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Original Research

A Comparison of Changes in Median Nerve Cross-sectional Area Between Endoscopic and Mini-Open Carpal Tunnel Release

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Purpose: The purpose of this study was to determine whether there is a difference in the change in cross-sectional area (CSA) of the median nerve in patients undergoing carpal tunnel release (CTR) based on surgical technique and whether this change is associated with changes in patient-reported outcomes evaluated using the Carpal Tunnel Syndrome Assessment Questionnaire.
Methods: Individuals with carpal tunnel syndrome were evaluated with ultrasound and the CTSAQ before and 6 weeks after surgery. Patients were eligible for inclusion if they underwent either a mini-open CTR (MOCTR) or endoscopic CTR (ECTR). A single surgeon performed all surgeries. Changes in median nerve CSA, Carpal Tunnel Syndrome Assessment Questionnaire scores, and their associated surgical technique (MOCTR vs ECTR) were analyzed.
Results: A total of 77 patients were enrolled, 13 of whom were lost to follow-up, which left 64 for analysis. Of those, 42 patients underwent ECTR and 22 MOCTR. Mean age was 55 years; there were 52 women and 12 men. Mean changes in CSA for endoscopic and mini-open techniques from before to 6 weeks after surgery were −1.9 mm^2 (95% confidence interval [CI], −1.1 to −2.7) and +0.6 mm^2 (95% CI, −1.6 to 0.4), respectively. Mean Symptom Severity Scores improved after endoscopic and mini-open release by 1.7 (95% CI, 1.4–2.1) and 1.5 (95% CI, 1.2–1.9), respectively. Mean Functional Status Scores improved after endoscopic and mini-open release by 1.2 (95% CI, 0.9–1.9) and 0.7 (95% CI, 0.03–1.3), respectively.
Conclusions: Patients undergoing ECTR demonstrated decreased median nerve CSA, whereas those undergoing MOCTR demonstrated increased median nerve CSA at 6 weeks. All patients undergoing surgical intervention demonstrated improvement in both Symptom Severity Scores and Functional Status Scores after surgery. Whereas both techniques successfully improve patient outcome scores, an increase in CSA after MOCTR may be seen in the initial postoperative period, potentially contributing to a slower short-term improvement in outcome in functional scores compared with ECTR.
Type of study/level of evidence: Therapeutic IV.

Carpal tunnel syndrome (CTS) is caused by compression of the median nerve at the wrist and remains the most common nerve compression syndrome of the upper extremity. The incidence of diagnosis increases annually by 2% to 4%.[1,2] Concordantly, the estimated 500,000 decompressions performed each year as of 1999 have since increased annually by 5% to 6%.[2] Open carpal tunnel release (CTR), considered the standard for surgical treatment, has been challenged by alternatives such as mini-open and endoscopic techniques with the growing popularity of minimally invasive surgery. Proposed advantages of endoscopic techniques include smaller incisions made away from the middle of the palm and division of the transverse carpal ligament (TCL) from within the carpal tunnel,

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leaving superficial structures intact, resulting in less pain, less scarring, and shorter recovery times.[3–7]

Several investigations concluded that endoscopic and open techniques are similarly effective, whereas others support the superiority of endoscopic CTR (ECTR) with respect to grip strength, early return to work, and lower rates of minor and overall complications.[7] These mixed findings have been viewed with caution in the literature owing to small differences and a lack of high-quality evidence, because optimal objective measurements of nerve function, symptom improvement, and functional response after CTR have remained elusive. Electrodiagnostic study (EDS) abnormalities and severity gradings are poor predictors of both symptom improvement and overall patient outcomes after surgical release.[8–12] These limitations have led to the proliferation of alternative methods such as high-resolution ultrasound (HRUS) to aid in outcome assessment of CTS patients by monitoring changes in median nerve cross-sectional area (CSA).

