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Predictors of Functional Outcomes After Simple Decompression for Ulnar Neuropathy at the Elbow: A Multicenter Study by the SUN study group

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Abstract

Objectives—To identify predictors of surgical outcome for ulnar neuropathy at the elbow (UNE).

Design—Prospective cohort followed for 1 year.

Setting—Clinics at five study sites.

Participants—Patients diagnosed with UNE (N=55).

Interventions—All subjects had simple decompression surgery.

Main Outcome Measures—The primary outcome measure was patient-reported outcomes such as overall hand function through the Michigan Hand Outcomes Questionnaire (MHQ). Predictors included age, duration of symptoms, disease severity, and motor conduction velocity across the elbow.

Results—Multiple regression models with the change in the overall MHQ score as the dependent variable showed that at 3 months post-operative time, patients with less than 3 months duration of

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symptoms showed 12 points (95% CI = 0.9, 23.5) greater improvement in MHQ scores than those with 3 months or longer symptom duration. Less than 3 months of symptoms was again associated with 13 points (95% CI = 2.9, 24.0) greater improvement in MHQ scores at 6 months post-op, but it was no longer associated with better outcomes at 12 months. Worse baseline MHQ score was associated with significant improvement in MHQ scores at 3 months (coeff=-0.38, 95% CI = -0.67, -0.09), and baseline MHQ score was the only significant predictor of 12-month MHQ scores (coeff=-0.40, 95% CI=-0.79, -0.01).

Discussion—Subjects with less than 3 months of symptoms and worse baseline MHQ scores, showed significantly greater improvement in functional outcomes as reported by the MHQ. However, duration of symptoms was only predictive at 3 or 6 months because most patients recovered within 3 to 6 months after surgery.

Keywords

ulnar neuropathy at the elbow; simple decompression; outcomes; Michigan Hand Outcomes Questionnaire

Ulnar neuropathy at the elbow (UNE) is a condition that is often treated with surgery to relieve compression on the nerve. There are several surgical options for UNE including simple decompression, anterior transposition (subcutaneous, submuscular, and intramuscular) and medial epicondylectomy. Several studies, including meta-analyses¹⁻³ and systematic reviews^{4,5}, have compared surgical treatments for UNE but no particular treatment has been found to be superior. More recently, simple decompression has been recommended as the preferred treatment because it is effective, less invasive and results in fewer complications.⁶

Few studies have focused on identifying factors that predict better surgical outcomes for UNE. Knowing those factors that improve outcomes will benefit patients and physicians through increased satisfaction and setting realistic goals. Predictive factors were identified in some of the surgical comparison studies and include increased nerve enlargement⁷, decreases in motor conduction velocity⁷, duration of symptoms⁸⁻¹⁰, gender¹¹, age¹², and stage of disease.^{9,13} A recent systematic review by Shi et al identified predictors of outcomes following anterior transposition of the ulnar nerve.¹⁴ The literature search resulted in 26 studies and found 6 factors (age, duration of symptoms, severity status, electrodiagnostic testing results, type of anterior transposition surgery, and worker compensation status) that were identified as predictors. However, because of conflicting results among the studies, the authors were unable to identify any predictors for ulnar nerve surgery outcomes.

This paper analyzes results from the Study of Ulnar Nerve (SUN) project, a multi-center prospective cohort study, to identify predictors of outcomes. The study sample consists of patients diagnosed with UNE who were treated with simple decompression at five study sites.

One of the aims of the study was to validate patient-reported outcome questionnaires for UNE. Research on UNE has lagged behind the most common compressive neuropathy,

carpal tunnel syndrome (CTS), in utilizing patient-reported outcome questionnaires.¹⁵ Several papers have reported that patient-reported outcome questionnaires are more responsive to clinical change than traditional measures such as grip or pinch strength for CTS.^{16,17} The Carpal Tunnel Questionnaire (CTQ) and the Disabilities of Hand and Shoulder (DASH) questionnaire have been validated for UNE.¹⁸ More recently, as a result of the SUN study, the Michigan Hand Outcomes Questionnaire (MHQ) was also validated for UNE.¹⁹ Given these results, overall change in MHQ scores was used as the outcome variable in the analysis presented in this paper. The purpose of this paper is to identify factors that will predict hand outcomes following simple decompression for UNE.

