Sonographic short-term follow-up after surgical decompression of the median nerve at the carpal tunnel: a single-center prospective observational study

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OBJECT Carpal tunnel syndrome causes increased cross-sectional area (CSA) of the median nerve, which can be assessed by high-definition ultrasonography. It is unclear today, however, whether high-definition ultrasonography may play a role in the postoperative period. This prospective study aimed to determine the natural history of the morphology of the median nerve at the carpal tunnel after surgical decompression assessed by high-definition ultrasonography.

METHODS Between October and December 2014, patients with suspected carpal tunnel syndrome who were referred to the authors' center for peripheral neurosurgery were prospectively enrolled and underwent pre- and postoperative (3 months) high-definition ultrasonography, electrophysiology, and clinical testing.

RESULTS Eighty-one patients were enrolled in the study, and 100% were clinically better at the 3-month follow-up. The mean CSA decreased from $14.7 \pm 4.9 \text{ mm}^2$ to $12.4 \pm 3.4 \text{ mm}^2$ (mean $\pm$ SD, $p < 0.0001$). The mean distal motor latency decreased from $6.6 \pm 2.4 \text{ msec}$ to $4.8 \pm 1.0 \text{ msec}$ (mean $\pm$ SD, $p < 0.0001$). Ninety-eight percent of patients who were available for electrodiagnostic follow-up showed an improvement of the distal motor latency; only 80% had a reduction in the CSA.

CONCLUSIONS The authors present the second-largest series of patients with sonographic follow-up after surgical decompression of the carpal tunnel reported in the literature so far. This study, which showed a decrease in size of the median nerve after surgical decompression, suggests that the preoperative increase in median nerve CSA at the carpal tunnel may be due to compression and that enlargement of the median nerve is (partially) reversible.

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KEY WORDS carpal tunnel syndrome; high-definition ultrasonography; carpal tunnel surgery

CARPAL tunnel syndrome (CTS) causes increased cross-sectional area (CSA) of the median nerve, which can be assessed by high-definition ultrasonography.^{2,3,5,6,12,15–17} The compression in the carpal tunnel leads to edema and proliferation of fibrous tissue proximal to the compression site, which in turn results in swelling of the nerve and increased CSA in the 2D image.^{8,10}

High-definition ultrasonography can thus be used for diagnosis of CTS with an accuracy that is equal to electrodiagnostic studies,^{10,13} it may give further information about an underlying pathological entity such as a ganglion cyst,¹⁴ or it may provide information about muscular atrophy.⁹

It is unclear today, however, whether high-definition ul-

trasonography may play a role in the postoperative period.¹¹ Patients who suffer from persistent or recurring symptoms may have a nerve that is still or again compressed and may benefit from a second decompression. If surgical decompression of the median nerve in the carpal tunnel results in normalization of the median nerve's CSA, this could help select patients who may benefit from a repeat surgery. On the other hand, if the nerve does not change morphologically postoperatively, then high-definition ultrasonography may not be helpful in the postoperative period to distinguish between patients whose nerve is still or again compressed and patients whose nerve is decompressed.

The goal of this prospective study was to determine the natural history of the morphology of the median nerve

ABBREVIATIONS CSA = cross-sectional area; CTS = carpal tunnel syndrome; dML = distal motor latency.

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at the carpal tunnel after surgical decompression, as assessed by high-definition ultrasonography.

Methods

Institutional review board approval was obtained by the regional medical board committee (Landesärztekammer Baden Württemberg; F-2015–004). Between October and December 2014, patients with suspected CTS referred to our center for peripheral neurosurgery were prospectively screened for the study. Patients gave written informed consent and were prospectively enrolled.

The patients then routinely underwent standardized nerve conduction studies and subsequent sonographic evaluation. Clinical, sonographic, and electrophysiological parameters were assessed, as shown in Table 1. Nerve CSA and age were post hoc dichotomized into $\geq 12 \text{ mm}^2$ or $< 12 \text{ mm}^2$ and ≥ 65 years or < 65 years to compare our findings with those of Vögelin et al.,¹⁵ who found a statistically significant difference in CSA reduction in these groups. Surgical decompression was then performed either in open fashion or endoscopically.

