Title

Prospective Pilot Study Comparing Pre- and Postsurgical CTSAQ and Neuro-QoL Questionnaire with Median Nerve High-Resolution Ultrasound Cross-Sectional Areas

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Pre- and Post-Surgery Assessment of Carpal Tunnel Syndrome (CTS) Patients: A Prospective Pilot Study Comparing CTSAQ and Neuro-QOL for Self-Assessment Outcomes and Characterizing Median Nerve Cross Sectional Area with High Resolution Ultrasound

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Abstract

Purpose—The aims of this study were 1) to assess the utility of the Neuro-QoL questionnaire in patients with carpal tunnel syndrome by comparing the validated patient reported outcome measure (PRO) Neuro-QoL to the validated CTSAQ before and following carpal tunnel release, 2) to compare the measurements of the median nerve cross sectional area (CSA) using high resolution ultrasound (HRUS) pre- and post-surgery, 3) to determine a correlation between HRUS and patient reported outcomes.

Methods—Individuals diagnosed with carpal tunnel syndrome were evaluated using the CTSAQ, Neuro-QoL, and HRUS preoperatively and at 3 months postoperatively.

Results—Twenty patients completed the study. Overwhelmingly, there was an improvement in symptoms and function assessed by patients on both the Neuro-QoL and CTSAQ at 3 months postoperatively. Neuro-QoL physical function and upper extremity scores had strong correlation with the CTSAQ activity score but had low to moderate correlation with the CTSAQ symptoms score, before and after surgery. High-resolution ultrasound measurements of the median nerve at the carpal tunnel inlet demonstrated a decrease in CSA whereas no noticeable changes were observed at mid-tunnel, and at the outlet (hook of hamate). The correlations between the ultrasound findings and patient outcome measures ranged from weak to strong.

Conclusions—Patients had resolution of symptoms and higher physical function following carpal tunnel release measured by both the CTSAQ and Neuro-QoL scores. The Neuro-QoL self-assessment questionnaire, a measurement of quality of life (QoL), correlated well with CTSAQ.

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Therefore, it could be used as a self-assessment outcomes tool in patients undergoing carpal tunnel release. At 3 months post-operatively, HRUS measurements of the median nerve CSA showed a noticeable decrease of cross of carpal tunnel. This objective improvement correlated with the improvement in CTSAQ and Neuro-QoL scores.

Keywords

Carpal; Tunnel; Neuro-QoL; CTSAQ; Ultrasound

INTRODUCTION

Carpal tunnel syndrome (CTS) is caused by compression of the median nerve at the wrist and is the most frequently occurring peripheral nerve compression disorder[1,2]. The diagnosis is mainly clinical and based on a classic triad of symptoms of night pain, paresthesia in the median nerve distribution, and thenar weakness[3,4]. After failing a trial of non-operative treatment, surgery is indicated.

Current concepts regarding the pathophysiology of CTS are based on anatomic factors, namely the cross sectional area of the carpal tunnel, and wrist and hand anthropometric measurements[5,6]. Detailed characterization of the spatial constraints in the carpal tunnel and of the median nerve itself is lacking due to unstandardized imaging protocols. Recent advances in high resolution ultrasound (HRUS) technology have the potential to solve these technical problems. A cross sectional view of the median nerve using HRUS at the carpal tunnel is an emerging technique in supporting the diagnosis of CTS and monitoring the efficacy of treatments[7–16]. Data are limited, however, due to poor protocol standardization and cross-sectional study designs. To our knowledge, no studies have correlated ultrasound findings of pre- and post-carpal tunnel release with patient reported outcomes (PRO) such as Neuro-QoL. The Quality of Life in Neurological Disorders (Neuro-QoL)[22,23] questionnaire is an emerging patient centered measurement tool to address Quality of Life issues in neurological conditions. It is used to assess health-related quality of life in many neurologic disorders (e.g. epilepsy, stroke, muscular dystrophies, Parkinson's disease, multiple sclerosis), and encompasses physical, mental and social domains.

Each domain includes self-reported questionnaires to assess quality of life including, but not limited to, upper and lower limb function, Activities of Daily Living, social interaction, depression and anxiety. As such it is a robust validated neurological disease PRO that is different from a disease specific or regional specific PRO.