METHODS

Study sample population

Subjects included in this analysis were recruited at five medical centers participating in the SUN study. These centers included the AA, BB, CC, DD, and EE. All centers received Institutional Review Board approval prior to patient recruitment. Consecutive patients diagnosed with UNE clinically and confirmed by electrodiagnostic studies were approached by a study coordinator and if consent was obtained, enrolled into the study. The inclusion criteria for the study included confirmation of UNE by electrodiagnostic testing, 18 years of age or older, and the ability to read and write in English. Confirmation of UNE was defined as having an ulnar nerve conduction velocity of less than 50m/sec across the elbow. Electrodiagnostic testing was performed at each study site and reports were sent to the coordinating site for review. The exclusion criteria were previous trauma to elbow, recurrent UNE after previous surgery, and concomitant conditions such as CTS. We collected data on diabetes diagnosis but did not exclude those subjects from the analysis. All enrolled subjects had simple decompression surgery to treat UNE. Subjects who were found to need further surgery such as anterior transposition were excluded from the study (n=1). After surgery, all patients were told to avoid strenuous activities for 6 weeks but did not have formal therapy. Payment for the surgery was the responsibility of the subject's insurance.

Outcome measures

Study measurements occurred at enrollment, 6 weeks, 3 months, 6 months, and 1 year after surgery. Physical measurements included grip and key pinch strength, 2 point discrimination, and the Semmes-Weinstein monofilament test. Using Dellon's criteria for staging, each subject was assigned as mild, moderate or severe stage at enrollment by the principal investigator.²⁰ The conduction velocity measurements across the elbow were obtained from the electrodiagnostic testing. In addition to physical measures, we collected patient-reported outcomes using the Michigan Hand Outcomes Questionnaire (MHQ). The MHQ is a 37 item hand specific questionnaire and contains six domains (function, activities of daily living (ADL), work, pain, aesthetics, and satisfaction).^{21,22} Scores range from 0 to 100 with higher scores indicating better performance, with the exception of the pain scale. For the pain scale, a higher score indicates more pain. An overall score is calculated by averaging the six domain scores. Patients initially filled out the MHQ in clinic but were mailed the questionnaires prior to follow-up visits.

Surgical procedure

Simple decompression was used for all patients in this cohort. The surgeons from all the study sites are trained in hand surgery, and used the following standardized procedure. A 3-centimeter curvilinear incision is made posterior to the medial epicondyle and the medial antebrachial cutaneous nerve is preserved. The ulnar nerve is identified proximally, and Osborne's ligament is divided to free the ulnar nerve. If the ulnar nerve subluxed anteriorly with elbow flexion, anterior transposition was performed and the patient was excluded from the study.

Data analysis

To identify factors associated with variability in hand outcomes following simple decompression for UNE, separate multiple regression analyses were done using change from baseline in the overall MHQ score at each of 3 follow-up assessment times (3 months, 6 months, and 1 year) as the dependent variable. Age, baseline MHQ scores, duration of symptoms, disease severity, and electrodiagnostic testing were used as potential predictors to assess their independent association with hand outcomes at each follow-up time. Duration of symptoms was collected as two levels of less than 3 months versus 3 months or longer, and preoperative disease stage was collected as three levels of mild, moderate, or severe. Disease stage was initially considered as three levels using indicator variables, but in the final model was collapsed into two levels, after finding that the parameter estimates of the adjacent categories were similar in size and not statistically different. We also fit a linear mixed-effects model using MHQ scores from all three follow-up times as the dependent variable to be able to make use of the larger data and to compare across times. The model included patient as random intercepts to account for potential within-person correlation of multiply assessed outcomes and dummy indicators for follow-up assessment times as well as baseline covariates including baseline values of the MHQ.