Increased CSA of the median nerve at the carpal tunnel inlet is sensitive and specific for diagnosis of CTS.[13–17] Chronic compression by the TCL leads to nerve swelling proximal and distal to the carpal tunnel. Once that compression is relieved, the nerve should return to baseline size. Whereas EDS are often used to track nerve function, often they do not return to baseline standards after intervention, and the testing itself is uncomfortable and time-consuming for patients. High-resolution ultrasound is a potentially viable option for objectively tracking changes in median nerve morphology after CTR because it is painless and more easily available. However, there are few published data regarding changes in median nerve CSA and how those changes correlate with patient-reported outcomes.[18] There is also potential variability between changes in median nerve CSA and patient-reported outcomes with different surgical techniques. It is possible that HRUS measurement of CSA of the median nerve will detect early changes after CTR that could explain the faster recovery of function and relief of symptoms.

The purpose of this study was to determine whether there is a difference in the change in CSA of the median nerve in patients undergoing CTR based on surgical technique, and whether this is associated with changes in patient-reported outcomes evaluated using the Carpal Tunnel Syndrome Assessment Questionnaire (CTSAQ).

Materials and Methods

This study was approved by the institutional review board at our institution; informed consent was obtained from each patient. Participants with a diagnosis of CTS, who had failed conservative treatment and were scheduled for surgical intervention, were prospectively enrolled from a single surgeon's hand clinic from 2014 to 2018. Carpal tunnel syndrome was diagnosed clinically with a combination of signs, symptoms, and provocative physical examination, and subsequently confirmed with EDS. Although clinical findings were not uniform among all patients, symptoms (numbness, tingling, and nocturnal pain in the median nerve distribution), positive EDS, and at least one positive physical examination finding (nerve compression test or Phalen test) were considered necessary for the diagnosis of CTS and enrollment. Exclusion criteria included patients aged under 18 years, negative EDS, pregnancy, and/or prior CTR.

Patients completed the CTSAQ and were evaluated with HRUS to assess median nerve CSA before and at 6 weeks after surgery. The CTSAQ is a questionnaire composed of 2 components: 11 questions make up the Symptom Severity Score (SSS) and 8 evaluate subjective hand function (Functional Status Score [FSS]). Each question is answered on a scale of 1 to 5, with higher scores indicating greater disease severity and providing a reliable measure responsive to clinical change.[19–21]

Using the technique previously described,[14,17,22–24] after patients had selected their preferred surgical technique, the senior author measured the median nerve CSA using HRUS examination with a 15-6-MHz linear array transducer. The patient sat comfortably with the dorsal forearm resting on the examination table. The elbow was flexed 90° and the forearm was fully supinated. The fingers were in a resting position. The CSA was measured at the carpal tunnel inlet at the level of the distal wrist crease, using the pisiform as a consistent internal landmark. The median nerve CSA was measured just inside the hyperechoic epineurium using the trace function.

Patients underwent mini-open CTR (MOCTR) or endoscopic CTR (ECTR) by a single surgeon, with monitored anesthesia care and a tourniquet. Patients selected their preferred technique after a description of each procedure and the associated risks and benefits at the time of scheduling. The MOCTR release was performed using a 2- to 3-cm incision in line with the radial border of the ring finger from the Kaplan cardinal line to the wrist crease and release of the TCL under direct visualization. We performed ECTR using a single 2-cm incision proximal to the wrist crease and insertion of an Agee-type commercially available cannula and camera (SmartRelease; MicroAire Surgical Instruments, Albemarle County, VA) into the carpal tunnel. No concurrent or additional procedures were performed on any patient.

After a 6-week postoperative evaluation, we analyzed changes in median nerve CSA, CTSAQ scores, and their associated surgical technique (MOCTR vs ECTR). Means and 95% confidence intervals (CIs) were reported for HRUS CSA measurements and CTSAQ scores for each surgical group. Statistical analysis also included 2-sided unpaired t tests, with $P < .05$ considered statistically significant.

Results

A total of 77 patients met inclusion criteria and were enrolled; 13 of them were lost to follow-up after surgery, which left 64 patients for analysis. Mean patient age was 54.7 years; 52 were women, and 12 men. Of those, 42 patients underwent ECTR and 22 underwent MOCTR. Table 1 lists patient characteristics and mean CSA data.