With respect to CTS, past research has focused on assessing objective clinical measures like electrodiagnostic tests with less emphasis on the development of validated patient-reported quality of life outcome tools, yet the treatment algorithm for CTS now relies heavily on patient reported symptoms. The current general and regional upper limb outcome measures that are used in CTS studies include the SF-36[17] and the Disability of Arm Shoulder Hand (DASH)[18] questionnaires. Hand function-specific and CTS-specific questionnaires have also been validated, and these include the CTS Assessment Questionnaire (CTSAQ)[19,20] and Michigan Hand Outcomes Questionnaire (MHQ)[21]. The CTSAQ is divided into two parts (symptom severity and function) and measures 8 common hand activity-related tasks and an

11 item symptom severity scale including night and daytime pain, numbness and weakness. The CTSAQ has been compared to objective tests, namely neurophysiological studies, with variable findings.

The Neuro-QoL upper extremity function domain (Table 1) is evaluated in this study and compared to objective structural changes of the median nerve before and after carpal tunnel release as well as to the reference standard CTSAQ outcome measure. While the Neuro-Qol has been validated in more severe neurologic diseases, its Upper Extremity Function Module has not been tested in an isolated upper extremity neurological condition. If it proves to be sensitive, it may be useful to include the mental health and social health modules for CTS and other upper extremity neurological conditions in future research.

In this pilot study, we aimed to use HRUS in a standardized protocol with a prospective study design to characterize median nerve cross sectional area before and after surgery. We also compared pre- and post-surgery patient reported outcomes comparing Neuro-QoL to the CTSAQ which served as the reference standard. Lastly, we examined the correlation between the HRUS findings and both patient reported outcome measures.

METHODS

Participants

This study was approved by the Institutional Review Board. Participants adhered to the study protocol and signed an informed consent to participate. Twenty patients with CTS were studied. Participants with a clinical diagnosis of CTS were recruited from a single surgeon's hand clinic from January 1, 2014 to March 1, 2016. CTS was diagnosed with a combination of the nerve compression test, Phalen's test, Tinel's test, two-point discrimination, light touch, and motor testing of the thenar muscles. While each finding was not present in every patient, the history of numbness, tingling and nocturnal pain in the median nerve distribution, positive electrodiagnostic tests and two or more positive physical findings were considered necessary for the diagnosis of carpal tunnel syndrome. A failure of non-operative treatment (night time splinting for 6 weeks) was an indication for surgery, which was a necessary component for being entered into this study. Patients with a diagnosis of moderate to severe CTS defined by electrodiagnostic criteria for the preceding two months were included. Electrodiagnostic evidence of CTS adhered to the American Association of Neuromuscular and Electrodiagnostic Medicine (AANEM) criteria. Patients with mild severity on electrodiagnostic study were treated with splinting and some with steroid injection and were not enrolled in the study. Adults unwilling to participate, children (age <18 years old), pregnant women, and patients with diabetes, rheumatologic conditions, thyroid dysfunction and/or evidence of diffuse peripheral neuropathy were excluded. Patients with previous carpal tunnel release of the contralateral hand within the past six months, history of hand/wrist fracture or severe trauma on the affected side, and history of neurologic disorders which may have caused confusion for the diagnosis of CTS were excluded. Over the course of two years, only 37 patients were willing to give their time to commute twice and have ultrasound examinations twice in addition to their surgical scheduling, and post-operative visits and only 20 completed the study.

Clinical data

Twenty patients completed the CTSAQ and Neuro-QoL questionnaires and ultrasound examination to quantify median nerve cross-sectional area prior to open carpal tunnel release surgery and three months post-operatively. Scores from the CTSAQ and Neuro-QoL were compared both pre- and post-operatively.