We performed a follow-up clinical, electrophysiological, and sonographic examination at baseline and at 3 months after surgical treatment.

High-Definition Ultrasonography

A real-time scanner (Toshiba Aplio MX with IStyle technology, Toshiba Medical Systems Europe) with a 19-MHz linear array transducer was used. Patients were seated in a chair with their arms extended and hands resting in a horizontal supinated position. The largest CSA of the median nerve was assessed at 2 positions: 1) distal to the carpal tunnel inlet between the pisiform bone and the scaphoid tubercle—i.e., the distal wrist flexion crease (rascetta); and 2) in the forearm 5 cm proximal to the mentioned line, using manual tracing in serial transverse scans. We used only transverse scans to localize the median nerve and exclude relevant pathologies other than CTS. The largest CSA was determined by visual inspection during transverse scanning. In case of uncertainty, several transverse measurements were taken until the largest CSA was identified. Assessments of the largest CSA were performed twice and the arithmetic means of the 2 assessments were recorded. Examinations before and after treatment were performed in the same standardized manner.

Statistical Analyses

The means of categorical variables were compared using a nonparametric test such as the Mann-Whitney U-test. Correlation analysis was done as an exploratory analysis, and subsequent factors were then compared with univariate and multivariate ANOVA. Commercially available software was used (SPSS 22.0; IBM, Inc.).

Results

Overall, 81 patients were recruited for the study and a 3-month clinical follow-up was obtained in 100%. Sixty-seven patients were recruited for another sonographic follow-up. Basic demographic variables are shown in Table

TABLE 1. Summary of pre- and postoperatively assessed parameters in patients with CTS

Variable
Clinical parameters assessed preop
Age
Sex
Laterality
Duration of symptoms (≤ 1 yr vs > 1 yr)
Paresthesias (yes vs no)
Numbness (yes vs no)
Motor deficits (yes vs no)
Atrophy (yes vs no)
Typical brachialgia nocturna (yes vs no)
Tendovaginitis stenosans (yes vs no)
Diabetes (yes vs no)
Clinical parameters assessed postop
Scar pain
Clinical improvement of preop symptoms
Paresthesias (complete reduction vs partial reduction vs no change)
Numbness (complete reduction vs partial reduction vs no change)
Motor deficits (complete reduction vs partial reduction vs no change)

2. The majority of patients had open surgery (85%). The main results for the clinical parameters are shown in Table 3. All of the patients improved clinically in the short-term follow-up. Most of the patients, however, had postoperative scar pain.

The main results of the sonographic and electrophysiological measurements are summarized in Table 4. Overall we observed a statistically significant reduction of the mean CSA of the median nerve proximally as well as distally 3 months after surgical decompression. Furthermore, distal motor latency (dmL) also improved statistically significantly after surgical decompression. Nevertheless, although all patients improved clinically, we did not see a reduction in the CSA in 20% of the patients. Whereas 98% of patients who were available for electrodiagnostic follow-up showed an improvement of the dmL, only 80% had a reduction in the CSA. An example of a postoperative reduction is shown in Fig. 1. The reduction of CSA was not statistically significantly correlated with the amount of reduction of the dmL (Pearson correlation coefficient = 0.230, $p = 0.067$).

All statistically significant subgroup analyses are shown in Table 5. If the patient had a CSA that was $\geq 12 \text{ mm}^2$ preoperatively or if they were < 65 years old, they had a significantly greater reduction of the percentage of their preoperative CSA ($p < 0.001$). Patients with motor deficits had statistically significantly longer preoperative dmL ($10.5 \pm 2.8 \text{ msec}$ vs $6.5 \pm 2.3 \text{ msec}$; $p = 0.021$ in multivariate analysis), but not a greater CSA ($p = 0.124$) or circumference ($p = 0.252$).

