Sonography in the Diagnosis of Carpal Tunnel Syndrome

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OBJECTIVE. The few papers published on the use of sonography in carpal tunnel syndrome suggest it may be a useful diagnostic test. This study aims to prospectively evaluate the use of sonographic measurements of the median nerve in the diagnosis of carpal tunnel syndrome.

SUBJECTS AND METHODS. Patients with documented carpal tunnel syndrome and a group of asymptomatic controls were enrolled and underwent high-resolution sonography of the carpal tunnel. A small-footprint linear array transducer was used to scan and measure the median nerve cross-sectional area and the maximum transverse and anteroposterior diameters. Data from the patient group and the control group were compared to establish optimal diagnostic criteria for carpal tunnel syndrome.

RESULTS. Sixty-eight carpal tunnel syndrome patients (50 women, 18 men) with 102 affected nerves and 68 nerves in 36 asymptomatic controls (23 women, 13 men) were examined. Qualitative assessment alone was found to be unreliable. All measurements showed significant differences between patients and controls. The most predictive measurement was swelling of the median nerve, which was significantly greater in carpal tunnel syndrome patients compared with controls (mean, 0.13 cm^2 versus 0.07 cm^2). Thus, quantitative assessment of the median nerve provides an accurate diagnostic test (sensitivity, 82%; specificity, 97%), with an area larger than 0.09 cm^2 being highly predictive of carpal tunnel syndrome.

CONCLUSION. We confirm that median nerve cross-sectional area measurement correlates well with the presence of carpal tunnel syndrome and is both sensitive and specific for the diagnosis.

Carpal tunnel syndrome is the most common form of peripheral nerve entrapment and is particularly prevalent in middle-aged women. Compression on the median nerve within the carpal tunnel leads to the symptom complex, but the underlying etiology is often uncertain. Carpal tunnel syndrome can be readily identified by most clinicians, and the clinical findings alone may be sufficient for diagnosis [1]. Nerve conduction studies are useful in the less typical cases and in cases in which other conditions such as entrapment of other nerves, cervical neural compression, demyelinating disease, diabetes, or peripheral neuritis could cause confusion. Although nerve conduction studies are highly specific [2], they have a substantial false-negative rate of between 10% and 20% [3, 4]. Although nerve conduction studies often indicate the level of the lesion, they do not provide spatial information about the nerve or its surroundings that could help in determining etiology. In recent years, MR imaging has been shown to be of value in the diagnosis of carpal tunnel syndrome [5–8]. Compared with MR imaging, sonography has the potential advantages of lower cost, shorter examination time, and the possibility of sonographically guided intervention and treatment; however, there is little data on sonographic evaluation of carpal tunnel syndrome other than the studies of Buchberger et al. [9, 10]. A recent study using sonography to assess cubital tunnel syndrome suggests that quantitative analysis may also prove useful in the diagnosis of nerve entrapment at sites other than the carpal tunnel [11].

With both MR imaging and sonography, it is necessary to measure the median nerve because subjective assessment alone has proven insufficiently diagnostic [5–10]. The aim of this study was to prospectively evaluate quantitative sonographic methods for the diagnosis of carpal tunnel syndrome.

Subjects and Methods

Consecutive patients with a provisional diagnosis of carpal tunnel syndrome (of any cause)

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referred to a single rheumatologist were enrolled in the study if they had either a nerve conduction study with positive findings, the signs and typical history of carpal tunnel syndrome as assessed by two physicians, or both. Patients with a history of wrist surgery or with anatomic variants of the median nerve were excluded. Abnormal nerve conduction was defined as a reduction in the median nerve sensory conduction velocity, prolongation of the distal motor latency without abnormalities in the ulnar nerve or proximal median nerve parameters, or both.

All patients underwent high-resolution real-time sonography of the carpal tunnel using an HDI 3000 and 7–10-MHz small-footprint 26-mm linear array transducer (Advanced Technology Laboratories, Bothell, WA). A group of asymptomatic control subjects with no prior condition affecting either arm were also examined.

All wrists were evaluated in the resting neutral position with the palm up. The full course of the median nerve in the carpal tunnel was assessed in both the transverse (Figs. 1 and 2) and sagittal planes (Fig. 3). The median nerve cross-sectional area and the transverse (major axis) and anteroposterior (minor axis) diameters were measured in the transverse plane at the proximal boundary of the carpal tunnel at the point of posterior angulation of the median nerve (Fig. 3). Our measurements were equivalent to measurements obtained by other researchers at the level of the pisiform bone [9, 10], which is usually the level of maximum swelling [10]. No measurements were taken in the distal carpal tunnel. The flattening ratio was defined as the ratio of the nerve's major to minor axis.

