Bifid Median Nerve in Carpal Tunnel Syndrome: Assessment with US Cross-sectional Area Measurement[1]

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Purpose: To evaluate the accuracy of ultrasonography (US) in the diagnosis of carpal tunnel syndrome (CTS) in patients with a bifid median nerve on the basis of cross-sectional area (CSA) measurements of the median nerve at the level of the carpal tunnel (CSAc), with additional measurements obtained more proximally (CSAp) at the level of the pronator quadratus muscle.

Materials and Methods: This HIPAA-compliant study was approved by the local institutional review board; informed oral and written consent were obtained. Fifty-three wrists in 49 consecutive patients with a bifid median nerve and CTS symptoms and 28 wrists in 27 healthy volunteers with a bifid median nerve were examined by using US. Two independent US examiners who were blinded to prior test results measured median nerve CSA at two levels, CSAc and CSAp. The difference between CSAc and CSAp (ΔCSA) was calculated for each wrist. Receiver operating characteristic (ROC) analysis was performed.

Results: The study population included 17 men and 32 women (mean age, 55.1 years; age range, 24–78 years). The control population included 13 men and 14 women (mean age, 52.6 years; age range, 24–86 years). Mean CSAc was approximately 5 mm^2 greater in patients with CTS than in healthy volunteers ($P < .0001$), while mean ΔCSA was 5.8–5.9 mm^2 greater in patients with CTS ($P < .0001$). A CSAc threshold of 12 mm^2 provided sensitivity and specificity of 84.9% and 46.5%, respectively, while a ΔCSA threshold of 4 mm^2 provided sensitivity and specificity of 92.5% and 94.6%, respectively. ROC analysis demonstrated a significant advantage of ΔCSA (area under ROC curve [A_z] = 0.95–0.96) compared with CSAc (A_z = 0.84–0.85) for the diagnosis of CTS ($P < .003$).

Conclusion: The use of a ΔCSA parameter improves the diagnostic accuracy of US for the presence of CTS in patients with a bifid median nerve.

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A bifid median nerve, a variation of nerve anatomy in the carpal tunnel described by Lanz (1) in 1977, is associated relatively frequently with carpal tunnel syndrome (CTS). A bifid median nerve may be predisposed to compression in the carpal tunnel because of its relatively higher cross-sectional area (CSA) compared with a nonbifid median nerve (1). A recent retrospective magnetic resonance imaging study (2) demonstrated a bifid median nerve in the carpal tunnel of 36 (18%) of 194 wrists.

The diagnosis of CTS is traditionally based on clinical history, physical examination results, and electrophysiologic study results (3). More recently, ultrasonography (US) has been shown to be an accurate and useful diagnostic tool in patients with CTS. By comparing CSA measurements of the median nerve obtained at the level of the carpal tunnel (or carpal tunnel CSA [CSAc]) with those obtained more proximally (or proximal CSA [CSAp]) at the level of the pronator quadratus muscle, US can provide sensitivity of 99% and specificity of 100% (4).

For the bifid median nerve, the size criterion for the diagnosis of CTS is slightly higher than for a nonbifid median nerve (5). The purpose of the present study was to evaluate the accuracy of US in the diagnosis of CTS with a bifid median nerve on the basis of CSAc and CSAp measurements.

Advances in Knowledge

- The diagnostic accuracy of US for carpal tunnel syndrome (CTS) in the presence of a bifid median nerve is significantly better with the difference of cross-sectional area (CSA) measurements obtained at the level of the carpal tunnel and those obtained more proximally (ΔCSA) than with measurements obtained only at the level of the carpal tunnel.
- Optimal diagnostic discrimination with ΔCSA is obtained at a threshold of 4 mm^2, which results in sensitivity and specificity greater than 90% with high interobserver agreement.

Materials and Methods

The Health Insurance Portability and Accountability Act–compliant study protocol was approved by the university ethics committee of Medical University Innsbruck; written and oral consent was obtained from all patients and healthy volunteers.

Among 684 consecutive patients clinically suspected of having carpal tunnel syndrome who were referred for evaluation, 49 patients had a bifid median nerve at US evaluation. In a control population of 551 consecutive healthy volunteers during a period of 2.5 years, a bifid median nerve was found in 27 patients by using US evaluation. A second and third radiologist (A.S.K. and R.F., with 12 and 4 years of experience, respectively, in musculoskeletal radiology), who were blinded to the clinical and electromyographic results used for the initial diagnosis of bifid median nerves, performed cross-sectional measurements for the purpose of this study.

