Clinical Radiology (2004) **59**, 916–925

Ultrasonographic assessment of mild and moderate idiopathic carpal tunnel syndrome

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Received 29 October 2003; received in revised form 17 February 2004; accepted 11 March 2004

KEYWORDS
Carpal tunnel syndrome; Ultrasonography; Diagnosis; Wrist; Median nerve

AIM: To investigate the diagnostic value of ultrasonography in mild and moderate idiopathic carpal tunnel syndrome (CTS).

MATERIALS AND METHODS: Cross-sectional areas (CSA), flattening ratios at three different levels, swelling ratio, and palmar displacement were analysed in 26 patients (14 with bilateral and 12 with unilateral disease, 40 wrists in total) for the presence and the severity of CTS. Twenty had normal nerve conduction studies (NCS) defined as "mild", and 20 of them had abnormal NCS defined as "moderate". The control group consisted of 20 healthy participants.

RESULTS: All parameters were significantly different between patient and control groups. Palmar displacement, swelling ratio, CSA at all levels and distal flattening ratio had the highest significance ($p < 0.0001$). The criterion with the highest sensitivity was the swelling ratio ≥ 1.3 (72.5%), followed by the middle CSA > 9 mm^2 and the palmar displacement > 2.5 mm. All of these criteria had a higher sensitivity in diagnosing moderate cases (85–100%) than diagnosing mild cases (30–55%). There was a significant difference between normal and mild CTS groups regarding palmar displacement, distal flattening ratio, middle CSA and swelling ratio ($p < 0.0001$ for all) and between normal and moderate groups regarding all parameters ($p < 0.01 - 0.0001$). When combined middle CSA, palmar displacement and swelling ratio had an overall discriminatory accuracy of 83.8%.

CONCLUSION: Additional diagnostic confirmation can be provided by ultrasonography and may be preferred as the initial step instead of electrophysiological studies. Detection of at least two of the three criteria (median nerve CSA > 9 mm^2 at pisiform level, swelling ratio ≥ 1.3, and palmar displacement > 2.5 mm) may be helpful for the verification of the diagnosis.

Introduction

Carpal tunnel syndrome (CTS) is an entrapment neuropathy involving the median nerve within its fibro-osseous tunnel at the wrist. Many orthopaedic and metabolic diseases may cause CTS, but more than half of the cases are idiopathic.[1] Diagnosis, usually based on clinical examination, is supported with nerve conduction studies (NCS) and imaging techniques.[2]

Plain films, ultrasonography (USG), computed tomography (CT), and magnetic resonance imaging (MRI) constitute the imaging armamentarium for the assessment of CTS. These methods play an important role in evaluating its bony and soft-tissue components and in detecting or excluding its pathological changes, such as synovitis, tumours, and anatomic malformations. Among these, MRI is

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0009-9260/$ - see front matter © 2004 Published by Elsevier Ltd on behalf of The Royal College of Radiologists.
doi:10.1016/j.crad.2004.03.019

widely accepted as the primary radiological method for the assessment of CTS.[3–5] However, it is expensive, relatively time-consuming, and still not widely available.

After the definition of the diagnostic MRI criteria for CTS,[4,5] Buchberger et al.[6,7] proposed the use of similar criteria (i.e. bowing of the flexor retinaculum, median nerve swelling at the pisiform level, and median nerve flattening at the hamate level) in USG assessment. This proposal has been variously evaluated, and several different diagnostic criteria and critical values were consequently defined.[8–14] However, in most of these studies NCS was the gold standard. Therefore, these studies had not provided an opinion regarding the validity of the relevant criteria, hence the value of USG in the early stages of this disease.

The purpose of this study was to assess the diagnostic value of USG and validity of previously described criteria in clinically diagnosed mild and moderate idiopathic CTS. The value of the USG parameters in the discrimination of the normal, mild and moderate cases was also investigated.