The cross-sectional area of the median nerve was calculated by two different methods: first with a direct method using a continuous boundary trace just within the echogenic boundary of the nerve (Fig. 2), second with an indirect calculation of the area using the transverse and anteroposterior dimensions as described by Buchberger et al. [10]. All measurements were rounded to the nearest 0.01 cm^2 and repeated at least once. Measurements of the median nerve in patients and controls were compared and then were used to calculate the accuracy of the technique using different diagnostic criteria.

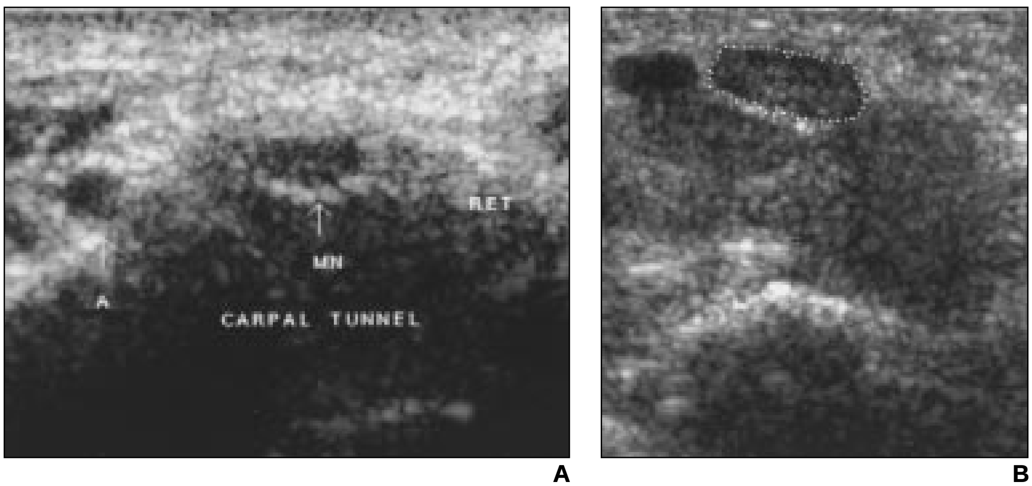

Fig. 1.—Carpal tunnel syndrome in
A, Cross-sectional sonogram obtained with HDI 3000 scanner (Advanced Technology Laboratories, Bothell, WA) of left carpal tunnel at level of pisiform bone shows median nerve. A = ulnar artery, MN = median nerve, RET = flexor retinaculum. Flexor tendons within carpal tunnel are depicted under the words "carpal tunnel."
B, Cross-sectional sonogram of left carpal tunnel at level of pisiform bone shows median nerve outlined using direct area measurement tool on HDI 3000 scanner (Advanced Technology Laboratories). Note caliper measurements of short and long axes of nerve. Cursor indicates tendons of flexor digitorum in region between bone interface and inferior surface of nerve. Considerable anisotropy, a sonographic hallmark of tendons, is seen in area around cursor.

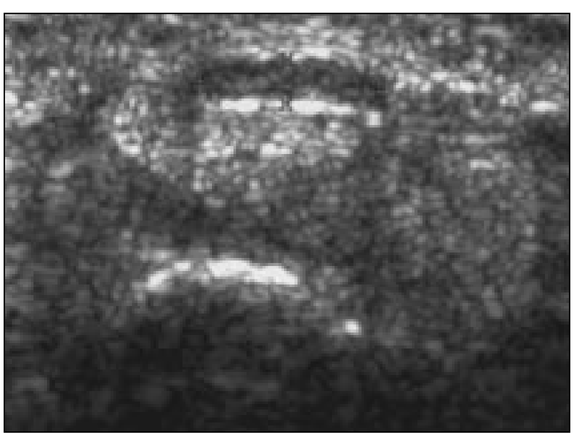

Fig. 2.—43-year-old man with carpal tunnel syndrome. Sonogram shows flattened, swollen, and hypoechoic left median nerve. Flexor retinaculum immediately superficial to nerve is seen to bow anteriorly. Caliper measurements of major and minor axes of nerve are shown.

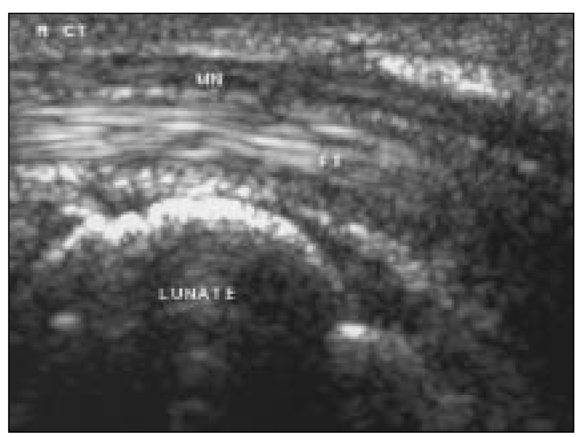

Fig. 3.—Sagittal sonogram of right carpal tunnel in asymptomatic 65-year-old man. R = right, CT = carpal tunnel, MN = median nerve, FT = flexor tendons, lunate = lunate bone. Cross-sectional measurements were taken at level where nerve angulated away from transducer on entering carpal tunnel (immediately distal to "MN" label).