The median nerve was defined as bifid if it branched proximal to the level of the distal radioulnar junction as determined at the initial US evaluation (5). All patients demonstrated characteristic clinical symptoms of CTS—paresthesia, pain, weakness, or clumsiness of the hand provoked or worsened by sleep or sustained hand or arm position, which is mitigated by changing posture or by shaking the hand; and/or sensory deficits in the median innervated region of the hand and/or motor deficit or hypotrophy of the median innervated thenar muscle (6) when presenting at the Department of Neurology or Hand Surgery. The diagnosis was confirmed with results from nerve conduction velocity testing which was performed within 2 weeks before or after US examination.

Implication for Patient Care

- The use of CSA provides a noninvasive US technique for accurate diagnosis of CTS in the presence of a bifid median nerve.

CTS severity was classified on the basis of electrophysiologic results as mild or moderate or as severe or extreme according to the modified scoring of Padua et al (7). Mild or moderate CTS was defined as minimally abnormal segmental or comparative test results, moderately abnormal digit-wrist sensory nerve conduction velocity, and/or abnormal distal motor latency. Severe or extreme CTS was defined by absent sensory responses, abnormal distal motor latency, reduced motor responses, or absent motor and sensory responses.

The patient group included 53 wrists in 49 patients. The control group included 28 wrists in 27 healthy volunteers with bifid median nerves. Control subjects had no clinical signs or symptoms of CTS when presenting at the Department of Hand Surgery. These control subjects came to the Surgery Clinic for hand problems (such as tendon rupture or trigger finger) unrelated to carpal tunnel. All subjects were additionally screened to exclude systemic disorders (ie, diabetes mellitus, connective tissue disorders, and kidney or thyroid abnormalities) that might result in neuropathy (8). Electrodiagnostic tests were not performed in healthy volunteers.

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Abbreviations:
A_z = area under ROC curve
CSA = cross-sectional area
CSAc = carpal tunnel CSA
ΔCSA = difference between CSAc and CSAp
CSAp = proximal CSA
CTS = carpal tunnel syndrome
ROC = receiver operating characteristic

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Guarantor of integrity of entire study, A.S.K.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, A.S.K., R.F., F.G., M.F.G., T.B., W.N.L.; clinical studies, A.S.K., F.G., M.F.G., R.A., T.B., M.S., W.N.L.; statistical analysis, A.S.K., E.J.H., F.G., W.N.L.; and manuscript editing, all authors

Potential conflicts of interest are listed at the end of this article.

