Prospective cohort study of symptom resolution outside of the ulnar nerve distribution following cubital tunnel release

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Abstract

Background Resolution of symptoms including pain, numbness, and tingling outside of the median nerve distribution has been shown to occur following carpal tunnel release. We hypothesized that a similar effect would be found after release of the ulnar nerve at the elbow.

Methods Twenty patients with isolated cubital tunnel syndrome were prospectively enrolled. The upper extremity was divided into six zones, and the location of pain, numbness, tingling, or strange sensations was recorded pre-operatively. Two-point discrimination, Semmes-Weinstein monofilament testing, and validated questionnaires were collected. The same data were collected at 6-week follow-up. Paired *t* tests or non-parametric Wilcoxon Signed-Rank tests were used where appropriate to examine for significant ($p \leq 0.05$) changes between pre- and post-operative scores.

Results Probability of resolution was greater outside of the ulnar nerve distribution than within at early follow-up. There was a decrease in pain, numbness, and tingling symptoms both within and outside the ulnar distribution after cubital tunnel release. There was a decrease in pain as measured by several validated questionnaires.

Conclusion This study documents resolution of symptoms in an extra-ulnar distribution after cubital tunnel release. Improvement in pain and function after cubital tunnel release may be associated with an improvement in symptoms both within and outside the ulnar nerve distribution. Future studies could be directed at correlating pre-operative disease severity

with probability of extra-territorial symptom resolution using a larger sample population.

Keywords Ulnar neuropathy · Cubital tunnel syndrome · Ulnar nerve · Extra-ulnar

Introduction

Cubital tunnel syndrome (CuTS) is the second most common compression neuropathy of the upper extremity second only to carpal tunnel syndrome [6]. The diagnosis of CuTS is typically made by a combination of clinical assessment with adjunctive electrodiagnostic studies (EDX) [13]. The canonical distribution of symptoms in the upper extremity which is referable to peripheral compression of the ulnar nerve at the level of the cubital tunnel includes numbness or parasthesias in the small finger [10] and pain localized to either the medial elbow or throughout the medial forearm [13]. Despite the peripheral anatomy supporting this distribution, patients with CuTS may present with symptoms of pain, numbness, tingling, or strange sensations outside of these typical locations. Resolution of extra-territorial symptoms has been documented to occur with release of the median nerve at the carpal tunnel [5]. In a prior study, the distribution of subjective complaints among patients undergoing carpal tunnel release was prospectively studied. The authors reported a greater than 90 % likelihood of symptom resolution outside of the median nerve distribution at early follow-up after surgical release. Based on this data, we hypothesized that a similar result would be seen with CuTS where symptoms outside of the typical ulnar nerve territory would resolve after surgery. The purpose of this prospective study was to provide information to improve the accuracy of pre-operative counseling for patients with cubital tunnel syndrome.

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Materials and Methods

Study Design

A consecutive series of 20 patients were prospectively enrolled in this study between July 2011 and July 2013. During this time period, 70 patients underwent cubital tunnel release by the senior author. All eligible patients who consented to participation were included in the study population. Patients were considered eligible for the study if they met the following inclusion criteria: age greater than 18, clinical history and physical examination consistent with the diagnosis of cubital tunnel syndrome, and EDX demonstrating slowing of ulnar nerve conduction across the elbow. All EDX were performed by one electrophysiologist under standardized conditions. Exclusion criteria included any evidence of cervical radiculopathy, median nerve compression at the wrist, diabetes mellitus, diffuse polyneuropathy present on the EDX studies, or history of prior surgical intervention. Of the 70 patients who underwent surgery, many were excluded due to diabetes or cervical radiculopathy and several refused to participate. Clinical diagnosis was made based on a history of numbness and/or paresthesias in the small and ring fingers exacerbated with prolonged elbow flexion. Physical exam revealed positive Tinel's sign over the cubital tunnel and reproduction of symptoms with elbow flexion. EDX studies consisting of nerve conduction and electromyographic components were routinely obtained to confirm the diagnosis and exclude co-existing pathology at other sites of potential compression. Indication for surgical intervention included failure of non-operative treatment with persistent symptoms.

