Research paper

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Ultrasound-guided therapeutic injection of the surgically transposed ulnar nerve at the elbow: sonographic appearances, technique and clinical follow-up

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Keywords

ultrasound; ulnar nerve; injection; transposition

Abstract

Aim: To evaluate the therapeutic efficacy of ultrasound-guided injection of the transposed ulnar nerve at the elbow. **Methods:** Fifteen patients who underwent injection of a transposed ulnar nerve between 2014–2024 were identified. Sonographic appearances of the injected segment were scored using a Likert grading system for abnormality, and the cross-sectional area (mm²) was measured. Follow-up with respect to clinical response, need for subsequent therapeutic injection or decompressive surgery was recorded. **Results:** The grade of abnormality was mild ($n = 4$), moderate ($n = 5$), and severe ($n = 3$), with the remainder morphologically normal ($n = 3$). Inter-rater agreement was 0.91 (95% CI 0.80–1.00) with $p < 0.001$. Cross-sectional area ranged from 8–18 mm². Fourteen of fifteen patients (93%) experienced relief at the time of injection, decreasing to 12/15 (80%) at short-term follow-up <3 months, and further falling to 7/15 (47%) >3 months. Five patients (33%) underwent subsequent therapeutic injections, and three (20%) proceeded to revision surgery. There were no significant differences in grade between patients who experienced relief at any of the three time-points ($p > 0.05$), nor differences in deformity or cross-sectional area between those who underwent subsequent injection ($p > 0.05$) or surgery ($p > 0.05$). **Conclusion:** Ultrasound-guided injection is a viable option for refractory neuropathic symptoms, although relief was often temporary, and 20% eventually required revision surgery.

Introduction

Treatment of refractory ulnar neuropathy at the cubital tunnel frequently involves surgical decompression of the nerve which focuses on relieving compression. Transposition procedures mobilize the nerve anteriorly into a more protected location, usually into a subcutaneous or submuscular position[1]. Although this provides satisfactory sensory and motor improvement for >90% of patients [2,3], a subset of patients fail surgical treatment and experience no improvement or recurrent symptoms, presenting a clinical challenge[4].

The ulnar nerve can be compressed at various levels. This may occur proximally at the cubital tunnel inlet by the arcade of Struthers and medial intermuscular septum, at the level of the medial epicondyle by the Osborne retinaculum, and distally at the cubital tunnel outlet where compression can be caused by the aponeurotic attachments of the two heads of the flexor carpi ulnaris muscle[5].

Electrodiagnostic testing may be helpful when compared with preoperative values, although the results are generally informative only when they show improvement or worsening. Unchanged electrodiagnostic studies add limited value because, despite successful surgery with symptom improvement, the studies often show no improvement. Therefore, a completely decompressed ulnar nerve cannot be reliably distinguished from an incompletely released nerve, as both may have an unchanged nerve conduction study or EMG[6].

On MRI, the ulnar nerve is generally larger and more T2-hyperintense post-transposition, but imaging features may not be predictive of recurrent neuropathy[7,8]. Ultrasound (US) is a cheaper and more readily accessible alternative and is therefore often the first-line imaging modality in the clinical context of persisting neuropathy[9]. High-frequency sonography can define morphological abnormalities such as nerve thickening, loss of fascicular architecture, constrictions, and caliber changes after transposition[5,10,11]. It can also provide information to stratify the need for re-intervention when electrodiagnostic tests are equivocal. In addition, it can be used to guide therapeutic perineural injections for the treatment of residual or recurrent neuritis[12]. Indeed, percutaneous US-guided therapeutic injection of the ulnar nerve at the cubital tunnel is a commonly performed, effective, and well-studied procedure in the setting of neuropathy[13–17].

Despite this, there remains limited published literature on the technique and clinical efficacy regarding the transposed ulnar nerve at the elbow. Therefore, the purpose of this study was to (1) evaluate the range of morphological nerve abnormalities on US using a simple Likert grading system, (2) measure the cross-sectional area (CSA) of injected nerves at the level of the surgical decompression, (3) evaluate the immediate, short-term, and long-term follow-up in these patients with respect to symptomatic relief, and (4) describe the frequency of re-intervention, specifically repeat injection or revision surgery.

Materials and methods

Patient selection

The study was approved by the Institutional Review Board with a waiver of informed consent.

