Accuracies for Each Injection Type.

	CTI (CI)	First CMC (CI)	First DC (CI)	RC (CI)
Participant 1	100%	40% (0.12-0.74)	80% (0.44-0.97)	90% (0.44-0.97)
Participant 2	100%	60% (0.26-0.88)	100%	100%
Participant 3	100%	90% (0.56-0.998)	100%	90% (0.56-0.998)
Participant 4	80% (0.44-0.97)	60% (0.26-0.88)	80% (0.44-0.97)	80% (0.44-0.97)
Overall	95% (0.83-0.99)	63% (0.46-0.77)	90% (0.73-0.99)	90% (0.76-0.97)

Note. Confidence interval (CI) reported at 95% interval. CTI = carpal tunnel injection; CMC = carpometacarpal; DC = dorsal compartment; RC = radiocarpal.

Figure 5. Anteroposterior wrist demonstrating a missed thumb carpometacarpal injection superficial to the scaphotrapezialtrapezoid joint.

need for radiographic guidance.¹³ Our study contrasts considerably with an injection accuracy of 38% (no U/S) in the setting of thumb CMC arthrosis.

There are few studies evaluating accuracy of carpal tunnel injections in the cadaveric model. These studies evaluated the diffusion of dye or the accuracy of needle location. Minamikawa et al determined that 2-mL injection of dye 3

Figure 6. Ultrasound images of the first dorsal compartment with and without an EPB subsheath (as indicated by the arrow mark). Note. EPB = extensor pollicis brevis.**Table 2.** Incidence of Success With and Without U/S Guidance.

Injection	No U/S (CI)	U/S (CI)	P value
Carpel tunnel	100%	90% (0.68-0.99)	.49
Thumb CMC joint	50% (0.27-0.73)	75% (0.51-0.91)	.19
First DC sheath	95% (0.68-0.99)	90% (0.68-0.99)	1.00
RC joint	95% (0.75-0.999)	85% (0.62-0.97)	.60

Note. Confidence interval (CI) reported at 95% interval. U/S = ultrasound; CMC = carpometacarpal; DC = dorsal compartment; RC = radiocarpal.

cm proximal to the distal wrist crease gave the optimal diffusion of dye.¹⁴ MacLennan et al compared two carpal tunnel injection techniques in a cadaveric model. The first technique was ulnar to the palmaris longus at the wrist crease, and the second technique was ulnar to the flexor carpi radialis at the wrist crease. They found that 4 out of 15 cadavers had median nerve injury when injected with the first technique and 1 out of 15 cadavers had median nerve injury with second

technique.¹¹ Ozturk et al performed a similar study and found the carpal tunnel injections ulnar to the palmaris longus tendon had the highest rate of median nerve injury.¹⁵ Our study utilized the traditional approach and showed no median nerve dye infiltration. However, we did not assess whether the median nerve was pierced during the injection.

When comparing U/S-guided carpal tunnel injection versus non-U/S-assisted carpal tunnel injections, our results did not show a difference in accuracy. In clinical studies, Makhoul et al showed U/S-guided injections resulted in a 77% decrease in injection pain, 63% reduction of pain scores, and 71% increase therapeutic duration when compared with no U/S use.¹² A recent randomized prospective study also demonstrated the positive effects of U/S use. They found that the U/S group showed statistically significant improved time to relief and better severity scores.¹⁷

Our accuracy for first DC injections was 90% among all participants. There are few clinical or anatomical studies comparing no U/S with U/S use for first DC injections. One clinical study demonstrated an injection accuracy of 84% with no U/S use and reported that 57% of the patients showed a marked decrease in pain.¹⁹ Moreover, in the presence of an EPB subsheath, the blue dye was found in both the EPB and APL in 33% of the cadavers. Kume et al compared 2 groups of patients with De Quervain's tenosynovitis. One group was injected only in the EPB with the guidance of U/S, and the second group used no U/S. At 4 weeks, the U/S guidance group showed better visual analog scale pain scores. The ability to use U/S to ensure steroid into both APL and EPB may help explain why other studies have found better results with U/S-guided injections.^{4,7}

The accuracy of RC injections in other studies has varied from 50% to 97%.^{2,6,9,10} Luz et al performed a double-blinded study comparing the no U/S guidance with U/S guidance for wrist injections and found no difference in accuracy.¹⁰ Also, Cunningham et al performed a similar study and found no increase in accuracy for wrist injections.² Our results showed similar results with no increase in accuracy with U/S guidance and a high accuracy of 90%.

Our study does have limitations. We used fresh frozen cadavers and thus no clinical conclusion could be made. The number of cadavers used (40) was limited due to expense and was not enough to perform a power analysis. Another weakness of the study design that could be inferred would be the inclusion of the PA. We felt it was important to have a participant in the study that was a nonsurgeon. Nonoperative physicians are using U/S guidance in the clinical setting and perform many U/S-guided injections.