Owing to missing data in some predictors and follow-up MHQ scores, parameter estimates of the predictors from the models were obtained using multiply imputed datasets. Using logistic regression models, we first examined if each baseline variable is associated with whether the patients were missing follow-up measurements or not at each follow-up times. Prior to imputation, normality of the continuous variables was checked, and for binary and categorical variables, imputations were done using logistic and multinomial logistic regression model, respectively. Five multiply imputed datasets were created where missing covariates and missing follow-up MHQ scores were imputed using all baseline covariates, including those not significantly associated with the missing follow-up MHQ scores, and all follow-up MHQ data to account for the correlation across longitudinally measured outcome data of an individual patient. The individual estimates of the predictors from the five imputed datasets and the standard errors (SE) from each of the five imputed datasets were pooled using Rubin's combining rules to obtain overall estimates and SEs accounting for missing data uncertainty by allowing for the between-and within-imputation components of variation.²³ All analyses were done using Stata 12.1 (College Station, TX), and statistical significance was set at 0.05.

RESULTS

A flowchart of the study enrollment is shown in Figure 1. One hundred and twelve patients were eligible for the study and 78 enrolled. Twenty three enrolled patients withdrew or were lost to follow-up or excluded from the study. A total of 55 subjects were included in the analysis. The number of subjects at each time period dropped from 50 at 3 months to 41 at 1 year. Demographic data for the sample are shown in Table 1. Race was missing in 1 patient, stage in 2 patients, symptom duration in 11 patients and electrodiagnostic testing values in 5 patients. The mean age of the sample was 48 years and subjects were predominantly white men. The majority of subjects had moderate severity UNE and had symptoms for 3 months or longer. Twenty two (40%) of the subjects had conservative treatment prior to surgery. Symptom duration and severity levels were not associated with each other ($\chi^2_{(2)} = 28$; $p = 0.87$).

The mean MHQ scores at each time period are shown in Figure 2. Overall, subjects start with lower MHQ scores, and scores increased up to 6 months post-operative time. After six months, MHQ scores showed no further improvement; this was also reflected in the mean change in MHQ scores from baseline. The mean change in MHQ scores from baseline was 14 at 6 weeks, 19 at 3 months, 21 at 6 months, and 18 at 1 year.

The number of subjects providing follow-up data got smaller with longer term follow-up time. About 16% of patients dropped out at 6 months and 25% at 1 year and thus were missing follow-up MHQ scores. White race was less likely to drop out at 3 months ($p = 0.04$) and higher conduction velocity across elbow was associated with dropping out at 6 months ($p = 0.06$). None of the other baseline variables, including MHQ scores, age and severity of disease, was associated with whether MHQ scores were missing or not at 3 months, 6 months or 12 months, neither by statistical significance nor by effect size. We also did not find MHQ scores from prior assessment time to be associated with missing the MHQ scores at following assessment time. Due to relatively large percent of missing data (e.g., 25% missing 1 year outcome data), primary results are from the regression models based on five imputed datasets (Table 2). The findings were not substantively different from the results based only on the observed data.

At 3 months after surgery, subjects with less than 3 months of symptoms showed 12 points (95% CI = 0.9, 23.5) greater improvement in their MHQ scores than those with longer symptom duration. Additionally, better baseline function (i.e., higher MHQ scores) was associated with smaller improvement at 3 months, controlling for other characteristics. Although only marginally significant ($p < 0.1$), older subjects showed poorer improvement in MHQ scores. At six months after surgery, duration of symptoms was the only statistically significant predictor of outcomes, although age and baseline MHQ scores were marginally significant. Subjects with less than 3 months of symptoms remained to show 13 points (95% CI = 2.9, 24.0) greater improvement in MHQ scores at six months than those with longer symptom duration. The Minimal Clinically Important Difference (MCID) is a 12 point change in MHQ scores among UNE patients,²⁴ and thus the difference in MHQ associated with patients with less versus greater than or equal to 3 months of symptoms at 3 and 6

months are considered clinically significant. This was no longer the case at 1 year after surgery, and only baseline MHQ score was a significant predictor of 1 year hand outcomes.