Figure 1

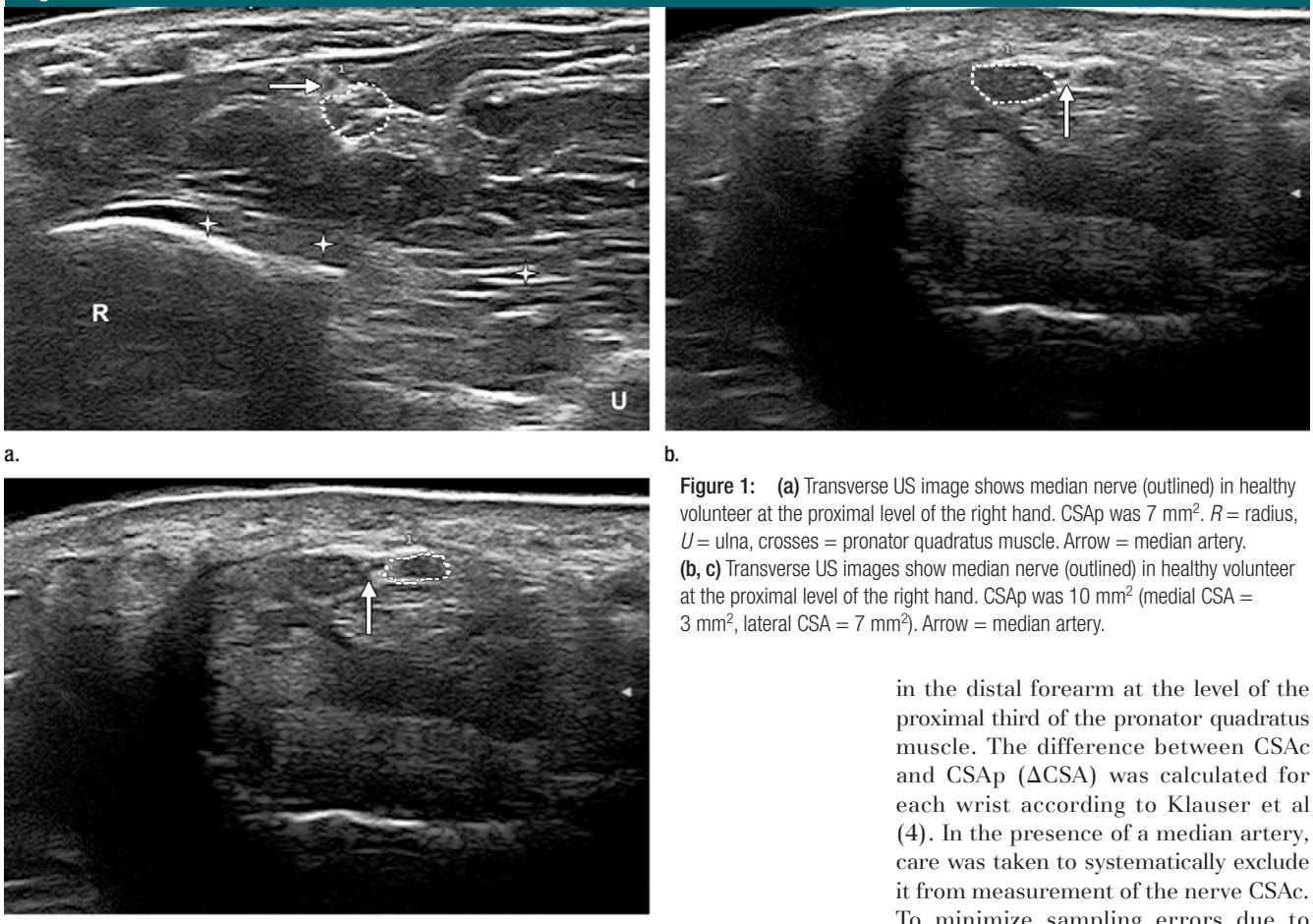

Figure 1: **(a)** Transverse US image shows median nerve (outlined) in healthy volunteer at the proximal level of the right hand. CSAp was 7 mm^2. *R* = radius, *U* = ulna, crosses = pronator quadratus muscle. Arrow = median artery. **(b, c)** Transverse US images show median nerve (outlined) in healthy volunteer at the proximal level of the right hand. CSAp was 10 mm^2 (medial CSA = 3 mm^2, lateral CSA = 7 mm^2). Arrow = median artery.

US Technique

US examinations were performed by two independent musculoskeletal radiologists (A.S.K. and R.F., with 12 and 4 years, respectively, of musculoskeletal US experience). Each radiologist was blinded to the results of clinical examination and electrodiagnostic tests at the time of the US study. Examination was performed with a 14–8-MHz (LA424, 14-8 MPX; Esaote, Genoa-Firenze, Italy) or an 18–6-MHz (LA435, MyLab90; Esaote) linear array transducer. Subjects were seated facing the examiner with their extended arms. Wrists were rested on a flat surface, forearms were supine, and fingers were semiextended in a neutral position. Transverse imaging of the median nerve from the distal forearm to the outlet of the carpal tunnel was performed.

Two measurements of maximal median nerve CSA were obtained: CSAc and CSAp. The CSAc measurement was obtained by summing the CSAs for the lateral and medial branches of the bifid median nerve according to the method described by Bayrak et al (5). In keeping with the findings of Ziswiler et al (9), the largest CSA was measured for each median nerve branch at the level of the carpal tunnel, which was defined to include the entrance under the transverse carpal ligament, the proximal tunnel (scaphoid-pisiform level), and the distal tunnel (trapezium-hamate level). At the level of the distal radius, after depiction of the pronator quadratus muscle, the median nerve was identified between the flexor pollicis longus tendon and the flexor digitorum superficialis tendons. CSAp was measured in the distal forearm at the level of the proximal third of the pronator quadratus muscle. The difference between CSAc and CSAp (ΔCSA) was calculated for each wrist according to Klauser et al (4). In the presence of a median artery, care was taken to systematically exclude it from measurement of the nerve CSAc. To minimize sampling errors due to compression of the median nerve, pressure during scanning and measurement was minimized. CSA was measured by tracing a continuous line around the inner hyperechoic rim of the median nerve with electronic calipers. Measurements at both the proximal and distal levels were repeated three times, and the mean of these three measurements was used for statistical evaluation. To quantify the level of intraobserver agreement, a standard deviation was calculated for the three measurements of CSAp, CSAc (medial), and CSAc (lateral).

Statistical Analysis

Patient age and sex and the number of right and left wrists were tabulated for patients with CTS and control subjects. Comparison of the two groups was performed with a *t* test (for age) or a χ^2 test (for sex and side), as appropriate.