Results

Sixty-eight carpal tunnel syndrome patients (50 women, 18 men) with 102 affected nerves and 68 nerves in 36 asymptomatic controls (23 women, 13 men) were examined. The average age of patients was 54 years; the average age of controls was 44 years. Most cases of carpal tunnel syndrome were of the primary (idiopathic) type, but possible etiologic factors were identified in 24 patients (35%). Associated diagnoses included rheumatoid arthritis (nine patients), diabetes (three patients), synovitis within wrist (three patients), flexor tenosynovitis (three patients), pregnancy (two patients), ganglion (one patient), chronic renal failure (one patient), gout (one patient), and systemic lupus erythematosus (one patient).

Each assessment took approximately 5 min per wrist. Identification of the exact boundaries of the median nerve was clear in the proximal carpal tunnel but became more difficult distally where the nerve is deeper, oblique to the transducer, and there is a poor signal-to-noise ratio. Sonographic area measurements done by direct trace were highly reproducible and never varied by more than 0.01 cm^2 when repeated. However, the area measurements done using an ellipse tool or the indirect method gave values that differed slightly by up to 0.015 cm^2. The correlation coefficient between the direct and indirect methods was 0.87 in carpal tunnel syndrome patients and 0.77 in controls.

Table 1 summarizes the measured values in carpal tunnel syndrome patients and asymptomatic controls. Using the *t* test, all differences between patients and controls were found to be highly significant. Qualitative assessment was of limited value in most patients because median nerve swelling or flattening was often subtle or mild. The diagnostic triad described by Buchberger et al. [9, 10] (fusiform proximal nerve swelling, bowing of the flexor retinaculum, and flattening of the nerve within the carpal tunnel) was identifiable in only seven (6.9%) of 102 affected nerves (Fig. 2).

Of the 102 nerves evaluated in the carpal tunnel syndrome group, 74 underwent nerve conduction studies; 62 of the 74 studies had positive findings, four were equivocal, and eight were normal. In the remaining 28 nerves, the diagnosis of carpal tunnel syndrome was based on clinical criteria alone. No significant differences were found between the carpal tunnel syndrome group as a whole and the subgroup that had nerve conduction studies with positive findings (Table 1). The average cross-sectional area in those carpal tunnel syndrome patients who had nerve conduction studies with positive findings was 0.137 cm^2 using the direct method and 0.126 cm^2 using the indirect method, compared with 0.116 and 0.102 cm^2 in patients whose diagnosis was made on clinical grounds alone. These differences were not significant. No significant differences in any measurements were found between men and women in either the carpal tunnel syndrome group or the control group. A weak, nonsignificant correlation between age and direct and indirect area measurements was seen in the control group (correlation coefficients, 0.21 [direct method] and 0.15 [indirect method]). Table 2 shows the diagnostic accuracy of the median nerve measurements at values selected for their greatest likelihood ratio.

TABLE 1 Sonographic Measurements of the Median Nerve in 68 Patients with Carpal Tunnel Syndrome and 36 Healthy Controls

Measurement	CTS-1 (SD)	CTS-2 (SD)	Healthy Controls (SD)	*t* test (CTS-1 vs Healthy Controls)	*t* test (CTS-2 vs Healthy Controls)
Number of nerves studied	102	62	68		
Mean cross-sectional area (cm^2) calculated by direct method	0.127 (±0.04)	0.137 (±0.4)	0.070 (±0.01)	$p < .001$	$p < .001$
Mean cross-sectional area (cm^2) calculated by indirect method	0.114 (±0.04)	0.126 (±0.4)	0.068 (±0.02)	$p < .001$	$p < .001$
Mean transverse diameter (mm)	6.62 (±1.2)	6.90 (±1.3)	4.7 (±0.9)	$p < .001$	$p < .001$
Mean anteroposterior diameter (mm)	2.18 (±0.5)	2.30 (±0.5)	1.8 (±0.3)	$p < .001$	$p < .001$
Mean flattening ratio	3.17 (±0.90)	3.09 (±0.71)	2.72 (±0.73)	$p = .012$	$p = .05$

Note.—CTS-1 = entire carpal tunnel syndrome group, CTS-2 = patients with carpal tunnel syndrome who had nerve conduction tests with positive findings.