Sonographic data

We performed HRUS pre-operatively and 3 months after surgery using Biosound MyLab 25-Gold ultrasound, and the Linear Array transducer (Model # LA435). The transducer being used in this study had a frequency range of 6–18 megahertz (MHz) specifically designed for imaging superficial nerves, tendons, ligaments, and muscles. To ensure quality sonographic measures, we followed the recommendations of Roll et al.[24] Ultrasound imaging of the median nerve was performed using a broad bandwidth transducer and a 12–15 MHz linear array using the method described by Wiesler et al.[15]. The ultrasound probe was placed at the midline between the radius and ulna with the center of the probe at the distal wrist crease. The length of the nerve was imaged in line with the wrist crease and the median nerve was imaged from the wrist crease to 2 cm distal to the wrist crease or until the nerve was no longer identifiable. The probe was kept directly perpendicular to the long axis of the nerve to ensure that the area measured reflected a true cross-sectional area. Spatial compound imaging was used to obtain static measurements with an axial resolution of 0.5 mm, lateral resolution 0.5 mm, and a slice thickness of 1.5 mm. We measured the cross-sectional area of the median nerve at the carpal tunnel inlet at the level of the distal wrist crease using the pisiform as a consistent internal landmark. The mid-tunnel cross-sectional area of the nerve was measured distal to the inlet under the transverse carpal ligament using bony landmarks that included the scaphoid (radially), and the pisiform (ulnarly). The tunnel outlet cross-sectional area was measured at the line that intersected the trapezium and the hook of hamate. The area measurements were repeated 5 times, deleting the highest and lowest values, and the mean of remaining values was used for statistical evaluation. To perform the largest cross-sectional area measurements, the ultrasound technician utilized the direct measurement technique, tracing a continuous line around the inner hyperechoic rim of the median nerve with electronic calipers. To minimize bias, the area measurement was not displayed until after the final trace was complete.

CTSAQ

This questionnaire uses a five point Likert-scale instrument composed of two components: 11 questions assess symptom severity and 8 questions evaluate subjective hand function (activity). Each question is answered on a 1 to 5 scale and higher CTSAQ scores indicated greater disease severity[25–2728,29] These scales are reliable and responsive to clinical change. [25] A decrease of 1.04 or more in the CTSAQ score indicated a clinically important improvement of health[20].

Neuro-QoL

Participants were interviewed by our research coordinator who administered the questionnaire. It has two components making up a total of 20 questions (Table 1). Each

question is answered on a 1 to 5 scale. A higher score indicates better physical function. The first component includes 14 questions relating to physical function, and 6 questions focused on the difficulty with performing an upper extremity task. This quality of life assessment measure utilizes item response theory and creates a continuous linear scale. For each individual, standard Neuro-QoL assessment software (www.Neuro-QoL.org) was used to estimate the participant's T-score for each domain in which the average T- score for the general U.S. population is 50 and the standard deviation is 10. We used these data to characterize our participants by self-reported upper extremity functional status. For Neuro-QoL, the clinically meaningful improvement was defined as an increase of 10 points or greater[23]. Both CTSAQ and Neuro-QoL questionnaires were administered at each ultrasound exam visit.

Statistical Analysis

Means and 95% confidence intervals were reported for HRUS measures, CTSAQ scores, and Neuro-QoL scores. A series of Pearson's correlations were conducted to determine any relationships between CTSAQ symptom severity, CTSAQ function and CTSAQ total scores, and Neuro-QoL physical function, upper extremity, and total T-scores before and after surgery.

RESULTS

While every carpal tunnel patient in our practice was asked to participate, 37 agreed and were screened. We excluded 17 patients: 3 patients did not meet the inclusion criteria; 5 patients did not have surgical intervention; and 9 patients either did not complete the post-operative questionnaires or did not undergo post-intervention HRUS evaluation. Twenty out of 34 eligible patients completed the study. All 20 patients (6 men and 14 women) underwent open unilateral carpal tunnel release by a single surgeon. Questionnaires and HRUS were completed pre-operatively and 3 months post-operatively. The mean age was 52.7 [SD = 13.0 years]. Ninety five percent of patients were right hand dominant and surgical release occurred on the right in 12 out of 20 wrists (60%) (Table 2). Four of the 20 patients had previous open carpal tunnel release on the contralateral wrist more than 6 months prior to the current intervention.

CTSAQ and Neuro-QoL

The mean Neuro-QoL scores improved after surgery from 37.3 to 48.2 on the 14 questions with a narrow 95% confidence interval(CI) indicating a meaningful clinically significant difference (MCD). While the 6 question mean upper extremity section score also improved from 39.2 to 48.35 with a narrow 95% CI, this did not qualify as a MCD (Table 3).

Pearson's correlations were used to assess the relationship between CTSAQ and Neuro-QoL scores before and after surgery (Table 4). CTSAQ activity (functional) scores were correlated with Neuro-QoL physical function and upper extremity scores both before (r_s = −0.73, and r_s = −0.61) and after surgery (r_s = −0.87 and r_s = −0.77). Weaker correlations were found between CTSAQ symptom severity score and both Neuro-QoL physical function and upper extremity scores before and after surgery.