However, we feel the results are important and impactful. Our data demonstrated that U/S-guided thumb CMC injection is more accurate. As the success rate of thumb CMC injection increases, more patients may experience more relief, last longer, and may not need a second injection. Also, U/S guidance did not statistically improve accuracy in the carpal tunnel, first DC, and RC joint

Carpal tunnel, first DC, and RC injections are accurate with observed accuracy of greater than 90%, among our surgeons. First CMC injections have a lower accuracy, and one can improve accuracy with U/S guidance. The accuracy of U/S-guided injections is dependent on the user and his or her experience.

Ethical Approval

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was obtained from all patients for being included in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References

1. Anderanin L. Coding tips for the orthopaedic office. Healthcare Information Services. <http://www.slideshare.net/ReimbursementMD/coding-tips-for-busy-orthopaedic-practices>. Published 2012. Accessed September 29, 2014.
2. Cunningham J, Marshall N, Hide G, et al. A randomized, double-blind, controlled study of ultrasound-guided corticosteroid injection into the joint of patients with inflammatory arthritis. *Arthritis Rheum*. 2010;62(7):1862-1869.
3. Di Sante L, Cacchio A, Scettri P, et al. Ultrasound-guided procedure for the treatment of trapeziometacarpal osteoarthritis. *Clin Rheumatol*. 2011;30(9):1195-1200.
4. Hajder E, de Jonge M, van der Horst C, et al. The role of ultrasound-guided triamcinolone injection in the treatment of De Quervain's disease: treatment and a diagnostic tool? *Chir Main*. 2013;32(6):403-407.
5. Helm A, Higgins G, Rajkumar P, et al. Accuracy of intra-articular injections for osteoarthritis of the trapeziometacarpal joint. *Int J Clin Pract*. 2003;57(4):265-266.
6. Jones A, Regan M, Ledingham J, et al. Importance of placement of intra-articular steroid injections. *BMJ*. 1993;307(6915):1329-1330.
7. Kume K, Amano K, Yamada S, et al. In de Quervain's with a separate EPB compartment, ultrasound-guided steroid injection is more effective than a clinical injection technique:

- a prospective open-label study. *J Hand Surg Eur Vol.* 2012;37(6):523-527.
8. Lohman M, Vasenius J, Nieminen O. Ultrasound guidance for puncture and injection in the radiocarpal joint. *Acta Radiol.* 2007;48(7):744-747.
 9. Lopes R, Furtado R, Parmigiani L, et al. Accuracy of intra-articular injections in peripheral joints performed blindly in patients with rheumatoid arthritis. *Rheumatology (Oxford).* 2008;47(12):1792-1794.
 10. Luz K, Furtado R, Nunes C, et al. Ultrasound-guided intra-articular injections in the wrist in patients with rheumatoid arthritis: a double-blind, randomised controlled study. *Ann Rheum Dis.* 2008;67(8):1198-1200.
 11. MacLennan A, Schimizzi A, Meier KM, et al. Comparison of needle position proximity to the median nerve in 2 carpal tunnel injection methods: a cadaveric study. *J Hand Surg Am.* 2009;34(5):875-879.
 12. Makhlof T, Emil NS, Sibbitt WL, et al. Outcomes and cost-effectiveness of carpal tunnel injections using sonographic needle guidance. *Clin Rheumatol.* 2014;33(6):849-858.
 13. Mandl LA, Hotchkiss RN, Adler RS, et al. Can the carpometacarpal joint be injected accurately in the office setting? implications for therapy. *J Rheumatol.* 2006;33:1137-1139.
 14. Minamikawa Y, Peimer CA, Kambe K, et al. Tenosynovial injection for carpal tunnel syndrome. *J Hand Surg Am.* 1992;17(1):178-181.
 15. Ozturk K, Esenyel CZ, Sonmez M, et al. Comparison of carpal tunnel injection techniques: a cadaver study. *Scand J Plast Reconstr Surg Hand Surg.* 2008;42(6):300-304.
 16. Umphrey GL, Brault JS, Hurdle M-FB, et al. Ultrasound-guided intra-articular injection of the trapeziometacarpal joint: description of technique. *Arch Phys Med Rehabil.* 2008;89(1):153-156.
 17. Ustun N, Tok F, Yagz AE, et al. Ultrasound-guided vs. blind steroid injections in carpal tunnel syndrome. *Am J Phys Med Rehabil.* 2013;92(11):999-1004.
 18. Wood MR. Hydrocortisone injections for carpal tunnel syndrome. *Hand.* 1980;12(1):62-64.
 19. Zingas C, Failla JM, Van Holsbeeck M. Injection accuracy and clinical relief of De Quervain's tendinitis. *J Hand Surg Am.* 1998;23(1):89-96.