Patients who underwent a US-guided injection of the transposed ulnar nerve between 2014–2024 were identified retrospectively using a search of the institutional PACS imaging database (Visage, San Diego) with the terms "transposition", "ulnar nerve," and "injection". All patient charts were reviewed in the electronic patient record (EPIC, WI). The US images were evaluated in PACS on diagnostic monitors. Two patients were excluded: one without adequate images available in PACS and another without documented clinical follow-up. The type of surgical transposition, i.e. submuscular versus subcutaneous, was also recorded. The interval between transposition and the first ultrasound, as well as the duration of ulnar nerve symptoms prior to the initial ultrasound, was documented.

Image evaluation

Patients were all imaged and injections performed using a Siemens Acuson Sequoia or S3000 machine (Mountain View, CA), with a 14-MHz linear array or hockey-stick transducer. Pre-injection grayscale and Doppler images were acquired in the transverse and longitudinal planes. A simple Likert grading system was used for US imaging evaluation scored by two readers with 10 and 28 years of experience. A score of 0 indicated a non-enlarged nerve with preserved echogenic internal fascicles; 1 indicated a non-enlarged or mildly enlarged nerve with low-grade partial (<50%) loss of normal fascicular morphology; 2 indicated an enlarged nerve with deformed fascicles or high-grade partial (>50%) loss of fascicular morphology; and 3 indicated an enlarged nerve with deformity/constrictions and complete loss of normal fascicular morphology (Fig. 1). The cross-sectional area (CSA) of the injected transposed segment of the nerve was measured using a manual freehand measuring tool (Fig. 2). The CSA was also measured proximal and distal to the transposition site, and the ulnar nerve caliber change was calculated. The selection of steroid was recorded, as was the therapeutic response at three timepoints: immediately following the injection, at <3 months clinical follow-up, and at >3 months (Fig. 3).

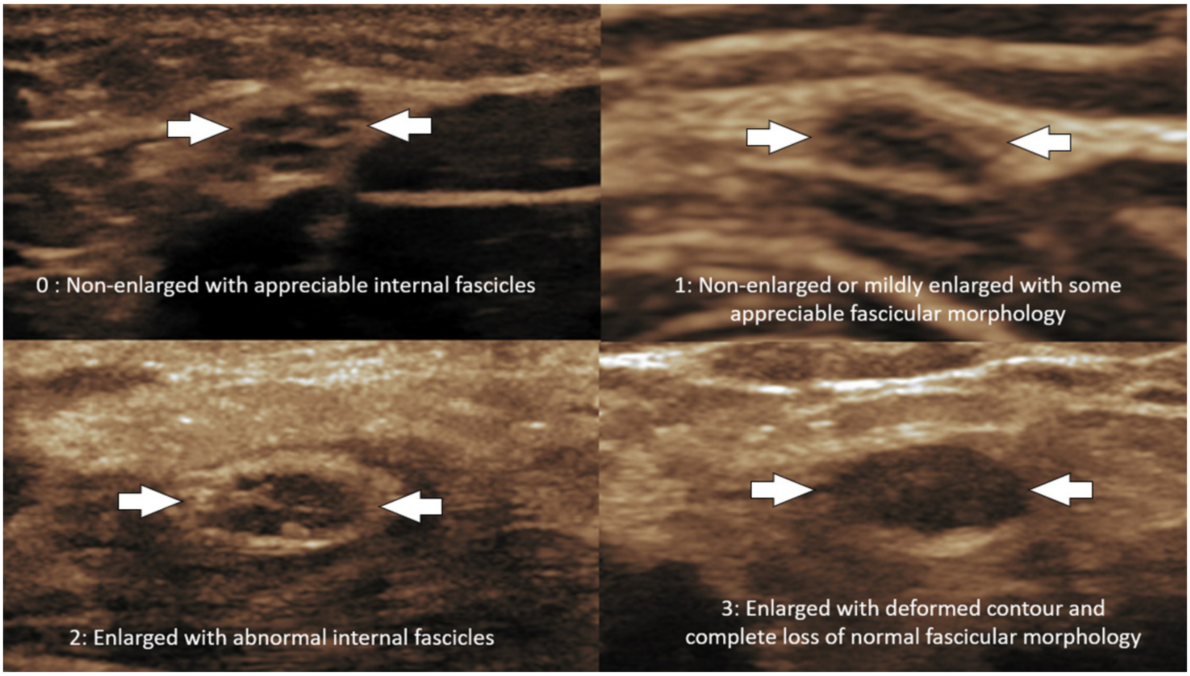

Fig. 1. *Grading system for ultrasound imaging evaluation with transverse images of the ulnar nerve (white arrows). 0 – Non-enlarged nerve with preserved echogenic internal fascicles. 1 – Non-enlarged or mildly enlarged nerve with low-grade (<50%) loss of normal fascicular morphology. 2 – Enlarged nerve with deformed nerve fascicles and partial loss (>50%) of normal fascicular morphology. 3 – Enlarged nerve with deformity/constrictions and complete loss of normal fascicular morphology*