Of all the other parameters that were assessed, we did not find a significant correlation between the parameters in the exploratory analysis (i.e., age, diabetes). We also did

TABLE 2. Summary of basic demographic and preoperative variables in the population of patients with CTS

Variable	Value (%)
Total no. of patients	81 (100%)
Mean age in yrs, $\pm$ SD	56.9 $\pm$ 16.4
Male/female ratio	1:1.3
Location of surgery	
Lt	51 (63%)
Rt	30 (37%)
Duration of symptoms	
≤ 1 yr	29 (35.8%)
> 1 yr	52 (64.2%)
Paresthesias	74 (91.3%)
Numbness	30 (37.0%)
Weakness	2 (2.5%)
Atrophy	2 (2.5%)
Typical brachialgia nocturna	80 (98.8%)
Concurrent tendovaginitis stenosans	12 (14.8%)
Concurrent hemodialysis	0
Concurrent diabetes	8 (9.9%)
No. w/ electrodiagnostic follow-up	79
No. w/ sonographic follow-up	67
Open surgery	69 (85.2%)
Endoscopic surgery	12 (14.8%)

not find any statistically significant difference between patients who underwent open and endoscopic surgery in any pre- and postoperative parameter, especially in the sonographic and electrophysiological results.

Discussion

Here we present the second-largest series of patients with sonographic follow-up after surgical decompression of the carpal tunnel that has been reported in the literature so far. For sonographic diagnosis of CTS, measurement of the CSA is the most reliable and common parameter.⁷ Further sonographic signs for CTS are palmar bowing and thickening of the flexor retinaculum and distal flattening of the median nerve, as well as loss of fascicular discrimination and reduced echogenicity. In addition to enlargement of the median nerve, distal flattening and especially reduction or even loss of fascicular texture were regularly seen in our patients; however, these parameters are less reliable because they are more difficult to quantify.

Most of our results are in line with the published literature (Table 6).^{1,11,15} Also, the subgroups of patients who are older (≥ 65 years) and those who have a greater CSA (≥ 12 mm²) are in line with the published results from the Swiss group.¹⁴ Variations in the results may be due to patient heterogeneity or different measurement protocols. This is in accordance with our results that patients with a larger preoperative CSA had a larger reduction in their CSA, even when corrected by using percentage of reduction related to preoperative values. Furthermore, those previous studies did not address whether endoscopic versus open surgery

TABLE 3. Summary of early clinical results in patients with CTS

Results at 3 Mos Postop	No. of Patients (%)
Clinical improvement	81 (100%)
No improvement	0 (0%)
Postop scar pain	
Yes	70 (86.4%)
No	11 (13.6%)
Paresthesias	
Complete resolution	67 (82.7%)
Partial resolution	7 (8.6%)
Persistent	0 (0%)
No paresthesias preop	7 (8.6%)
Numbness	
Complete resolution	24 (29.6%)
Partial resolution	6 (7.4%)
Persistent	0 (0%)
No numbness preop	51 (63%)
Weakness	
Complete resolution	2 (2.5%)
Partial resolution	0 (0%)
Persistent	0 (0%)
No weakness preop	79 (97.5%)

can lead to a difference in postoperative CSA. In retrospective analysis, we could not find any difference.

In general, sonographic short-term follow-up seems to be inferior to electrodiagnostic short-term follow-up. Whereas 98% of patients who were available for electrodiagnostic follow-up showed an improvement, only 80% had a reduction in the CSA. This point was not addressed in the previous studies, which did not report the number of patients who did not improve sonographically.^{1,11,15} The morphological improvement might be lagging behind the electrical improvement, when we hypothesize that the CSA will still decrease, which is unclear.

The large study of Smidt and Visser could not find any correlation between time of follow-up and reduction in CSA size, which could indicate that after 3 months the CSA will not decrease further.¹¹ On the other hand, the study by Abicalaf et al. showed a time-dependent reduction, but only until 3 months postoperatively, when that study was terminated.¹

TABLE 4. Main results in 81 patients with CTS*

Parameter	Preop	3 Mos Postop	p Value†
Mean CSA of median nerve at wrist, in mm ²	14.7 $\pm$ 4.9	12.4 $\pm$ 3.4	<0.0001
Mean CSA of median nerve at forearm, in mm ²	9.9 $\pm$ 2.8	8.0 $\pm$ 1.6	<0.0001
Mean dML, in msec	6.6 $\pm$ 2.4	4.8 $\pm$ 1.0	<0.0001

* Values are expressed as the mean $\pm$ SD. All parameters showed significant improvement postoperatively. Only 80% of the patients showed an improvement in their CSA.