Although the coefficients are not significant at any assessment time, subjects with severe stage reported greater improvement in functional outcomes, controlling for other variables. Severe stage patients begin with lower MHQ scores (mean MHQ scores of 58 for mild, 56 for moderate, and 50 for severe stage at baseline), but at six months the mean MHQ scores were about the same for all stages of disease (76, 75, 78, respectively) and similarly at one year after surgery (75, 69, 75, respectively).

Results from a linear mixed-effects model based on data from all three follow-up times were similar to those from models fit separately for each follow-up time (Table 3). After controlling for baseline values of MHQ, age and severity, an overall MHQ was estimated to be 14.1 points higher across the three follow-up times than baseline in those with 3 months or longer symptoms, with no further improvement at later follow-up times. Consistent with the findings from the separate analysis at each follow-up time, those with less than 3 months of symptom, compared with those with 3 month or longer symptoms, had 8.3 points higher MHQ at 3 months and 12.5 points higher MHQ at 6 months, but hardly a difference was seen at one year. In addition, effects of age and baseline MHQ were significant, and severe stage of the disease were marginally significant predictors of post-surgical MHQ.

DISCUSSION

Resolution of symptoms, improvement in functional status and controlling disease progression are the goals for UNE surgery. Knowledge of factors that predict favorable outcomes can help patients to set realistic expectations and increase satisfaction. Our analysis found that duration of symptoms is a potential predictor for outcomes after UNE surgery. However, we found this factor to be a predictor of outcomes only during 3 to 6 months after surgery.

Our results showing the relationship between longer duration of symptoms and poorer outcomes during the first six months after surgery has been reported in several retrospective studies. For example, Charles et al's retrospective study of 49 patients treated with anterior transposition found that those with symptoms longer than 6 months had worse outcomes.¹⁰ Another retrospective study with 107 patients with UNE found that patients with symptoms for greater than 3 years had poor results.⁹ Furthermore, LeRoux et al's retrospective study of simple decompression for UNE found that the best results were seen for those with symptoms for less than 1 year.⁸ Patients who had symptoms for longer than a year and muscle wasting had the worst outcomes.

Based on previous studies, we hypothesized that those with more severe disease would show less improvement in overall function. In our sample, subjects with more severe disease tended to show greater improvement than those with mild or moderate disease, controlling for baseline values of MHQ and other characteristics. However, this result was not statistically significant at any of the follow-up times. Previous studies such as Dellon's review of 50 studies found that severe stage of disease was associated with poor results

regardless of the type of surgery.²⁰ Additionally, Mowlavi et al's meta-analysis of 30 studies found that patients with severe disease were not helped by any type of surgery.² Bimmler and Meyer found that stage of disease was independent of outcome, but those patients with severe disease at baseline do not improve as much.¹³ The difference between our study and previous studies is that we are using patient-reported outcomes as our response variable. It may be that those with more severe disease perceive a marked improvement in overall function and symptoms, compared to those with milder disease and this is reflected in improved MHQ scores. An important discovery of outcomes research is that patient reported outcomes often do not correlate with so called more objective outcomes such as grip strength or motion. In other words, even though the sensation and strength do not improve much for those with severe disease, some alleviation of discomfort after nerve decompression translated into perceived good outcomes by the patients. Because severe staged patients and those with worse baseline function start with worse symptoms and function, they perceive more improvement, which is reflected in a greater change in MHQ scores at all follow-up times.

We found that duration as a predictor is only significant up to six months post-operative in this sample. This result is consistent with a previous analysis looking at the trend of recovery after surgery.²⁵ The analysis found there is significant recovery in patient reported outcomes in the 6 week post-operative period and recovery tends to plateau between 3 and 6 months after surgery. Because the majority of patient-reported outcomes have improved by 6 months, the lack of predictors at 1 year is not surprising. At one year, factors such as duration and other demographics variables have little impact on outcomes because the majority of patients have recovered at that point in time.