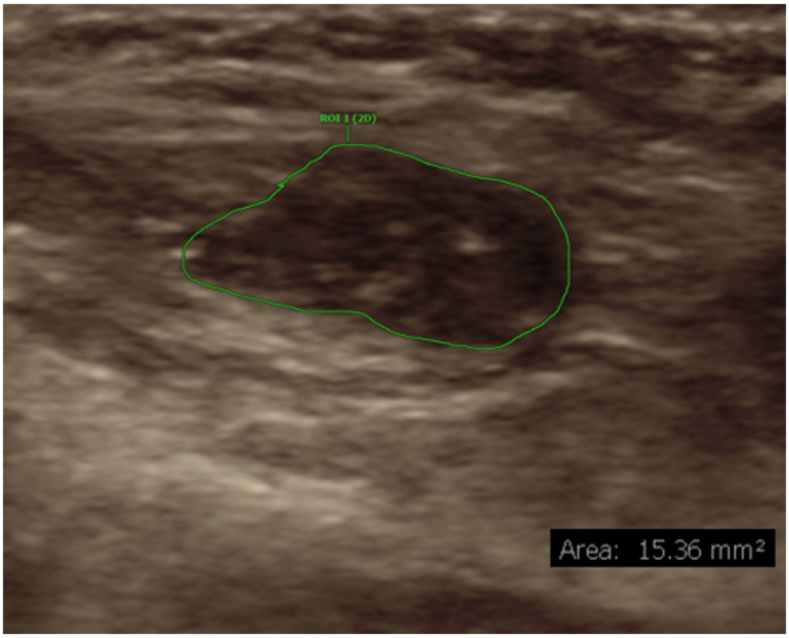

Fig. 2. *Transverse ultrasound image of a transposed ulnar nerve prior to injection, with cross-sectional area measured at 15 mm². The nerve is enlarged and deformed with complete loss of normal fascicular morphology (grade 3)*

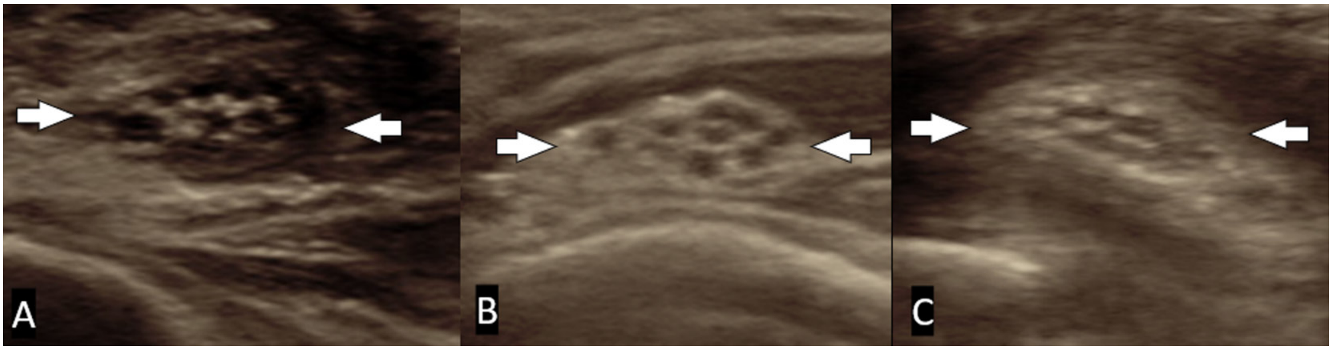

Fig. 3. *63-year-old male with ulnar neuropathy treated with subcutaneous transposition. Short-axis ultrasound images demonstrate the ulnar nerve (white arrows) at the time of injection (***A***), at 2-month follow-up (***B***), and at 6-month post-injection. Hypoechoic enlargement and mild distortion of fascicles are present at all time points*