Materials and methods

Patients and controls

Patients were selected from among those undergoing diagnostic work-up for CTS in the pre-treatment period. Based on clinical findings independent of the NCS results, they were diagnosed as having CTS. Clinical criteria assessed were as follows: (1) pain and numbness in the median nerve territory; (2) sensory disturbances in the median nerve territory compared with the contralateral median nerve or ipsilateral ulnar nerve; (3) a positive finding in Tinel or Phalen tests.[8,13,14] All three criteria were required to make the diagnosis. Patients with systemic or orthopaedic conditions that may cause CTS were not included. These conditions were determined by careful evaluation of the patients' medical history and their laboratory and imaging findings. In order to restrict the study to mild and moderate cases, patients having thenar atrophy or requiring immediate surgery were not included. All patients underwent non-surgical treatment including activity avoidance and ergonomic job modification, splinting, non-steroidal anti-inflammatory drugs and single or intermittent intra-carpal steroid injections. Various combinations of the above-mentioned methods were used. Adequate relief of symptoms after non-surgical treatment was taken as the confirmation of the CTS diagnosis.

Twenty-six patients (five men and 21 women, mean age 38 years, range 23–71 years) were included in the final analysis using the above-mentioned criteria. Fourteen patients had bilateral, whereas the remaining 12 patients had unilateral CTS resulting in 40 wrists included in the analysis. Of these, 20 wrists had normal NCS and were defined to have "mild", whereas 20 wrists had abnormal NCS and were defined to have "moderate" disease.

Forty wrists of 20 healthy participants, without any CTS-related disease or occupations, formed the control group. These participants were four men and 16 women (mean age 41 years, range 21–68 years). This group was selected from the outpatients attending for irrelevant causes. Inpatients, hospital staff and medical students were not recruited to eliminate a biased result. Informed consent was obtained from both patients and controls.

NCS assessment

Electrophysiological studies were performed in all patients. Surface electrodes were used for data registration. Extremities were warmed up if skin temperature was below 32 °C. CTS diagnosis was based on the following criteria: distal motor nerve latencies greater than 4.7 ms; distal sensory nerve latencies greater than 2.35 ms; sensory nerve conduction velocity less than 45 m/s; a difference between the sensorial peak latencies of the palm-to-wrist segments of the median and ulnar nerves greater than 0.3 ms. In the absence of a sensory, motor or mixed response of the median nerve, patients were accepted as having severe CTS and they were not included in the study.

USG assessment

These evaluations were performed by the same radiologist (T.A.) who was unaware of the clinical and electrophysiological data using the same machine (HDI 5000; Philips Medical Systems, Bothell, WA, USA). The study interval between USG and NCS was less than a week in all patients. The median nerve was initially imaged along its transverse and longitudinal axes. Transverse ultrasonograms were obtained from tree levels: radio-ulnar joint (proximal level), pisiform bone (middle level) and hook of hamate (distal level).[6,7] The transducer was always kept perpendicular to the median nerve and any compression that could cause nerve deformation was avoided. At each level, the major and minor axes were measured using the scanner's own software. Cross-sectional areas

(CSA) were calculated using a continuous boundary trace just within the echogenic rim indicating the perineurium. The flattening ratio (major axis to minor axis) for each three level and a swelling ratio (middle CSA to proximal CSA) were then calculated. Palmar displacement was measured as the distance from a line drawn between the trapezium and the hamate to the palmar apex of the outer surface of the flexor retinaculum. Median nerve measurements were performed using a 7–10 MHz 26 mm linear transducer and palmar displacement measurements were performed using a 4–7 MHz 38 mm linear transducer.

Statistical analysis

The normality of the distributions for each USG parameter in each group were determined by the Kolmogorov-Smirnov test. The difference between the patients and controls regarding normally distributed parameters were analysed by independent samples *t*-test. The sensitivity, specificity, positive and negative predictive values of previously defined USG criteria and their 95% confidence intervals were calculated. The differences between the means of these parameters were tested by using one-way analysis of variance (ANOVA) for three party comparisons of the wrist with normal NCS (mild cases), abnormal NCS (moderate cases) and control groups (healthy participants). LSD (least significant difference) post-hoc test was employed for pair-wise comparisons when ANOVA resulted in a significant F test. In order to build a predictive model of group membership based on observed characteristics of each case, a discriminant analysis was performed. Sets of discriminant functions based on linear combinations of the significant predictor variables that provide the best discriminations between the groups were generated using univariate ANOVA. For all tests mentioned above, $p < 0.05$ was considered statistically significant.