Measurements of CSAc and CSAp from the two independent observers were compared by using a *t* test to evaluate for the presence of any systematic difference between the observers, with a Pearson correlation coefficient to demonstrate the level of correlation between the two observers. In addition, Bland-Altman plots were presented to demonstrate the level of agreement between the independent observers.

The median nerve CSAc in the carpal tunnel and ΔCSA were compared between CTS cases and control subjects and then were compared again among patients with CTS who had a mildly positive nerve conduction velocity and those who had a highly positive nerve conduction velocity. To determine whether a systematic difference in CSAc or ΔCSA between men and women might confound our results, we tested for differences between CSAc and ΔCSA as a function of sex in both the patient and control populations. The diagnostic accuracy of US for CTS was tabulated for CSAc alone (with threshold values of 10, 11, and 12 mm^2), as well as for ΔCSA (with threshold values of 2, 3, and 4 mm^2). To test whether ΔCSA provided a better diagnostic test than CSA in the carpal tunnel, parametric receiver operating characteristic (ROC) analysis was performed to compare the areas under the ROC curves (A_z) for the diagnosis of CTS versus a normal result, as well as for the distinction between mild or moderate CTS and severe or extreme CTS. All statistical tests were performed with software (Stata, version 10.0; Stata, College Station, Tex), and results were given as mean ± standard deviation. ROC analysis was performed with the default settings in the ROCCOMP command. *P* less than .05 indicated a significant difference.

Figure 2

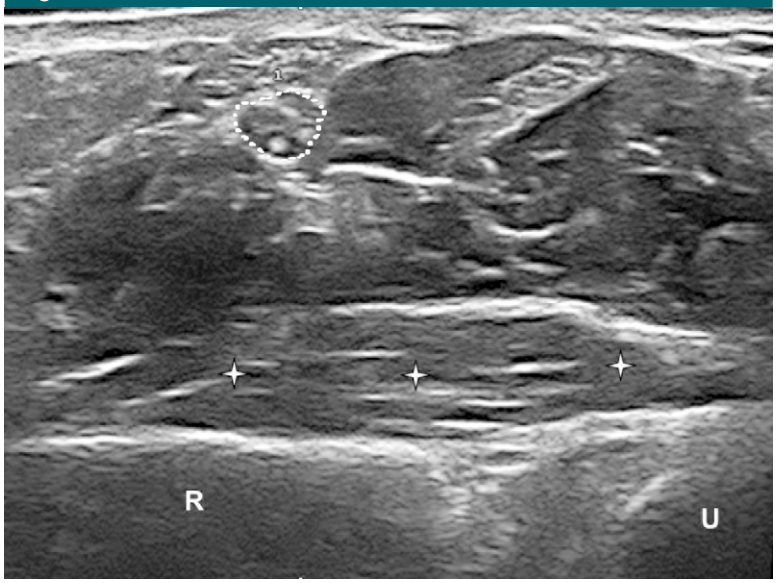

Figure 2: Transverse US image shows median nerve (outlined) in patient at the proximal level of the right hand. CSAp was 9 mm^2. *R* = radius, *U* = ulna, crosses = pronator quadratus muscle.

Figure 3

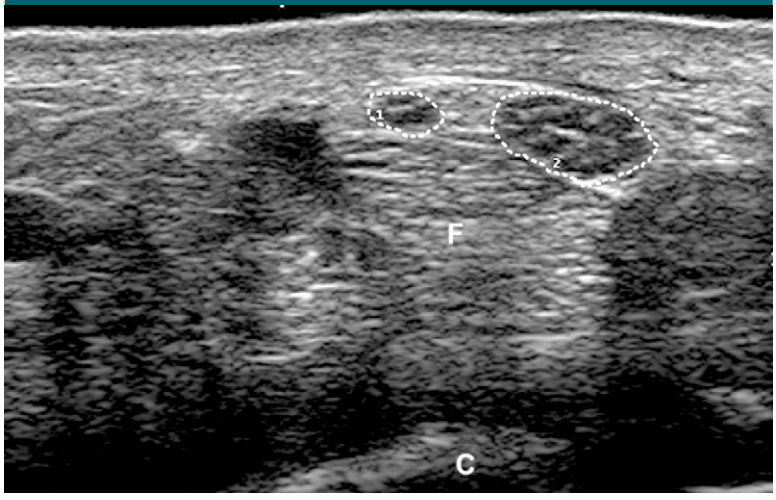

Figure 3: Transverse US image shows bifid median nerve (outlined) in patient at the level of the carpal tunnel. CSAc was 15 mm^2 (medial CSA *[2]* = 12 mm^2, lateral CSA *[1]* = 3 mm^2). *C* = carpus, *F* = flexor tendons.