Ultrasound and injection technique

Injections were performed by four fellowship-trained radiologists, with experience ranging from 7–28 years, all using real-time sonographic guidance. Patients were positioned supine or in lateral decubitus with the shoulder abducted to 90° and the forearm supinated, or alternatively in the prone position with the elbow flexed and the hand placed beneath the abdomen. In all cases, the nerve was injected at the site of surgical transposition in the region of greatest morphologic abnormality, i.e., loss of fascicular echotexture and caliber change. First, a 25-gauge, 1.5-inch needle was introduced and 1% lidocaine was injected into the subcutaneous soft tissues for local anesthesia. The needle tip was then advanced into the perineural space adjacent to the echogenic epineurium. Subsequently, injection was performed around the nerve using a mixture containing steroid – either 9 mg betamethasone (6 mg/cc) (Celestone Soluspan, betamethasone sodium phosphate and betamethasone acetate injectable suspension, Merck, Rahway, NJ) or 40 mg triamcinolone (40 mg/cc) (Kenalog, triamcinolone acetonide, Bristol-Myers Squibb, Princeton, NJ) combined with 1.5 cc ropivacaine, ensuring adequate circumferential spread of injectate around the nerve (Fig. 4).

Follow-up

Response to injection was evaluated at the time of injection, within 3 months of injection, and later than 3 months. Any subsequent therapeutic injection or surgical intervention was recorded.

Statistical analysis

All statistical analyses were performed in SAS Studio version 3.8 (SAS Institute, Cary, NC). Inter-rater agreement for sonographic nerve grading was assessed using Kendall's coefficient of concordance. Nerve grading between patients who did and did not experi-

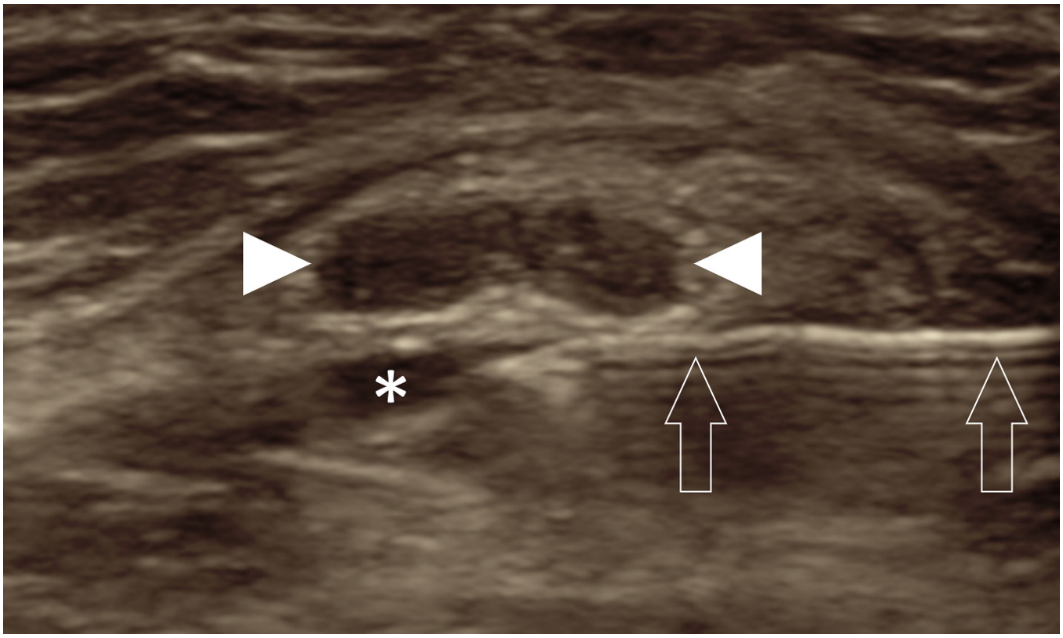

Fig. 4. *56-year-old male with a history of ulnar nerve transposition and persistent ulnar neuropathy. Ultrasound-guided injection of the transposed ulnar nerve at the level of the medial condyle. The needle (hollow arrows) is introduced with the tip adjacent to the epineurium, and injectate consisting of corticosteroid and local anesthetic is administered around the nerve (asterisk). The nerve (white arrowheads) demonstrates complete loss of normal fascicular morphology*

ence relief at the time of injection, at 3 months after injection, or at >3 months after injection was compared using the Mann-Whitney U test. Likewise, nerve grading and CSA between patients who did and did not undergo subsequent injection or subsequent surgery were compared using the Mann-Whitney U test. All p-values <0.05 were considered significant.