Study Limitations

A limitation of the study is the extent of missing data. To compensate for this, we used multiple imputations to handle missing data. We found no difference in our findings based on multiply imputed datasets from the results based on observed data. The study is also limited by the sample size. Our lack of significant findings may be due the small sample and low power to detect change. We limited our follow-up to one year and therefore were unable to determine predictors for those with more severe injuries who take longer to recover. We collected information on diabetes at enrollment but did not adjust for this in our analysis. Although diabetes has been considered a risk factor for ulnar neuropathy²⁶, several studies have not shown diabetes to be associated with UNE outcomes.^{27,28} However, if the diabetics in our study had worse outcomes this could have affected our results. Lastly, the majority of our study sample, although geographically diverse, was seen at academic medical centers and may not reflect the general population.

CONCLUSION

Our results support the association of duration of disease and baseline function as potentially important predictors of outcomes after simple decompression for UNE. Physicians should take these factors into consideration when communicating expected outcomes with patients and evaluating short-term recovery and outcomes. Additionally, it is important to note, that

by six months post-operative, the majority of patients have recovered and these factors no longer are valid predictors of functional outcome at one year.

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Abbreviations

MHQ	Michigan Hand Outcomes Questionnaire
UNE	Ulnar neuropathy at the elbow
CTS	Carpal tunnel syndrome
CTQ	Carpal Tunnel Questionnaire
DASH	Disabilities of Hand and Shoulder Questionnaire
SUN	Study of Ulnar Nerve
ADL	Activities of Daily Living
MCID	Minimal Clinically Important Difference

References

1. Zlowodzki M, Chan S, Bhandari M, Kallianen L, Schubert W. Anterior transposition compared with simple decompression for treatment of cubital tunnel syndrome. A meta-analysis of randomized, controlled trials. *J Bone Joint Surg Am.* 2007; 89:2591–2598. [PubMed: 18056489]
2. Mowlavi A, Andrews K, Lille S, Verhulst S, Zook EG, Milner S. The management of cubital tunnel syndrome: a meta-analysis of clinical studies. *Plast Reconstr Surg.* 2000; 106:327–334. [PubMed: 10946931]
3. Macadam SA, Gandhi R, Bezuhly M, Lefaivre KA. Simple decompression versus anterior subcutaneous and submuscular transposition of the ulnar nerve for cubital tunnel syndrome: a meta-analysis. *J Hand Surg Am.* 2008; 33:1314, e1311–1312. [PubMed: 18929194]
4. Caliendo P, La Torre G, Padua R, Giannini F, Padua L. Treatment for ulnar neuropathy at the elbow. *Cochrane Database Syst Rev.* 2011:CD006839. [PubMed: 21328287]
5. Bartels RH, Menovsky T, Van Overbeeke JJ, Verhagen WI. Surgical management of ulnar nerve compression at the elbow: an analysis of the literature. *J Neurosurg.* 1998; 89:722–727. [PubMed: 9817408]
6. Chung KC. Treatment of ulnar nerve compression at the elbow. *J Hand Surg Am.* 2008; 33:1625–1627. [PubMed: 18984348]
7. Beekman R, Wokke JH, Schoemaker MC, Lee ML, Visser LH. Ulnar neuropathy at the elbow: follow-up and prognostic factors determining outcome. *Neurology.* 2004; 63:1675–1680. [PubMed: 15534254]
8. LeRoux PD, Ensign TD, Burchiel KJ. Surgical decompression without transposition for ulnar neuropathy: factors determining outcome. *Neurosurgery.* 1990; 27:709–714. discussion 714. [PubMed: 2259400]
9. Yamamoto K, Shishido T, Masaoka T, Katori Y, Tanaka S. Postoperative clinical results in cubital tunnel syndrome. *Orthopedics.* 2006; 29:347–353. [PubMed: 16628995]