Results

The study population included 17 men and 32 women (mean age, 55.1 years; age range, 24–78 years; right-to-left wrist ratio, 33:20). The control population consisted of 13 men and 14 women (mean age, 52.6 years; age range, 24–86 years; right-to-left wrist ratio, 15:13). When comparing the patient and control groups, there was no significant difference in patient age (*P* = .49), in the distribution of men versus women (*P* = .23), or in the distribution of right versus left wrists (*P* = .51).

Measurements of the median nerve in a healthy control subject are illustrated in Figure 1. Measurements of the median nerve proximal to the carpal tunnel and at the level of the carpal tunnel in a patient with CTS are illustrated in Figures 2 and 3. With respect to intraobserver agreement, the repeated measurements of CSAp demonstrated a mean standard deviation of 0.32 mm, while the repeated measurements of the two CSAc branches demonstrated

Figure 4

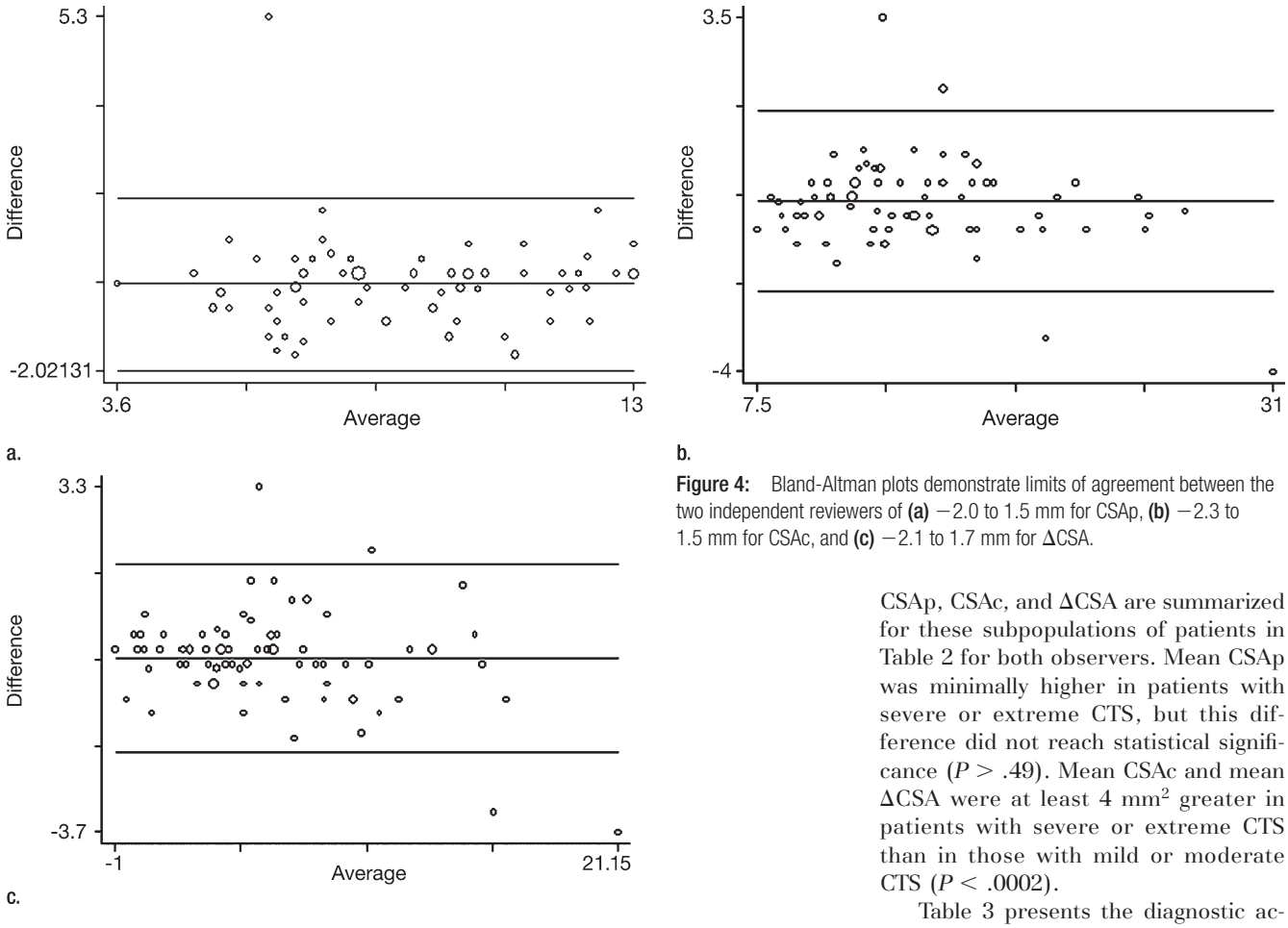

Figure 4: Bland-Altman plots demonstrate limits of agreement between the two independent reviewers of **(a)** −2.0 to 1.5 mm for CSAp, **(b)** −2.3 to 1.5 mm for CSAc, and **(c)** −2.1 to 1.7 mm for ΔCSA.

mean standard deviation of 0.349 for the lateral branch and 0.222 mm for the medial branch. With respect to interobserver agreement, there was no significant difference in the mean values of CSAp, CSAc, or ΔCSA between the two observers among either the patients or the healthy volunteers. The Pearson correlation coefficients between measurements by the two observers were 0.93 for CSAp, 0.98 for CSAc, and 0.98 for ΔCSA. Bland-Altman plots for CSA, CSAc, and ΔCSA in Figure 4 demonstrate limits of agreement of −2.0 to 1.5 mm for CSAp, −2.3 to 1.5 mm for CSAc, and −2.1 to 1.7 mm for ΔCSA.

Measured areas for CSAp, CSAc, and ΔCSA are summarized in Table 1 for both observers. Among healthy volunteers, there was no significant difference between men and women for CSAp, CSAc, and ΔCSA ($P > .2$). Among patients, there was no significant difference between men and women for CSAc and ΔCSA ($P > .2$), although mean CSAp was 2.2 mm greater in men than in women ($P < .01$). Mean CSAp was slightly lower in patients with CTS than in healthy volunteers, but this difference did not reach statistical significance ($P > .07$). Mean CSAc was approximately 5 mm^2 greater in patients than in healthy volunteers ($P < .0001$). The difference between patients and healthy volunteers was even greater for ΔCSA (mean difference = 5.8–5.9 mm^2; $P < .0001$).