† A paired t-test was used for statistical analysis.

FIG. 1. Example of a postoperative reduction of a CSA in 1 patient, as assessed by high-definition ultrasonography. **Upper:** Preoperative image. **Lower:** Postoperative image obtained after 3 months. Of note is a significant change in texture of the nerve that highlights the typical change from a dark nerve to the better visibility of the internal fascicular structure.

Several authors have studied the value of high-definition ultrasonography for the diagnosis of CTS.^{5,6,16,17} In addition to contributing to the diagnostic workup of patients with suspected CTS, sonographic examination allows noninvasive detection of aberrations.^{4,9,10} In our investigation, however, electrodiagnostic studies seemed to

TABLE 5. Statistically significant findings of the subgroup analyses in patients with CTS

Subgroup	Mean CSA Reduction, in % of Preop Value*	p Value†
Age		
≥65 yrs	5.6% ± 26%	0.046
<65 yrs	17.4% ± 19%	
Preop CSA		
≥12 mm ²	20.2% ± 18%	<0.001
<12 mm ²	-1.5% ± 22%	

* Values are expressed as the mean ± SD.
† According to multivariate ANOVA.

TABLE 6. Comparison of results of the current study with the data available in the literature

Authors & Year	No. of Participants	Follow-Up	Mean CSA in mm ² *	
			Preop	Postop
Vögelin et al., 2010	58	6 mos	12.4 ± 3.3	10.0 ± 2.7
Abicalaf et al., 2007	20	3 mos	15.0 ± 2.1	8.6 ± 1.6
Smidt & Visser, 2008	79	19 mos	14.0	11.5
Present study	67	3 mos	14.7 ± 4.9	12.4 ± 3.4

* Values for CSA are expressed as the mean ± SD.

be more sensitive in picking up preoperative deficits—our patients with motor deficits had statistically significantly longer preoperative dmL (10.5 ± 2.8 msec vs 6.5 ± 2.3 msec; $p = 0.021$ in multivariate analysis), but not greater CSA ($p = 0.124$) or circumference ($p = 0.252$).

Our stratified analyses provided little evidence that decreases in CSA depend on baseline characteristics other than the actually measured CSA at baseline. Whereas one study found an almost statistically significant correlation between CSA and clinical improvement,¹⁵ we could not find any correlation. In our particular study this is due to the high number of patients with clinical improvement. This could change in the longer term, for example if patients develop late recurrences.

We found a 100% improvement rate in the first 3 months after release. This is better than in most of the large published series and might be surprising given the reader’s personal experience. However, release of the carpal tunnel is a worthwhile procedure and if the diagnosis is correct (i.e., a typical clinical presentation and pathological electrophysiological parameters including an increased dmL), a high degree of improvement can be achieved. The 100% improvement found in this study might be related to the relatively small number of patients, participation bias, and a short follow-up. In larger patient series, participants with persistent complaints are likely.

The strengths of our study include a prospective design in unselected consecutive patients, the standardized protocol, experience of the surgeons (F.S. and T.D.), and the large number of patients. The major limitations of our study are its short-term follow-up and the nonrandomized nature, which may have resulted in confounding based on indication. Furthermore, the exceptionally good clinical results hinder the assessment of a relationship between general clinical outcome and sonographic follow-up. We are not able to answer the question whether a good sonographic reduction can go along with a bad clinical outcome.

Conclusions

Our study, which showed a decrease in size of the median nerve after surgical decompression, suggests that the preoperative increase in median nerve CSA at the carpal tunnel may be due to compression and that enlargement of the median nerve is (partially) reversible.

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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Duetzmann, Staub. Acquisition of data: Tas, Staub, Dombert. Analysis and interpretation of data: Duetzmann. Drafting the article: Duetzmann. Critically revising the article: Staub, Marquardt, Senft. Statistical analysis: Duetzmann. Administrative/technical/material support: Staub, Dombert, Marquardt, Seifert. Study supervision: Staub, Dombert.

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