High resolution ultrasound

The mean cross-sectional area of the median nerve at the inlet before surgery was 12.26 [SD = 4.06] mm ^{2}. The mean cross-sectional area of the median nerve at the inlet at 3 months follow up was 11.00 [SD = 3.16] mm^2. The ultrasonographic findings of the mid tunnel and the outlet were shown in Table 5. The mean diameter of the median nerve at the inlet and mid tunnel decreased after carpal tunnel release and the median nerve diameter at the outlet increased after surgery but these changes were not statistically significant possibly due to the small sample size.

Correlation of questionnaires to Ultrasound

The CTSAQ functional scores were strongly correlated with ultrasound findings at the carpal tunnel inlet ($r_s = 0.61$). The CTSAQ symptom severity score was weakly correlated ($r_s = 0.26$). The 6 Neuro-QoL upper extremity questions T-score was moderately correlated with ultrasonographic findings at the inlet ($r_s = 0.45$,), whereas Neuro-QoL 14 question physical function T-score did not correlate (Table 6).

DISCUSSION

To date, no objective measures of anatomical or electrophysiological tests have correlated repeatedly with any subjective outcomes measures in CTS. The Neuro-QoL has not been used for the assessment of CTS and its individual components have not been tested against either a validated outcome measure for CTS or a physiological or anatomic measure. Since electrophysiological tests have already been compared with the CTSAQ with controversial results, we decided to explore any anatomic change in median nerve structure as delineated by ultrasound to both the CTSAQ and a potentially useful new PRO measure, the Neuro-QoL. We chose to look at the upper extremity functional portion of this measure alone but consider looking at the mental and social modules as they may reveal other unrecognized benefits gained from carpal tunnel release surgery. While the Neuro-QoL is limited to measurement of quality of life related to upper extremity function including fine motor skills and activities of daily living, the CTSAQ combines questions on symptom severity such as numbness, tingling and pain which is not evaluated in the Neuro-QoL upper extremity module but may be reflected in the social and mental health modules. We compared Neuro-QoL to the validated CTSAQ to determine its validity as a self-assessment tool for evaluating patient reported outcomes with CTS before and after surgery. Based on our studies, both the CTSAQ and Neuro-QoL questionnaires are equivalent in the assessment of upper limb functional activity pre- and post-operative carpal tunnel release. There is a strong correlation between CTSAQ activity scores and Neuro-QoL pre-and post-operative outcomes. However, there is moderate correlation between the CTSAQ symptom severity and Neuro-QoL, likely due to the lack of symptom severity outcome measurement scoring components within the Neuro-QoL upper extremity questionnaire. While the Neuro-QoL is a validated and comprehensive assessment of functional outcome and quality of life, the CTSAQ is a more sensitive measure of carpal tunnel symptoms, including assessment of diurnal and nocturnal pain and paresthesias. Currently the CTSAQ is a more comprehensive assessment of both quality of life and carpal tunnel symptoms than the Neuro-Qol before and after surgery. It is not clear or intuitive how the distinction is made by the Neuro-QoL

developers for the rationale for the difference in analyzing the 4 questions separated from the 16 questions. We feel that still needs to be investigated and explained. The usefulness of the Neuro-QoL compared to the CTSAQ as disease specific outcome measure for clinically mild to moderate carpal tunnel syndrome has not been proven by this study but utilization of the entire Neuro-QoL with all 3 domains is worthy of further investigation.

Since Buchberger's publication in 1992[30], HRUS has gained substantial ground on diagnosing CTS. The CTS diagnostic criteria by ultrasound includes median nerve enlargement at the tunnel inlet, flexor retinaculum bowing and the flattening ratio of the nerve in the tunnel. Using cross-sectional area of the median nerve at the inlet, mid-tunnel and the outlet, we found a decrease in the means after surgery at the tunnel inlet only. Post-surgical decrease in the median nerve cross-sectional area proximal to the inlet is suggestive of nerve recovery, due to a reduction in intra-fascicular edema that is caused by mechanical compression.[31,32] The study's findings at the inlet agree with current literature in that the most common anatomical compression site of median nerve is at the inlet where there is an appreciable change in rigidity and thickness from the antebrachial fascia to the transverse carpal ligament.[33]

The CTSAQ activity score and the Neuro-QoL upper extremity T-score correlate positively with the ultrasonographic changes at the carpal tunnel inlet after surgery. HRUS measurements at the carpal tunnel inlet correlate well with patient reported outcomes. Our study corroborates previous literature in correlating high resolution ultrasound findings at the tunnel inlet to symptom improvement.[29,34,35] HRUS maybe a better objective test against which to judge outcome measures than electrodiagnostic studies. In severe clinical CTS, symptoms of pain are replaced with marked numbness, which is more tolerated by patients and perhaps explains the lack of correlation of outcome measures which are weighted towards pain symptoms.