Results

Four patients were excluded from the final analysis after USG examinations. These were consisted of one patient having marked bilateral flexor tenosynovitis, one patient having unilateral hypertrophic synovium, and two patients having unilateral bifid median nerves. All patients included in the final analysis had satisfactorily non-surgical treatment options in a follow-up period of at least 3 months. This finding was used as an additional confirmation of the CTS diagnosis.

All USG parameters were found to be normally distributed. Mean values and standard deviations (SD) of these parameters along with the statistical significance of the differences between CTS and controls, and between mild and moderate cases are listed in Table 1. There was a statistically significant difference between patient and control groups regarding all USG parameters investigated. Palmar displacement, swelling ratio, CSA at proximal, middle and distal levels, and distal flattening ratio produced higher significance ($p < 0.0001$) than the flattening ratios at proximal ($p = 0.012$) and middle ($p = 0.003$) levels.

The sensitivity, specificity, positive and negative predictive values of each previously defined USG criteria[8–14] in diagnosing CTS and their 95% confidence intervals are listed in Table 2. Swelling ratio ≥ 1.3 had highest sensitivity (72.5%) than the remaining criteria. This criterion was followed in sensitivity by the middle CSA being larger than 9 mm^2 (65%) and the palmar displacement (62.5%) being more than 2.5 mm. All criteria investigated had similar values for specificity (i.e. 90–97.5%).

The sensitivity, specificity, positive and negative predictive values for the criteria that have highest sensitivities (CSA at pisiform level >9 mm^2, swelling ratio ≥ 1.3, and palmar displacement >2.5 mm) and their 95% confidence intervals are listed in Tables 3 and 4 for wrists with normal and abnormal NCS, respectively. All of these criteria had higher sensitivity in diagnosing CTS with abnormal NCS (85–100%) than in diagnosing of CTS with normal NCS (30–55%). In 19 out of 20 wrists with abnormal NCS, at least two of these three criteria were present, whereas this observation was true for eight out of 20 wrists with normal NCS and only for two out of 40 normal wrists. According to the figures presented above, the presence of at least two of the three criteria produce a sensitivity of 40% and a specificity of 95% in identifying mild CTS. For moderate CTS, these figures were both 95%, respectively.

When multiple comparisons are made, there was a significant difference between normal and mild CTS groups regarding palmar displacement, distal flattening ratio, middle CSA and swelling ratio ($p < 0.0001$ for all; Figs. 1–4). The difference between normal and moderate groups was significant for all USG parameters ($p < 0.01$–0.0001). The difference between mild and moderate groups was significant for all USG parameters except proximal and middle flattening ratios ($p < 0.01$–0.0001).

Stepwise discriminant analysis produced the highest accuracy (83.3%) in classifying the cases to normal, mild and moderate groups when middle CSA, palmar displacement and swelling ratio were

Table 1 Comparison and statistical significance of the ultrasonographic parameters for carpal tunnel syndrome (CTS) patients and controls