10. Charles YP, Coulet B, Rouzaud JC, Daures JP, Chammas M. Comparative clinical outcomes of submuscular and subcutaneous transposition of the ulnar nerve for cubital tunnel syndrome. *J Hand Surg Am.* 2009; 34:866–874. [PubMed: 19410989]
11. Shi Q, MacDermid J, Grewal R, King GJ, Faber K, Miller TA. Predictors of functional outcome change 18 months after anterior ulnar nerve transposition. *Arch Phys Med Rehabil.* 2012; 93:307–312. [PubMed: 22289242]
12. Terzis JK, Kokkalis ZT. Outcomes of secondary reconstruction of ulnar nerve lesions: our experience. *Plast Reconstr Surg.* 2008; 122:1100–1110. [PubMed: 18827643]
13. Bimmler D, Meyer VE. Surgical treatment of the ulnar nerve entrapment neuropathy: submuscular anterior transposition or simple decompression of the ulnar nerve? Long-term results in 79 cases. *Ann Chir Main Memb Super.* 1996; 15:148–157. [PubMed: 8791977]
14. Shi Q, MacDermid JC, Santaguida PL, Kyu HH. Predictors of surgical outcomes following anterior transposition of ulnar nerve for cubital tunnel syndrome: a systematic review. *J Hand Surg Am.* 2011; 36:1996–2001. e1991–1996. [PubMed: 22123047]
15. Macadam SA, Bezuhly M, Lefaivre KA. Outcomes measures used to assess results after surgery for cubital tunnel syndrome: a systematic review of the literature. *J Hand Surg Am.* 2009; 34:1482–1491. e1485. [PubMed: 19801108]
16. Katz JN, Gelberman RH, Wright EA, Lew RA, Liang MH. Responsiveness of self-reported and objective measures of disease severity in carpal tunnel syndrome. *Med Care.* 1994; 32:1127–1133. [PubMed: 7967853]
17. Gay RE, Amadio PC, Johnson JC. Comparative responsiveness of the disabilities of the arm, shoulder, and hand, the carpal tunnel questionnaire, and the SF-36 to clinical change after carpal tunnel release. *J Hand Surg Am.* 2003; 28:250–254. [PubMed: 12671856]
18. Zimmerman NB, Kaye MB, Wilgis EF, Zimmerman RM, Dubin NH. Are standardized patient self-reporting instruments applicable to the evaluation of ulnar neuropathy at the elbow? *J Shoulder Elbow Surg.* 2009; 18:463–468. [PubMed: 19393937]
19. Song JW, Waljee JF, Burns PB, et al. An Outcome Study for Ulnar Neuropathy at the Elbow: A Multicenter Study by the SUN Study Group. *Neurosurgery.* 2013; 72:971–982. [PubMed: 23426153]
20. Dellon AL. Review of treatment results for ulnar nerve entrapment at the elbow. *J Hand Surg Am.* 1989; 14:688–700. [PubMed: 2666496]
21. Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. *J Hand Surg Am.* 1998; 23:575–587. [PubMed: 9708370]
22. Chung KC, Hamill JB, Walters MR, Hayward RA. The Michigan Hand Outcomes Questionnaire (MHQ): assessment of responsiveness to clinical change. *Ann Plast Surg.* 1999; 42:619–622. [PubMed: 10382797]
23. Rubin, DB. *Multiple Imputation for Nonresponse in Surveys.* Wiley; New York: 1987.
24. Malay S, Chung KC. The Minimal Clinically Important Difference After Simple Decompression for Ulnar Neuropathy at the Elbow. *J Hand Surg Am.* 2013; 38:652–659. [PubMed: 23474160]
25. Giladi AM, Gaston RG, Haase SC, et al. Trend of Recovery after Simple Decompression for Treatment of Ulnar Neuropathy at the Elbow. *Plast Reconstr Surg.* 2013; 131:563e–573e.
26. Cutts S. Cubital tunnel syndrome. *Postgrad Med J.* 2007; 83:28–31. [PubMed: 17267675]
27. Friedman RJ, Cochran TP. A clinical and electrophysiological investigation of anterior transposition for ulnar neuropathy at the elbow. *Arch Orthop Trauma Surg.* 1987; 106:375–380. [PubMed: 3435238]
28. Nakamichi K, Tachibana S, Ida M, Yamamoto S. Patient education for the treatment of ulnar neuropathy at the elbow. *Arch Phys Med Rehabil.* 2009; 90:1839–1845. [PubMed: 19887206]