There was a mean change in CSA for ECTR and MOCTR from before to 6 weeks after surgery of -1.9 mm^2 (95% CI, -2.7 to -1.1) and $+0.6$ mm^2 (95% CI, -1.6 to 0.4), respectively ($P < .05$). The SSS improved after ECTR and MOCTR by 1.7 (95% CI, 1.4–2.1) and 1.5 (95% CI, 1.2–1.9), respectively ($P = .55$). The FSS improved after ECTR and MOCTR by 1.2 (95% CI, 0.9–1.9) and 0.7 (95% CI, 0.03–1.3), respectively ($P = .1$). Mean improvements in CTSAQ score are detailed in Table 2. The 13 patients lost to follow-up were similar in demographics; there were 6 MOCT and 7 ECTR patients, with a slightly older average age of 65.6 years and higher mean CSA preoperative values of 13.6 and 13.3 for MOCTR and ECTR patients, respectively.

Discussion

This study demonstrated greater improvement in median nerve CSA, as measured by HRUS at the carpal tunnel inlet, with ECTR compared with MOCTR. Previous research demonstrated faster return to work and earlier improvement in patient-reported symptoms and function for ECTR; however, there has been limited evidence of objective changes in the median nerve to explain this early recovery.[7] Previously proposed advantages of ECTR include smaller incisions made away from the middle of the palm and division of the TCL from within the carpal tunnel, leaving

Table 1
Demographic Data Including Sex, Age (y), and Affected Side, as Well as Mean CSA of Median Nerve Before and After Surgery for Patients Undergoing MOCTR Versus ECTR

Patient Characteristics (n = 64)	Mini-Open (n = 22)	Endoscopic (n = 42)	
Sex	18 female	34 female	
Mean age, y (SD)	56.8 (9.5)	51.1 (13.8)	
Affected side	10 L, 12 R	14 L, 28 R	
Mean CSA before surgery, mm^2 (SD)	10 (2.4)	12.3 (4.2)	
Mean CSA 6 wk after surgery, mm^2 (SD)	10.6 (3)	10.5 (3.9)	
Mean difference (SD)	0.6 (2.2)	−1.9 (2.7)	95% CI, −3.9 to −1.3 ($P < .05$)

Table 2
Mean CTSAQ Scores, Including SSS and Subjective FSS, After MOCTR or ECTR, With Comparison Based on Whether Preoperative CSA was Less Than or Equal to Versus Greater Than the Mean CSA*

	Mini-Open (n = 22)	Endoscopic (n = 42)	*P* Value	95% CI
Preoperative SSS	3 (0.7)	3.5 (0.7)	.01	−0.85 to −0.11
Preoperative FSS	2.5 (1.0)	2.9 (0.8)	.08	−0.97 to 0.05
Postoperative SSS	1.5 (0.6)	1.7 (0.8)	.42	−0.58 to −0.24
Postoperative FSS	1.7 (0.8)	1.7 (0.9)	.93	−0.47 to 0.44
SSS improvement	1.5 (0.78)	1.8 (0.92)	.21	−0.77 to 0.17
FSS improvement	0.9 (1.17)	1.2 (1.05)	.26	−0.92 to 0.25
Preoperative CSA less than or equal to mean				
SSS improvement	1.6 (0.61)	1.7 (1.03)	.68	−0.8 to 0.53
FSS improvement	0.9 (1.11)	1.3 (1.1)	.31	−1.23 to 0.41
Preoperative CSA greater than mean				
SSS improvement	1.4 (0.99)	1.9 (0.81)	.17	−1.23 to 0.22
FSS improvement	0.9 (1.31)	1.15 (1.02)	.57	−1.17 to 0.66

* Reported *P* values represent a comparison of the 2 groups; $P < .05$ is considered statistically significant. Standard deviation are given in parentheses.

superficial structures intact and resulting in less soft tissue dissection, less pain, and shorter recovery times.[3−7] This may account for the observed decrease in the median nerve CSA after ECTR, with less soft tissue disruption and trauma to the nerve during surgical dissection, resulting in decreased edema and swelling. However, insertion of the endoscopic cannula may also traumatize the nerve, causing neurapraxia after surgery. Therefore, it is unclear whether the technique truly results in less trauma to the nerve or whether perhaps the smaller incision outside the palm causes less inflammation around the nerve after surgery. An additional consideration regarding the increase in median nerve CSA after MOCTR may be the possibility of incomplete release of the TCL; however this is a rare complication for MOCTR.[25,26]

Severity scores were similar between groups, although variable degrees of functional improvement were suggested. It is possible that a larger sample size would have identified a statistically significant difference. However, based on the findings of this study, that difference is unlikely to be clinically relevant.