Patients were enrolled in clinic at their pre-operative visit. 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. Informed consent was obtained from all patients for being included in the study. Each patient was enrolled by an examiner who was unaware of the extent of conduction velocity decrease on the EDX studies. After an informed consent process, patients were asked if they had regularly experienced four different symptom types throughout their operative extremity during the prior 2 weeks. The four symptoms were pain, numbness, tingling, and strange sensations that were clarified as burning or electrical type of sensations. Patient responses were indicated as presence or absence of the symptom at each location. The upper extremity was divided into six zones as shown in Fig. 1.

A physical examination was performed consisting of static two-point discrimination, tested with the Mackinnon-Dellon Discriminator (Lafayette Instruments, Lafayette, IN, USA) at all fingertips. Light touch sensation was tested at all digits using Semmes-Weinstein monofilaments (Smith & Nephew Roylan, Inc., Germantown, WI, USA). Patients also completed

Fig. 1 Division of the upper extremity into six zones. Note the exclusion of the ring finger due to dual innervation

questionnaires including the Boston Carpal Tunnel Questionnaire (CTQ) [11], the Michigan Hand Outcomes Questionnaire (MHQ) [4], and the visual analogue scale (VAS) [20]. The patients were instructed to complete the VAS based on the worst pain they experienced, and not in a particular zone or distribution. The MHQ and CTQ scales were chosen as they have been previously validated for studying outcomes of CuTS and are more responsive than other measures of upper extremity function [15]. At their 6-week follow-up, patients were asked to complete the same assessment of their symptom location and physical exam as well as questionnaires. Our post-operative protocol consisted of a soft dressing for simple in situ decompression and 1 week of above-elbow splinting for transposition cases, with gentle range of motion allowed as tolerated at 1 week. Sutures were usually removed at the 2-week post-operative visit. Physical therapy was instituted on all patients with transposition and

selected patients who lacked full range of motion at 2 weeks after simple decompression.

Statistical Analyses

This sample size was determined based on an a priori power analysis. We reasoned that if one of every two patients with extra-ulnar symptoms reported resolution (number needed to treat=2) that this would represent a clinically significant difference. Variability in the distribution of symptom reports was estimated based on prior work [5]. Therefore, a power analysis for a paired *t* test revealed that a minimum of 18 patients was necessary to detect symptom resolution outside of the ulnar nerve distribution. Assuming a 10 % dropout rate, we enrolled two additional patients and arrived at a justifiable target group of 20 patients.

Descriptive statistics were used to calculate a mean and standard deviation for the number of zones with symptoms per patient. Further analysis revealed a non-normally distributed data set and, therefore, the Wilcoxon Signed-Rank test was used to evaluate for significant differences between means. Probability of symptom resolution in each zone was calculated by dividing the number of post-operative reports by pre-operative reports for each zone and symptom type. Differences in objective outcome data from both the questionnaires and physical examination data was analyzed using paired *t* tests.

Results

Study Population

A total of 20 patients were enrolled in the study. The average age was 44 years (range 30–65) and 25 % of the patients were female. Out of the 20 procedures performed, 15 were in situ decompression of which 11 were open and 4 endoscopic, and 5 patients had anterior transposition performed. Indication for anterior transposition was any evidence of an unstable nerve with elbow flexion intra-operatively. Follow-up assessment occurred at an average of 6.7 weeks (range 4.3–14 weeks) post-operatively.

Probability of Resolution

The largest number of symptom reports pre-operatively occurred in an ulnar distribution with 90 % of the patients reporting numbness in zone I. However, 80 % of the cohort also reported at least one symptom outside of the canonical ulnar nerve distribution. The total pre- and post-operative number of reports per zone as well as the likelihood of resolution for each symptom type per zone is shown in

Table 1. Overall, numbness and tingling were more likely to resolve in zones II through VI than in zone I. Pain symptoms demonstrated a similar pattern with increased probability of resolution in zones representing the median, radial, and axillary nerve distributions (zones III, V, VI). Strange symptoms along the medial arm and forearm showed a higher likelihood of resolution when compared with pain in the same areas.