Results

Fifteen injections were performed in 15 different patients (11 males, 4 females). The mean age was 53.7 years (range 31–80). The steroids used were betamethasone (n = 9) and triamcinolone (n = 6). Twelve cases were subcutaneous transpositions, whereas the remaining three were submuscular. The mean interval between transposition and the first ultrasound was 32.2 months (range 3–72 months). The duration of ulnar nerve symptoms prior to the initial ultrasound was 18.8 months (range 1–37 months).

Sonographic abnormalities

The degree of abnormality was mild (n = 4), moderate (n = 5), and severe (n = 3) according to the more senior author, with the remainder considered morphologically normal (n = 3). Inter-rater agreement, as measured by Kendall's coefficient of concordance, was 0.91 (95% confidence interval, 0.80–1.00) with p <0.001, indicating almost perfect to perfect agreement. The ulnar nerve CSA proximal to the transposition measured 14.6 mm^2 (range 9–20 mm^2) and distal to the transposition was 11.3 mm^2 (range 6–15 mm^2), with the mean caliber change measuring 3.2 mm^2 (1–6 mm^2). The CSA of the injected nerve was 12.3 mm^2 (range 8–18 mm^2).

Response to injection

Fourteen of fifteen patients (93%) experienced immediate relief following the injection, decreasing to 12/15 (80%) at short-term follow-up within 3 months, and further falling to 7/15 (47%) beyond 3 months (Fig. 3). A breakdown of injection response by ulnar nerve grading is provided in Table 1. There were no significant differences in grade of deformity (as measured by either reader) between patients who did and did not experience relief following the injection at any of the three time points (all p >0.05). Nerve CSA was significantly lower among patients who had relief within 3 months of injection (p = 0.049), but otherwise there were no significant differences in CSA between patients who did and did not have immediate relief or relief beyond 3 months (all p >0.05).

Five patients (33%) underwent a subsequent therapeutic injection, and three (20%) proceeded to additional decompressive surgery. A breakdown of subsequent procedures by ulnar nerve grading is provided in Table 2. There were no significant differences in grade of deformity (as measured by either reader) or CSA between patients who underwent subsequent injection (all p >0.05) or surgery (all p >0.05). A comparison of ulnar nerve grading and CSA by need for subsequent injection, surgery, and symptom relief at various time points is provided in Table 3.

Discussion

In short, this study describes the use of US-guided injection of the transposed ulnar nerve in patients with refractory symptoms and their clinical outcomes over time. Using a simple Likert grading system to classify nerve abnormalities, the analysis demonstrated no significant differences in deformity or CSA between patients who did and did not undergo subsequent injections (all p >0.05), nor

Tab. 1. Ulnar nerve grading among patients who had symptom relief at various time points following their initial injection

	Nerve grade	Duration of symptom relief		
		At the time of injection	**Within 3 months following injection**	**>3 months following injection**
Reader 1	0 (*n* = 1)	1 (100.0%)	1 (100.0%)	0 (0%)
	1 (*n* = 6)	6 (100.0%)	6 (100.0%)	4 (66.7%)
	2 (*n* = 3)	2 (66.7%)	2 (66.7%)	1 (33.3%)
	3 (*n* = 5)	5 (100.0%)	3 (60.0%)	2 (40.0%)
	All grades (*n* = 15)	14 (93.3%)	12 (80.0%)	7 (46.7%)
Reader 2	0 (*n* = 1)	1 (100.0%)	1 (100.0%)	0 (0%)
	1 (*n* = 5)	5 (100.0%)	5 (100.0%)	3 (60.0%)
	2 (*n* = 4)	3 (75.0%)	3 (75.0%)	2 (50.0%)
	3 (*n* = 5)	5 (100.0%)	3 (60.0%)	2 (40.0%)
	All grades (*n* = 15)	14 (93.3%)	12 (80.0%)	7 (46.7%)

Tab. 2. Ulnar nerve grading among patients who underwent further injections and/or surgery following their initial injection