A postoperative decrease in median nerve CSA proximal to the carpal tunnel inlet is suggestive of nerve recovery, as a result of reduced intrafascicular edema caused by mechanical compression.[27,28] Reports investigating direct correlations between preoperative and postoperative median nerve CSA and patient-reported outcomes using a validated outcome measures such as the CTSAQ are limited in the literature,[18] as are comparisons of potential variability between changes in median nerve CSA and patient-reported outcomes with different surgical techniques (MOCTR vs ECTR).

Tuan et al[18] showed that ultrasound findings at the carpal tunnel inlet strongly correlated with CTSAQ SSS and weakly with CTSAQ FSS after surgery, with a postsurgical decrease in median nerve CSA proximal to the inlet suggestive of nerve recovery. All patients in the current investigation improved in both SSS (1.7 for ECTR and 1.5 MOCTR) and FSS (1.2 ECTR and 0.7 MOCTR) after surgical intervention. A decrease of 1.04 or more in the CTSAQ score has been demonstrated to be a clinically important improvement in health.[29] The current data suggest that an endoscopic technique may provide a clinically important improvement in both SSS and FSS, whereas mini-open technique may provide a clinically measurable improvement in only SSS in the short term after surgery. This difference correlates with observed changes in CSA from before to after surgery between techniques in the current study group.

Previous literature correlated decreased CSA at the carpal tunnel inlet with symptom improvement.[21,30,31] Although evidence has been mixed, ECTR demonstrated functionally significant improvement in grip strength and faster return to work (8 days sooner, on average) in various reports.[6,7] Patients who underwent ECTR had a decrease in median nerve CSA (−1.9 mm^2), in contrast to an increase in CSA (+0.6 mm^2) in the MOCTR group. Both groups demonstrated a statistical improvement in both SSS and FSS; however, the improvement in FSS in the MOCTR group lacked a clinically important change when using a change of 1.04 as a threshold. It is clear that other factors may be involved, but the increase in CSA observed in this group, in contrast to the decreased CSA observed in the ECTR group, may account for this clinical difference in the short term. The HRUS measurement of median nerve CSA and the CTSAQ are effective in monitoring response to treatment in CTS. Our findings corroborate those in previous literature in correlating HRUS findings at the tunnel inlet with symptom improvement.[21,30,31]

This study had several limitations. First, this was a single-center study in which one surgeon performed both the surgical procedures and the preoperative and postoperative ultrasound measurements. Patients were allowed to select the treatment method and were not randomized, which introduced potential bias. Furthermore, the skill and experience of the ultrasound examiner might have considerably affect the results; however, measurement of the median nerve CSA demonstrated moderate agreement among examiners of varying levels of experience.[22] Second, patient outcomes and nerve recovery were measured by the CTSAQ as opposed to sensory and motor examination findings more commonly described in previous literature, such as 2-point discrimination or thenar strength testing. The CTSAQ has been shown to quantify symptom improvement and functional status adequately, whereas the reliability of sensibility testing such as 2-point discrimination and Semmes-Weinstein tests have been challenged.[32,33] In addition, whereas measures such as grip strength and return to work status ideally reflect function and recovery, return to work is an imperfect measure of recovery because it is highly dependent on factors unrelated to nerve recovery itself, such as patient motivation, occupation, and surgeon expectations.[6,7] Finally, the follow-up of 6 weeks after surgery is short; however, Atroshi et al[1] showed that improvement in symptoms and functional status can be expected in the first 6 weeks, as supported by the statistically significant differences in CTSAQ scores observed here.

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