To further analyze the zoned resolution of symptoms, the extremity was divided into an ulnar and non-ulnar distribution. For the symptoms of numbness and tingling, the ulnar distribution was defined as zone I only, because compression of the ulnar nerve at the elbow would be expected to produce sensory changes only at that area. For the symptoms of pain and strange sensations, the ulnar distribution was defined as zones I, II, and IV. We reasoned that inflammation within the nerve would be expected to cause radiating symptoms along the course of the nerve through the medial arm and forearm [13]. For each symptom type, the mean number of zones in which symptoms were reported was determined for both the ulnar and non-ulnar distributions. Table 2 (A) shows the results for numbness and tingling. Statistically significant resolution of symptoms was noted both within ($p=0.002$, $p=0.007$) and outside of the ulnar distribution ($p=0.018$, $p=0.003$). As shown in Table 2 (B), pain symptoms were found to be significantly improved after surgery in both distributions ($p=0.019$, $p=0.013$). Strange symptoms showed a trend toward improvement in both areas but this did not reach significance ($p=0.071$, $p=0.102$).

Objective Outcome Measures

There was significant improvement on the VAS from 48 pre-operatively to 22 post-operatively ($p=0.008$) (Table 3). There was an improvement in both domains of the CTQ, but only the symptom severity scale demonstrated statistical significance (SSS, $p=0.004$). The average MHQ score improved from 65 to 83 after surgery ($p=0.002$). Physical examination data showed significant improvement in two-point discrimination at the small finger from an average of 7.9 mm pre-operatively

Table 1 Probability of symptom resolution by zone

Symptom	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI
Total pre-op	45	36	8	10	14	6
Total post-op	17	11	0	3	2	2
Numbness	0.55	0.57	1	0.66	1	n/a
Tingling	0.64	0.85	1	0.66	0.75	n/a
Pain	0.77	0.5	1	0.5	0.8	0.75
Strange	0.5	1	n/a	1	1	1

Total pre- and post-operative reports per zone shown in rows 1–2. Probability of resolution of each symptom by zone shown in rows 3–6
n/a not applicable (no reports occurred pre-operatively)

Table 2 Mean number of zones with symptom reports pre- and post-op

	Symptom	Ulnar (<i>red</i>)			Non-ulnar (<i>white</i>)		
		Pre-op	Post-op	Significance	Pre-op	Post-op	Significance
<p>A</p>	Numbness	0.9 (0.31)	0.4 (0.5)	$p=0.002$	0.8 (1.15)	0.2 (0.52)	$p=0.018$
	Tingling	0.7 (0.47)	0.25 (0.44)	$p=0.007$	1.1 (1.07)	0.25 (0.64)	$p=0.003$
<p>B</p>	Pain	1.15 (0.81)	0.45 (0.76)	$p=0.019$	0.6 (0.68)	0.1 (0.31)	$p=0.013$
	Strange	0.5 (0.88)	0.1 (0.31)	$p=0.071$	0.2 (0.52)	0 (0)	$p=0.102$

Reported as mean (SD). Ulnar distribution shown in *red* in the figure

(SD=4.1, range 5–15) to 5.9 mm post-operatively (SD=3.1, range 5–13, $p=0.02$). Similarly, the Semmes-Weinstein monofilament data revealed a significant improvement in small finger sensibility from the 4.31 monofilament pre-operatively (range 2.83 to 6.65 monofilament) to the 3.61 monofilament post-operatively (range 2.83 to 6.65

monofilament, $p=0.037$) but failed to reach significance in the remaining digits.