	Nerve grade	**Subsequent injection**	**Subsequent surgery**
Reader 1	0 (*n* = 1)	1 (100.0%)	0 (0%)
	1 (*n* = 6)	1 (16.7%)	1 (16.7%)
	2 (*n* = 3)	1 (33.3%)	1 (33.3%)
	3 (*n* = 5)	2 (40.0%)	1 (20.0%)
	All grades (*n* = 15)	5 (33.3%)	3 (20.0%)
Reader 2	0 (*n* = 1)	1 (100.0%)	0 (0%)
	1 (*n* = 5)	1 (20.0%)	1 (20.0%)
	2 (*n* = 4)	1 (25.0%)	2 (50.0%)
	3 (*n* = 5)	2 (40.0%)	0 (0%)
	All grades (*n* = 15)	5 (33.3%)	3 (20.0%)

Tab. 3. Comparison of ulnar nerve abnormality grading and cross-sectional area at the injection site on ultrasound by need for subsequent injection, subsequent surgery, and symptom relief at various time points

Subsequent injection?	**No (*n* = 10)**	**Yes (*n* = 5)**	***p*-value**
Reader 1 nerve grade	1.5 (2.0)	2.0 (2.0)	1.000
Reader 2 nerve grade	2.0 (2.0)	2.0 (2.0)	1.000
Cross-sectional area (mm^2)	12.0 (5.0)	12.0 (4.0)	0.758
Subsequent surgery?	**No (*n* = 12)**	**Yes (*n* = 3)**	***p*-value**
Reader 1 nerve grade	1.5 (2.0)	2.0 (2.0)	0.760
Reader 2 nerve grade	2.0 (2.0)	2.0 (1.0)	0.705
Cross-sectional area (mm^2)	10.5 (4.5)	15.0 (3.0)	0.217
Relief at the time of injection?	**No (*n* = 1)**	**Yes (*n* = 14)**	***p*-value**
Reader 1 nerve grade	2.0 (0)	1.5 (2.0)	0.903
Reader 2 nerve grade	2.0 (0)	2.0 (2.0)	1.000
Cross-sectional area (mm^2)	15.0 (0)	11.5 (4.0)	0.352
Relief within 3 months of injection?	**No (*n* = 3)**	**Yes (*n* = 12)**	***p*-value**
Reader 1 nerve grade	3.0 (1.0)	1.0 (1.5)	0.109
Reader 2 nerve grade	3.0 (1.0)	1.5 (1.5)	0.130
Cross-sectional area (mm^2)	15.0 (4.0)	10.5 (4.0)	0.049*
Relief for >3 months after injection?	**No (*n* = 8)**	**Yes (*n* = 7)**	***p*-value**
Reader 1 nerve grade	2.0 (2.0)	1.0 (2.0)	0.760
Reader 2 nerve grade	2.0 (2.0)	2.0 (2.0)	0.952
Cross-sectional area (mm^2)	13.0 (5.0)	11.0 (5.0)	0.560

Values reported as median with interquartile range.
**p*-value <0.05

were differences observed between those who later required revision surgery.

Sivakumaran et al. reported that, on MRI, the ulnar nerve post-operatively demonstrated statistically significant increases in size, T2 signal intensity, and abrupt caliber change[7]. However, none of the imaging features, except for higher pre-transposition signal intensity, were predictive of symptom recurrence. They also found that inter-rater agreement for CSA measurements of the ulnar nerve at the cubital tunnel was excellent, as was post-operative agreement on nerve signal intensity and perineural scarring (ACs of 0.90 and 0.88), although agreement for caliber change was only slight (0.15). These findings are consistent with the present study, in which inter-rater agreement measured by Kendall's coefficient of concordance was 0.91 (95% CI 0.80–1.00) with p <0.001, indicating almost perfect to perfect agreement.

The present study also found that 93% of patients experienced immediate relief following the injection, decreasing to 80% at short-term follow-up within 3 months, and further falling to 47% beyond 3 months. To our knowledge, outcomes of injection specifically targeting the transposed ulnar nerve have not been previously studied. However, limited studies of corticosteroid injection for cubital tunnel syndrome in the non-operated elbow have shown similar outcomes. Albas et al. found that 5 out of 9 patients experienced symptomatic improvement at 3-month follow-up[18]. Rampen et al. reported that 4 out of 7 patients experienced symptomatic improvement at 6-week follow-up[19]. Choi et al. found statistically significant improvement in both symptom scores and electrophysiologic parameters at 1-week and 4-week follow-ups in a cohort of 10 patients[20].