Figure 1.
Flowchart of study enrollment

Figure 2.
Mean MHQ Scores by Follow-up Time

Table 1

Baseline Patient Characteristics (N = 55)

<u>Patient Characteristics</u>	<u>Mean (Range)</u>
Age in years	48(19-79)
Conduction velocity across elbow	41 (15-64)
Overall MHQ score	55 (14-88)
	N (%)
Gender - Male	32 (58)
Race *	
White	43 (80)
Black	6 (11)
Other	5 (8)
Duration*	
< 3 months	15 (34)
3-12 months	29 (66)
Stage *	
Mild	16 (30)
Moderate	23 (43)
Severe	14 (27)

* 1 missing race, 11 missing duration, 2 missing stage

Table 2

Regression models of change in MHQ at 3, 6 and 12 months follow-up times based on five multiply imputed datasets

Baseline Characteristics	3 months			6 months			1 year		
	Coef.	p-value	95% CI	Coef.	p-value	95% CI	Coef.	p-value	95% CI
Baseline MHQ	-0.38	0.01	-0.67, -0.09	-0.23	0.09	-0.49, 0.04	-0.40	0.04	-0.79, -0.01
Age in years	-0.37	0.09	-0.81, 0.07	-0.32	0.07	-0.67, 0.02	-0.48	0.14	-1.1, 0.18
Duration < 3 months [*]	12.2	0.03	0.94, 23.5	13.4	0.02	2.87, 24.0	-4.2	0.51	-17.1, 8.8
Severe Stage [§]	11.1	0.23	-8.46, 30.7	8.6	0.22	-5.84, 23.0	8.6	0.29	-8.2, 25.4
Across elbow CV	0.40	0.32	-0.44, 1.24	0.08	0.82	-0.70, 0.86	-0.27	0.44	-1.0, 0.45
Constant [#]	10.2	0.01	2.75, 17.59	14.2	0.001	7.09, 21.22	18.10	0.001	8.88, 27.33

Abbreviations: CI is confidence interval, MHQ is Michigan Hand Outcomes Questionnaire, CV is conduction velocity.

^{*} Reference level is duration 3 months.

[§] Reference level is mild or moderate stage.

[#] Expected change in MHQ for "average" person of age 50, baseline MHQ score of 55, baseline across elbow CV of 40, with longer than 3 months of symptoms and mild/moderate stage of disease.

Table 3

Linear mixed-effects model of change in MHQ at 3, 6 and 12 months follow-up times based on five multiply imputed datasets

MHQ Change	Coef.	t	p-value	95% Conf. Interval
Baseline MHQ	−0.34	−2.91	0.005	−0.56, −0.11
Age in years	−0.39	−2.31	0.023	−0.73, −0.06
3 Month by Duration < 3 months	8.29	1.65	0.101	−1.61, 18.19
6 Months by Duration < 3 months	12.51	2.35	0.021	1.95, 23.06
12 Months by Duration < 3 months	0.66	0.12	0.905	−10.26, 22.58
Severe Stage [§]	9.44	1.87	0.067	−0.67, 19.54
Across elbow CV	.07	0.22	0.826	−0.58, 0.71
Constant [*]	14.14	5.20	<0.001	8.79, 19.50

Abbreviations: CI is confidence interval, MHQ is Michigan Hand Outcomes Questionnaire, CV is conduction velocity.

#Time-averaged expected change in MHQ for “average” person of age 50, baseline MHQ score of 55, baseline across elbow CV of 40, with longer than 3 months of symptoms and mild/moderate stage of disease.

[§]Reference level is mild or moderate stage.