Discussion

Prior studies have documented resolution of symptoms outside of the canonical median nerve distribution following carpal tunnel release [5]. In this study, we sought to prospectively investigate whether a similar pattern of symptomatic resolution would occur at early follow-up after ulnar nerve release at the elbow. Such information would have prognostic importance when counseling patients regarding expectations for symptom improvement after cubital tunnel release. Our data suggest not only that a large percentage of patients with electrodiagnostic studies consistent with CuTS also have symptoms outside of the typical ulnar nerve distribution but moreover, that these symptoms have a high likelihood of resolving after surgery. Overall, there was a

Table 3 Patient-reported outcome measures

Questionnaire	Pre-operative	Post-operative	Significance ^a
VAS	48.4 (31.3)	22.1 (27.4)	$p=0.008$
FSS	1.98 (0.99)	1.74 (1.05)	$p=0.355$
SSS	2.65 (0.81)	1.84 (0.83)	$p=0.004$
MHQ	64.9 (21.5)	82.6 (18.1)	$p=0.002$

Reported as mean (SD) ($n=15$)

VAS visual analogue scale, FSS functional status scale from the Boston Carpal Tunnel Questionnaire, SSS symptom severity scale from the Boston Carpal Tunnel Questionnaire, MHQ Michigan Hand Outcomes Questionnaire

^a Significance level determined using a paired t test

greater than 66 % probability of extra-territorial symptoms to improve (Table 1). Statistically significant decreases in the mean number of zones with symptoms were found in three of the four symptom types, namely, pain, numbness, and tingling (Table 2 (A and B)). The average number of zones in which strange symptoms were reported pre-operatively was lower than the other symptom types, and although there was a trend toward resolution, there may have been insufficient numbers of reports to reach statistical significance.

The probability of pain resolution after surgery was lower within the ulnar distribution than elsewhere. This may be due to post-operative discomfort around the area of the incision which might be experienced both in the medial arm and/or forearm and may not have completely resolved by 6 weeks which would explain the continued reports of pain in zones II and IV at follow-up. While compression of sensory nerve fibers may produce complaints of numbness, tingling, and paresthesias, compression of motor nerve fibers will give patients a sense of aching and discomfort. The pain reported in zone II along the medial border of the forearm is commonly found among patients with CuTS with aching in the ulnar-innervated muscles. Similarly, the zone IV pain is common with patients with CuTS and may be associated with compression of the ulnar nerve from the arcade of Struthers. Interestingly, all pre-operative reports within zone III, the typical median nerve distribution, resolved after surgery. This propensity for symptoms outside of the canonical normal distribution of the compressed nerve after decompression mirrors previous results [5]. In that study of patients with confirmed isolated median nerve compression, the highest probability of symptom resolution occurred outside of the typical median nerve distribution.

In this study, numbness and tingling within the ulnar distribution, zone I, were least likely to resolve at early follow-up, with only 55 and 64 % probability of resolution, respectively. This is not indicative of failure of surgery to relieve symptoms of CuTS as other studies have demonstrated continued improvement in patient-rated outcomes and physical examination measures for up to 1 year post-operatively; moreover, our primary goal was not to examine long-term outcome as this has already been described, rather we chose to examine for symptom resolution specifically at early follow-up. In this study as in the previous work, we confined our focus to early resolution to allow readers to accurately use our estimates of symptom resolution in counseling patients regarding expected outcomes in the early post-operative period.

Giladi and colleagues reported that significant improvements in the MHQ and CTQ are seen up to 6 months after

surgery, and improvements in two-point discrimination may take 3 months to become significant and may continue for at least 1 year [7]. The present study found a significant improvement in two-point discrimination in the small finger at an earlier follow-up of 6 weeks that may be explained by the presence of several patients with markedly increased values before surgery (>15 mm). Therefore, this finding is not in conflict with the low early probability of resolution in zone I or with the existing literature.