Among patients with CTS, 26 wrists were classified according to electrophysiologic results as mild or moderate, while 27 wrists were classified as severe or extreme. Measured areas for CSAp, CSAc, and ΔCSA are summarized for these subpopulations of patients in Table 2 for both observers. Mean CSAp was minimally higher in patients with severe or extreme CTS, but this difference did not reach statistical significance ($P > .49$). Mean CSAc and mean ΔCSA were at least 4 mm^2 greater in patients with severe or extreme CTS than in those with mild or moderate CTS ($P < .0002$).

Table 3 presents the diagnostic accuracy of US for CTS with CSAc alone (with threshold values of 10, 11, and 12 mm^2), as well as with ΔCSA (with threshold values of 2, 3, and 4 mm^2). Optimal diagnostic discrimination was obtained with a ΔCSA threshold of 4 mm^2, with correct identification of 49 of 53 wrists with CTS and correct identification of all but one or two of the 28 asymptomatic wrists (depending on which observer's measurements were used).

In a pooled analysis with both right and left wrists, ROC analysis demonstrated excellent discriminating ability for both CSAc and ΔCSA to distinguish patients with CTS from healthy volunteers (Table 4). A parametric ROC comparison of A_z for this pooled analysis demonstrated that the discriminating ability of ΔCSA was superior to that of CSAc ($P < .003$) for each of our

observers. When the ROC analysis was repeated for either right or left wrists alone, the discriminating ability of ΔCSA remained superior to that of CSAc (A_z = 0.96 vs 0.83; $P < .05$ for the 33 left wrists and $P < .01$ for the 48 right wrists). With respect to discriminating between CTS wrists that were mild or moderate and those that were severe or extreme according to nerve conduction velocity tests (Table 5), both CSAc and ΔCSA tended to be greater in wrists with highly positive nerve conduction velocity and both were significantly better predictors than CSAp ($P < .001$), but neither parameter demonstrated a statistically significant advantage over the other ($P = .75$).

Table 1

Nerve Measurements in Patients with CTS versus Healthy Volunteers

	Patients with CTS		Healthy Volunteers	
Measurement	Examiner 1	Examiner 2	Examiner 1	Examiner 2
CSAp (mm^2)	8.3 ± 2.3	8.6 ± 2.4	9.3 ± 2.3	9.4 ± 2.2
CSAc (mm^2)	16.2 ± 4.6	16.6 ± 4.9	11.3 ± 2.1	11.6 ± 1.9
ΔCSA (mm^2)	7.9 ± 3.8	8.0 ± 4.2	2.0 ± 1.7	2.2 ± 1.8

Note.—Data are means ± standard deviations.