TABLE 2 Diagnostic Accuracy of Median Nerve Measurements in Carpal Tunnel Syndrome

Criteria	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)	Likelihood Ratio[a]
Area > 0.09 cm^2 using direct method (all patients)	82.4	97.1	97.7	78.6	28.00
Area > 0.09 cm^2 using indirect method (all patients)	76.5	88.2	90.7	71.4	6.50
Area > 0.09 cm^2 (female patients only)	80.6	95.5	96.7	75.0	17.72
Area > 0.09 cm^2 (male patients only)	86.7	100	100	85.7	>20
Width > 6.5 mm	50.0	98.5	98.1	56.8	34.00
Area > 0.09 cm^2 (direct method) and width >4.9 mm	80.4	98.5	98.8	77.0	54.67
Flattening ratio > 3.3	38.2	75.0	69.6	44.7	1.53
Area > 0.09 cm^2 (direct method) or flattening ratio > 3.3	88.2	72.1	82.6	80.3	3.16

[a]Likelihood ratio = [sensitivity]/[1–specificity] and is an indicator that is independent of prevalence bias: The higher the likelihood ratio, the better the test, with a ratio of 1 indicating that the test is no better than random.

Discussion

Buchberger et al. [9, 10] were the first to quantify anatomic changes in carpal tunnel syndrome using sonography. Their findings confirmed those of earlier MR imaging studies [12, 13]. Diffuse or localized swelling of the median nerve and flattening of the nerve are consistent findings on sonography [9, 10] and MR imaging [5–8, 10, 12, 13].

This study confirms the usefulness of quantitative sonographic assessment in the diagnosis of carpal tunnel syndrome. This study found that the best criterion for sonographic diagnosis of carpal tunnel syndrome is a median nerve cross-sectional area greater than 0.09 cm^2 at the level of the pisiform bone. Most MR studies of carpal tunnel syndrome have found a similar degree of swelling of the median nerve. MR imaging may be better than sonography in subtle cases because of its soft-tissue contrast [10] and because it has the additional diagnostic feature of showing signal changes caused by edema [8, 10, 12]. However, two recent studies [14, 15] have cast some doubt on the validity of using specific MR features in the diagnosis of carpal tunnel syndrome.

Although the indirect method for area calculation is simpler to perform and is probably more reproducible, the direct method used in our study has a higher diagnostic accuracy. Using the ellipse tool available on many sonography machines should give the same result as the indirect method.

The mean cross-sectional area of the median nerve (at the level of the pisiform bone) of the 68 nerves in 36 asymptomatic controls was 0.070 cm^2 (SD, 0.016 [direct method]) and 0.067 cm^2 (SD, 0.017 [indirect method]). In comparison, Buchberger et al. [10] found an average area of 0.079 cm^2 (SD, 0.011 [indirect method]). In patients with carpal tunnel syndrome, Buchberger et al. [10] found an average area of 0.145 cm^2 (using the indirect method at the level of the pisiform bone) and a flattening ratio of 2.7, which is comparable with the results of 0.11 cm^2 and 3.2 in this study. Buchberger et al. [10] did not state whether their measurements of the median nerve were inclusive or exclusive of the echogenic rim surrounding the nerve. This factor may explain slight differences in average measurements between this study and theirs, but in both studies all measurements in carpal tunnel syndrome patients were significantly different from normal values. We found that the flattening ratio was highly variable (Table 1) and thus poorly predictive (likelihood ratio, 1.53 [Table 2]). We did, however, also find that a combination of median nerve width greater than 4.9 mm and an area greater than 0.09 cm^2 may be even more specific and predictive than the area criterion alone. Buchberger et al. [10] suggested that the flattening ratio may be better assessed at the level of the hamate bone.

We did not quantify transverse sliding of the median nerve, which Nakamichi and Tachibana [16] found was reduced in carpal tunnel syndrome. Like Chen et al. [17], we found transverse sliding difficult to quantify; however, this observation may be helpful when measurements are borderline or indeterminate.

Further standardization of the sonographic technique and prospective evaluation of these suggested diagnostic criteria are needed before measurement of the median nerve can be accepted as a routine investigation. Each laboratory should establish its own range of reference measurements.

Like Buchberger et al. [10], we found that subjective assessment of the median nerve alone is not sensitive for carpal tunnel syndrome; the triad of swelling and flattening of the nerve with bowing of the flexor retinaculum was present in only seven patients. However, sonographic evaluation of the median nerve is a simple, relatively low-cost, rapid, and accurate technique for the diagnosis of carpal tunnel syndrome. Sonography may have greater diagnostic usefulness in the assessment of peripheral nerve entrapment if quantitative techniques are used.

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