The mean caliber proximal and distal to the transposition measured 14.6 mm^2 and 11.3 mm^2, respectively, with a mean caliber change of 3.2 mm^2. The mean CSA at the site of the injection was 12.3 mm^2. Similar findings were described by Gruber et al., who evaluated eight subjects with persistent symptoms after nerve transposition for compressive neuropathy. They also identified marked caliber changes along the course of the transposed nerve across six defined segments: 7.45mm^2 proximal to the upper fascial passage, 11.96 mm^2 at the upper fascial passage, 11.49 mm^2 distal to the upper fascial passage, 10.84 mm^2 proximal to the lower fascial passage, 12.12 mm^2 at the lower fascial passage, and 7.89 mm^2 distal to lower fascial passage[10]. Although nerve morphology may provide valuable information for diagnosing persistent neuropathy after transposition, it may not always reliably predict therapeutic response, as a large proportion of patients in the present cohort experienced symptomatic relief regardless of the severity of sonographic abnormalities. For comparison, Chang et al. showed that in individuals without cubital tunnel syndrome, the mean CSA of the untreated ulnar nerve at the elbow ranged from 5.5–7.4 mm^2, with upper limits ranging from 6.3–9.0 mm^2. This indicates that the CSA of a normal untreated ulnar nerve rarely exceeds 10 mm^2. In their meta-analysis, they noted that across the seven studies with available data for calculating diagnostic accuracy, a CSA >10 mm^2 was the most commonly used cutoff value to define cubital tunnel syndrome[5].

Three patients (20%) in the present cohort did not respond to conservative management and subsequently underwent revision decompressive surgery. The options for revision surgery include simple neurolysis, neurolysis with subcutaneous transposition, and neurolysis with submuscular transposition. Autogenous (vein) and non-autogenous nerve wraps may be placed around the nerve to prevent recurrent scarring[6]. Hutchinson et al. found that the long-term reoperation rate was 12% at 5-year follow-up in a cohort of 59 patients who had previously undergone subcutaneous transposition[21].

Although grading systems for the evaluation of peripheral neuropathy using MRI have been described, for example, the MRI-based Neuropathy Score Reporting And Data System (NS-RADS)[22–24], there are limited publications specifically grading nerve abnormalities on US[25,26]. A sonographic grading system based on the Sunderland classification has been proposed in the setting of trauma, in which grade I injury corresponds to a normal-appearing nerve, grade II to mild nerve swelling, grade III to focal swelling and fascicular thickening, grade IV to focal fascicular disruption, and grade V to nerve transection with epineurial discontinuity[25]. Given the patients in the present cohort were evaluated in a post-operative but otherwise atraumatic setting, there was no evidence of nerve transection, as expected; therefore, this trauma-based grading system would not have been appropriate. Instead, a simple Likert system (0–3) was selected grading to describe the extent of morphologic abnormality in a similar way to the E-score used in the MRI NS-RADS system[22].

There are several limitations of this study that require consideration. The relatively small sample size, retrospective design, and absence of a control group limit the ability to attribute treatment outcomes solely to the intervention. The use of two different corticosteroids, although similar in potency, introduces additional variability[27]. The reliance on only three relatively short-term follow-up time points represents another design limitation, whereas longer-term standardized follow-up would allow for more generalizable conclusions. Furthermore, the grading system is novel and requires validation in larger cohorts. The analysis focused specifically on the injected segment of the transposed nerve with fibrotic changes, without assessing adjacent proximal and distal nerve segments. From a surgical perspective, there are two widely accepted surgical options for cubital tunnel syndrome, in situ decompression and decompression with anterior transposition[28], as well as use of a modified fascial sling[29]. We did not differentiate between these techniques. Lastly, patients with more severe preoperative findings are known to be at a higher risk of treatment failure; however, this factor was not incorporated into the analysis[6].

Conclusion

In conclusion, the data presented represent the first study to our knowledge specifically evaluating the utility of US-guided injection for the management of recurrent neuropathic symptoms following surgical transposition of the ulnar nerve. While our findings suggest that long-term relief is not guaranteed and a significant proportion of patients ultimately require further interventions, corticosteroid injections may provide relief as an initial management strategy. Further large-scale studies with extended follow-up will be required, ideally comparing the effectiveness of US-guided injections with other treatments.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: CJB, VT, RA. Writing of manuscript: CJB, RA. Analysis and interpretation of data: CJB, AW, DS, RA. Final acceptation of manuscript: CJB, RA. Collection, recording and/or compilation of data: CJB, VT, AW, DS, RA. Critical review of manuscript: CJB, VT, DS, RA.

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