Table 2

Nerve Measurements in Patients with Mild or Moderate CTS versus Those with Severe or Extreme CTS at Nerve Conduction Testing

	Mild or Moderate CTS		Severe or Extreme CTS	
Measurement	Examiner 1	Examiner 2	Examiner 1	Examiner 2
CSAp (mm^2)	8.1 ± 2.1	8.4 ± 2.3	8.5 ± 2.5	8.8 ± 2.5
CSAc (mm^2)	13.9 ± 3.5	14.2 ± 3.4	18.3 ± 4.5	18.9 ± 5.0
ΔCSA (mm^2)	5.8 ± 2.2	5.8 ± 2.3	9.8 ± 4.0	10.1 ± 4.6

Note.—Data are means ± standard deviations.

Discussion

The diagnosis of CTS traditionally is based on typical clinical signs and symptoms and may be confirmed by using electrodiagnostic studies (8). More recently, US has been implemented as an additional noninvasive approach for the diagnosis of CTS (3,7–16). While electrodiagnostic studies depict physiologic malfunctions of the median nerve, US depicts structural abnormalities of CTS (17). A bifid median nerve occurs relatively frequently in patients with CTS and may be more commonly associated with compression of the median nerve in the carpal tunnel because of its relatively higher CSA than that of a nonbifid median nerve. In cases with unilateral or severe CTS, especially in the nondominant hand, the physician should consider the possible presence of a median nerve variation (5). In the present study, we demonstrated that optimal diagnostic discrimination of CTS by using US in the setting of a bifid median nerve should be based on a ΔCSA of 4 mm^2 or greater, which results in high sensitivity and specificity with high interobserver agreement.

Bifid median nerves have been described in relatively few imaging studies (18–20). However, the bifid median nerve as an anatomic variation has been reported extensively in the surgical literature (1,21–25). The bifid median nerve anomaly has been reported to have an incidence of 0.8%–2.8% in patients with CTS, and in most cases, it has been reported with a concomitant persistent median artery (1,20,23). Propeck et al (18) suggested that the sonographic size criteria for diagnosing CTS in nonbifid median nerves may not be accurate for evaluating bifid median nerves. Iannicelli et al (19) compared sonographic and magnetic resonance imaging findings in six patients with a bifid median nerve selected from a population of 294 patients with CTS. Propeck et al (18) reported three cases of a bifid median nerve, one of which was in a patient with CTS, whereas the remaining two were found in cadaveric specimens. Both studies concluded that sonography can allow effective diagnosis and delineation of a bifid median nerve. Gassner et al (20) described Doppler sonographic findings in two patients with CTS associated with a persistent median artery and reported 16 hands with a persistent median artery among 50 asymptomatic volunteers.

The largest study of bifid median nerves in the literature was by Bayrak et al (5), who evaluated a bifid median nerve in 32 cases, unilaterally in 22 and bilaterally in 10 with a relatively high percentage of bifid median nerves (19%). Their data suggested an optimal cutoff value for CSAc of 11 mm^2 for diagnosis of CTS in bifid median nerves. Our results in a larger population with bifid median nerves suggested that the optimal threshold for CSAc may be as high as 12 mm^2 to obtain better specificity.

Prior US studies have provided a range of cutoff values for CSA of the median nerve at the level of the carpal tunnel. Mean normal values for CSA of the median nerve in the literature vary from 6.1 to 10.4 mm^2; the difference between these two values (4.3 mm^2) amounts to 51% of the normal median nerve CSA (8.4 mm^2) (18). The threshold suggested for median nerve abnormality varies from 9 to 14 mm^2; the difference between these two values (5 mm^2) amounts to 59% of the normal CSA (8.4 mm^2). A recent study by Klauser et al (4) demonstrated improved accuracy for the diagnosis of CTS by comparing the degree of nerve swelling in the carpal tunnel relative to that in the CSA of the more proximal portion of the nerve to

Table 3

Sensitivity and Specificity of Nerve Measurements for US Diagnosis of CTS

	Sensitivity (%)		Specificity (%)	
Measurement	Examiner 1	Examiner 2	Examiner 1	Examiner 2
CSAc with 10-mm^2 threshold	94.3	96.2	35.7	17.9
CSAc with 11-mm^2 threshold	86.8	92.5	39.3	39.3
CSAc with 12-mm^2 threshold	83.0	86.8	50.0	42.9
ΔCSA with 2-mm^2 threshold	98.1	100	39.3	39.3
ΔCSA with 3-mm^2 threshold	96.2	94.3	53.6	50.0
ΔCSA with 4-mm^2 threshold	92.5	92.5	92.9	96.4

Table 4

A_z for Patients with CTS versus Healthy Volunteers

Measurement	Examiner 1	Examiner 2
CSAp	0.38 ± 0.07	0.40 ± 0.06
CSAc	0.84 ± 0.04	0.85 ± 0.04
ΔCSA	0.96 ± 0.02	0.95 ± 0.02

Note.—Data are means ± standard deviations.