This study has several limitations. First, it has a small sample size, which does not allow for meaningful analysis to address sex-difference (e.g. stratified, subgroup or interaction analyses). Moreover, this small sample size does not demonstrate a linear correlation between the anatomic factors such as the space of the carpal tunnel and symptoms of CTS. Secondly, it is a single center study with one surgeon, one supervising physical medicine and rehabilitation physician, and one ultrasonographer. Thirdly, we do not measure the wrist to forearm ratio because our focus is not on the specificity or sensitivity of diagnosing CTS. Fourthly, patient outcomes are measured by CTSAQ and Neuro-QoL questionnaires as opposed to sensory and motor exam findings such as two-point discrimination or Semmes-Weinstein monofilament test or thenar strength. However, our objective is the improvement of symptoms, activities of daily living, and quality of life, which are adequately addressed by the 2 questionnaires. Finally, our follow up period is short although we think that 3 months is enough to evaluate a meaningful change in patient's symptoms and function. Atroshi et al. has shown that improvement in symptoms and functional status can be expected in the first 6 weeks.[1]

In conclusion, pre- and post-CTS surgical outcomes may be assessed subjectively by clinical history, and patient reported questionnaires, and objectively with physical exam, EMG/NCS,

and HRUS. This study found decreasing cross-sectional area of the median nerve at the carpal tunnel inlet by HRUS with corresponding improvements in post-operative patient reported outcomes using both Neuro-QoL and CTSAQ questionnaires. Although patient reported outcomes in both CTSAQ activity scores and the Neuro-QoL were comparable, the CTSAQ was found to be a more comprehensive measure of both carpal tunnel symptoms and upper limb function before and after surgery. A larger multicenter study would be needed in the future to increase the sample size, and to evaluate the generalizability of our study's findings.

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Table 1

Neuro-QOL – Upper Extremity Function- Fine Motor, ADL

In the past 7 days...	**5 – No difficulty**	**4 - With a little difficulty**	**3 - With some difficulty**	**2 - With much difficulty**	**1 - Unable to do**
1. Are you able to turn a key in a lock?					
2. Are you able to brush your teeth?					
3. Are you able to make a phone call using a touch tone key-pad?					
4. Are you able to pick up coins from a table top?					
5. Are you able to write with a pen or pencil?					
6. Are you able to open and close a zipper?					
7. Are you able to wash and dry your body?					
8. Are you able to shampoo your hair?					
9. Are you able to open previously opened jars?					
10. Are you able to hold a plate full of food?					
11. Are you able to pull on trousers?					
12. Are you able to button your shirt?					
13. Are you able to trim your fingernails?					
14. Are you able to cut your toe nails?					
15. Are you able to bend down and pick up clothing from the floor?					
In the past 7 days...	**5 - No difficulty**	**4 - A little difficulty**	**3 - Some difficulty**	**2 - A lot of difficulty**	**1 - Can't do**
16. How much DIFFICULTY do you currently have using a spoon to eat a meal?					
17. How much DIFFICULTY do you currently have putting on a pullover shirt?					
18. How much DIFFICULTY do you currently have taking off a pullover shirt?					
19. How much DIFFICULTY do you currently have removing wrappings from small objects?					
20. How much DIFFICULTY do you currently have opening medications or vitamin containers (e.g., childproof containers, small bottles)?					

Neuro-QoL: Quality of Life in Neurologic Disorder – Item Bank v1.0 (*Upper Extremity Function – Fine Motor, ADL*); Neuro-QoL physical function: 14 questions (1,2,4-15; Neuro-QoL upper extremity: 6 questions (3, 16–20. T score calculated using www.Neuroqol.org computer adaptive test (CAT) [50 = norm, 0 = worst, 100 = best].