Data from studies of extra-median symptoms in patients with carpal tunnel syndrome (CTS) provides one hypothesis to explain the findings of the present study. Compression of the ulnar nerve at Guyon's canal from increased pressure within the carpal tunnel due to close anatomic proximity was thought to explain the spread of symptoms beyond the median nerve distribution in CTS patients [1, 8, 14]. Subsequent reports indicated that EDX studies of the ulnar distribution in patients with CTS do not correlate with the severity of symptoms, and this argues against distal compression of the ulnar nerve at the wrist as a cause of extra-median spread of symptoms [16, 22]. Interconnections between the median and ulnar nerves in the forearm, or Martin-Gruber connections, have also been ruled out previously as a cause of extra-median spread of symptoms in CTS as they typically involve motor branches and rarely sensory pathways and have been shown with EDX studies to be absent in patients with extra-median symptoms [23].

Instead, spinal, subcortical, and cortical pathways have been implicated in the pathophysiology of symptomatic extra-anatomic peripheral neuropathy [16, 23]. Tecchio and colleagues used magnetoencephalography to study cortical reorganization and plasticity in CTS patients with extra-median symptoms. They found that patients with paresthesias or pain demonstrated altered cortical representation of the affected hand in the contralateral hemisphere, and they hypothesize that aberrant cortical reorganization may underlie persistent symptomatology in patients who fail to improve after carpal tunnel release [17]. NMDA-mediated central sensitization to afferent pain signals within the spinal cord as a result of increased release of spinal dynorphin has been observed in animal models after peripheral nerve injury that may also explain extra-territorial neuropathic pain [12, 22]. Other possible explanations of this phenomenon include associated sub-electrical compression neuropathy such as carpal tunnel syndrome with negative EDX studies or associated thoracic outlet syndrome which could be improved either with post-operative rest, decreased use of the extremity, or physical therapy from a hand therapist. It has been reported that as many as 25 % of patients with clinical symptoms of carpal tunnel syndrome have normal nerve conduction studies

[21], which may partially explain why some patients in the present study experienced median nerve distribution symptoms pre-operatively.

The present study has several limitations. We chose to include multiple surgical approaches to cubital tunnel release; however, in excluding patients who had undergone established, accepted procedures for the treatment of CuTS, we feared rendering our results relevant to only one type of surgical procedure. Previous studies have indicated that similar outcomes can be expected after in situ, anterior transposition, and endoscopic techniques [3], and we found the same in our population. In a prospective trial, Watts and co-workers studied outcomes after endoscopic compared to open in situ release and found no differences at 12-month follow-up [19]. Meta-analyses of different techniques have failed to identify any differences in outcomes after anterior transposition compared to simple decompression [2, 24]. Therefore, we reasoned that inclusion of different approaches to cubital tunnel release would not alter the main outcome of extra-ulnar symptom resolution and perhaps broaden the applicability of our results.

In this study, only patients with EDX-positive CuTS were included; however, other authors have suggested that surgical intervention for clinical symptoms alone without EDX studies is acceptable and effective in the treatment of CuTS [9, 18]. The reliability of extra-ulnar symptoms to resolve without EDX-proven isolated involvement of the ulnar nerve at the elbow cannot be estimated from this report. Indeed, increased reports of extra-territorial symptoms were found among patients with milder CTS disease on neurographic studies [22] and, therefore, one might expect that patients with milder EDX studies would demonstrate a higher probability of resolution compared to a more severe disease, but this cannot be addressed with the current data.

Taken together, the present data suggest that pre-operative counseling of patients with EDX-proven isolated CuTS and symptoms outside of the typical ulnar nerve distribution should indicate a high likelihood (>66 %) of resolution after cubital tunnel release. Future studies could investigate any correlation between disease severity and likelihood of resolution, which would further improve the accuracy of pre-operative information that could be given to patients.

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Conflict of Interest Peter C. Chimenti declares that he has no conflicts of interest.

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Sean M. Childs declares that he has no conflicts of interest.

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Statement of Human and Animal Rights 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 (5).

Statement of Informed Consent Informed consent was obtained from all patients who were included in the study.

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