Table 5

A_z for Mild or Moderate CTS versus Severe or Extreme CTS

Measurement	Examiner 1	Examiner 2
CSAp	0.56 ± 0.08	0.55 ± 0.08
CSAc	0.77 ± 0.06	0.78 ± 0.06
ΔCSA	0.80 ± 0.06	0.80 ± 0.06

Note.—Data are means ± standard deviations.

compensate for interindividual variability in CSA of the median nerve. Among nonbifid median nerves, a ΔCSA of 2 mm^2 or more represented an optimal test threshold for the diagnosis of CTS with a sensitivity of 99% and specificity of 100%. In the present study, we investigated the same ΔCSA parameter for cases in which a bifid median nerve was present. Our findings suggested that a ΔCSA threshold of 4 mm^2 provides the optimal distinction between healthy subjects and patients with CTS who have bifid median nerves. ROC analysis demonstrated a significant diagnostic advantage of ΔCSA compared with CSAc for the diagnosis of CTS (Table 4) ($P < .003$).

With respect to severity of CTS at electrodiagnostic studies, both CSAc and ΔCSA were higher in patients with severe or extreme CTS than in patients with mild or moderate CTS. ROC analysis suggested that both CSAc and ΔCSA increase with the severity of CTS but that neither technique provides excellent discriminating ability between mildly and highly positive CTS. There was no significant advantage of ΔCSA over CSAc for prediction of the severity of CTS. Nonetheless, these US findings may be helpful for the grading of CTS.

US imaging with electrodiagnostic tests as a reference standard has shown to be of value in diagnosing CTS, with sensitivity of 82%–94% and specificity of 65%–97% (7–9,12). This wide range of reported diagnostic accuracy contributes to the controversy about the wisdom of additional testing with US. Seror (26) stated that US appears to be of little use in the diagnosis of CTS. By contrast, Wong et al (3) proposed an algorithm involving initial US examination of patients suspected of having CTS and secondary electrodiagnostic tests performed only when US results were negative. US may be used to detect space-occupying lesions that cause CTS symptoms, including ganglia, fibromata, neural tumors, and tenosynovitis, and to determine increased median nerve CSA in patients with CTS. Additional US features such as median nerve echogenicity or mobility, flattening ratio of the distal nerve, and flexor retinaculum bulging may provide further information for the diagnosis of CTS (10).

We noted several limitations of our study. The presence of a larger CSAp among male patients than female patients may be a limitation if CSAp is used as a diagnostic criterion for CTS. However, CSAp has not been used for the diagnosis of CTS. CSAc and ΔCSA were the two useful diagnostic parameters in our study. No significant sex differences were found in measurements of CSAc and ΔCSA, which suggests that similar threshold values of these parameters should be useful for male and female patients. Although we evaluated several CSA measurements, no additional US parameters were evaluated; bulging of the transverse carpal ligament, the flattening ratio of the median nerve in the distal carpal tunnel, and echogenicity and mobility of the nerve were not analyzed, although these parameters may provide additional diagnostic information for CTS. Furthermore, our study did not attempt to correlate CSA with body mass index and/or hand physiognomies (small or strong wrists). Additional studies are needed to determine whether these factors influence median nerve thickness and whether indexed measurements of the median nerve CSA may provide additional information.

The present study focused on evaluation of CSA measurements of the median nerve for the diagnosis of CTS. Our results demonstrated that an additional CSA measurement at the distal forearm with calculation of ΔCSA improves the diagnostic accuracy of US for the diagnosis of CTS in bifid median nerves (just as it does with nonbifid median nerves). The use of a ΔCSA parameter partially compensates for variation in the size of the median nerve among individuals and improves the diagnostic accuracy of US for the presence of CTS by reducing the overlap in measurement obtained in healthy volunteers and patients with CTS. Optimal diagnostic discrimination with ΔCSA was obtained at a threshold of 4 mm^2, resulting in sensitivity and specificity greater than 90% with high interobserver agreement.

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