TABLE 2

Patient Characteristics, N = 20

Age	**Mean=52.7 (SD=13.04), min=23, max=68**	
Sex	Female: 14 (70%)	Male: 6(30%)
Hand dominance	Left: 1 (5%)	Right: 19 (95%)
Side included in study	Left: 8 (40%)	Right: 12 (60%)
Height, cm	Mean=167.9 (SD=8.7), min=152.4, max=185.4	
Weight, kg	Mean=86.7 (SD=18.3), min=47.6, max=111.8	
BMI	Mean=30.71 (SD=6.17), min=20.49, max=42.15	

SD: standard deviation

TABLE 3

CTSAQ and Neuro-QoL Pre- and Post-surgery Scores

Questionnaire (Score)	Before Surgery, N=20		After Surgery, N=20	
	Min, Max	Mean (95% CI)	Min, Max	Mean (95% CI)
CTSAQ Symptoms Total	26.00, 44.00	33.35 (31.04, 35.66)	11.00, 31.00	15.50 (12.98, 18.02)
CTSAQ Symptoms Average	2.40, 4.00	3.05 (2.83, 3.27)	1.00, 3.13	1.45 (1.17, 1.73)
CTSAQ Function Total	10.00, 30.00	19.15 (15.89, 22.41)	8.00, 20.00	11.25 (9.31, 13.19)
CTSAQ Function Average	1.25, 3.75	2.42 (2.02, 2.82)	1.00, 2.50	1.40 (1.15, 1.65)
Neuro-QoL : Physical Function T-score	25.00, 55.40	37.31 (34.17, 40.44)	29.20, 55.40	48.24 (43.74, 52.74)
Neuro-QoL: Upper Extremity T-score	25.40, 47.50	39.02 (36.37, 41.66)	37.10, 55.80	48.35 (44.89, 51.80)

N: number of patients; CTSAQ: carpal tunnel syndrome questionnaire; CTSAQ symptoms: 11 symptom severity questions; CTSAQ function: 8 task related questions; CTSAQ symptoms Total: total score of 11 symptom severity questions. CTSAQ symptoms Average: total score divided by 11. Neuro-QoL: Quality of Life in Neurologic Disorder – Item Bank v1.0 (*Upper Extremity Function – Fine Motor, ADL*); Neuro-QoL physical function: 14 questions; Neuro-QoL upper extremity: 6 questions. T score calculated using www.Neuroqol.org computer adaptive test (CAT) [50 = norm, 0 = worst, 100 = best].

TABLE 4

CTSAQ and Neuro-QoL Domain-specific Score Pearson's Correlation Pre- and Post-Surgery

Score	CTSAQ Symptoms Pre-op	CTSAQ Function Pre-op	CTSAQ Total Pre-op	CTSAQ symptoms Post-op	CTSAQ Function Post-op	CTSAQ Total Post-op
Physical Function T-score Pre-op	−.50	−.73				
Upper Extremity Tscore Pre-op	−.44	−.61				
Total T-score Pre-op			−.51			
Physical Function Tscore Post-op				−.59	−.87	
Upper Extremity Tscore Post-op				−.54	−.77	
Total T-score Post-op						−.60

CTSAQ scores: 1 is best, 5 is worst. Neuro-QoL scores: 1 is worst, 5 is best. Therefore, there is a negative correlation.

TABLE 5

Median Nerve Cross-sectional Area Pre- and Post-surgery

Measurement	Before Surgery, N=20		After Surgery, N=20	
	Min, Max	mean (95% CI)	Min, Max	mean (95% CI)
Average Median nerve CSA at tunnel inlet, mm^2	6.16, 21.73	12.26 (10.36, 14.16)	6.13, 16.10	11.00 (9.52, 12.48)
Average Median nerve CSA at mid tunnel, mm^2	5.30, 19.67	10.99 (9.27, 12.70)	5.13, 16.90	10.97 (9.39, 12.55)
Average Median nerve CSA at tunnel outlet, mm^2	3.53, 22.00	10.36 (8.54, 12.17)	4.23, 21.17	10.68 (8.93, 12.43)

CSA = Cross-sectional area

TABLE 6

Spearman correlations comparing pre and post-surgical differences in CTSAQ and Neuro-QoL scores to pre and post-surgical changes in Median Nerve Cross-sectional Area.

Difference between pre- and post-surgery measurements	Difference between post- and pre-surgery scores			
	CTSAQ Symptoms Total	CTSAQ Function Total	NeuroQOL : Physical Function T-score	NeuroQOL: Upper Extremity T-score
Average Median nerve CSA at tunnel inlet, mm^2	.26	.61	.22	.45
Average Median nerve CSA at mid tunnel, mm^2	−.080	−.15	−.13	−.06
Average Median nerve CSA at tunnel outlet, mm^2	.077	.28	.11	.26

CSA = Cross-sectional area