	Palmar displacement (mm)	Proximal flattening ratio	Middle flattening ratio	Distal flattening ratio	Proximal CSA (mm^2)	Middle CSA (mm^2)	Distal CSA (mm^2)	Swelling ratio
Control group ($n = 40$)	1.40 ± 0.58	2.01 ± 0.36	2.07 ± 0.27	2.33 ± 0.28	6.05 ± 1.23	6.82 ± 1.51	6.57 ± 1.44	1.13 ± 0.12
Wrists with CTS ($n = 40$)	2.94 ± 1.10	2.20 ± 0.29	2.27 ± 0.31	2.96 ± 0.40	7.55 ± 1.58	10.30 ± 2.36	9.00 ± 1.98	1.36 ± 0.12
p-Value, comparison with control group	<0.0001*	0.012*	0.003*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Wrists with abnormal NCS ($n = 20$)	3.45 ± 0.94	2.26 ± 0.27	2.33 ± 0.33	3.11 ± 0.26	8.55 ± 1.19	12.00 ± 1.58	10.35 ± 1.26	1.41 ± 0.12
p-Value, comparison with control group	<0.0001*	0.008*	0.002*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Wrists with normal NCS ($n = 20$)	2.43 ± 1.02	2.15 ± 0.32	2.21 ± 0.28	2.81 ± 0.46	6.55 ± 1.27	8.60 ± 1.69	7.65 ± 1.69	1.31 ± 0.10
p-Value, comparison with control group	<0.0001*	0.14	0.085	<0.0001*	0.14	<0.0001*	0.09	<0.0001*
p-Value, comparison with abnormal NCS	<0.0001*	0.28	0.19	0.006*	<0.0001*	<0.0001*	<0.0001*	0.017*

Values are mean ± SD. CSA, cross-sectional area; NCS, nerve conduction studies. *Statistically significant values.

Table 2 Sensitivities, specificities, positive predictive values (PPV) and negative predictive values (NPV) in diagnosing carpal tunnel syndrome (CTS) using diagnostic criteria defined in the relevant literature

	CTS ($n = 40$)	Control ($n = 40$)	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	PPV (%) (95% CI)	NPV (%) (95% CI)
Palmar displacement >2.5 mm [9]	**25**	**4**	**62.5** (45.8-76.8)	**90** (75.4-96.7)	**86.2** (67.4-95.4)	**70.6** (55.9-82)
Palmar displacement >3.7 mm [6,7]	**8**	**1**	**20** (10-36.1)	**97.5** (85.2-99.8)	**88.9** (50.6-99.4)	**54.9** (42.7-66.6)
Middle CSA >9 mm^2 [8]	**26**	**3**	**65**% (48.3-78.8)	**92.5** (78.5-98)	**89.7** (71.5-97.2)	**72.5** (58-83.6)
Middle CSA >10 mm^2 [6,7,9]	**21**	**2**	**52.5** (36.3-68.1)	**95** (81.7-99.1)	**91.3** (70.4-98.4)	**66.7** (52.8-78.2)
Middle CSA >11 mm^2 [10]	**12**	**2**	**30** (17-46.7)	**95** (81.7-99.1)	**85.7** (56.1-97.4)	**57.6** (44.8-69.4)
Distal flattening ratio >3.3 [8]	**10**	**2**	**25** (13.2-41.5)	**95** (81.7-99.1)	**83.3** (50.8-97)	**55.9** (43.3-67.7)
Swelling ratio ≥ 1.3 [11]	**29**	**3**	**72.5** (55.8-84.8)	**92.5** (78.5-98)	**90.6** (73.8-97.5)	**77.1** (62.3-87.4)

References are listed in brackets.

Table 3 Sensitivities, specificities, positive predictive values (PPV) and negative predictive values (NPV) in diagnosing carpal tunnel syndrome (CTS) with normal nerve conduction studies (NCS) using most sensitive criteria found

	Normal NCS ($n = 20$)	Control ($n = 40$)	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	PPV (%) (95% CI)	NPV (%) (95% CI)
Palmar displacement >2.5 mm [10]	**8**	**4**	**40** (19.9-63.5)	**90** (75.4-96.7)	**66.7** (35.4-88.7)	**75** (60.1-85.8)
Middle CSA >9 mm^2 [8]	**6**	**3**	**30** (12.8-54.3)	**92.5** (78.5-98)	**66.7** (30.9-90.9)	**72.5** (58-83.6)
Swelling ratio ≥ 1.3 [11]	**11**	**3**	**55** (32-76.1)	**92.5** (78.5-98)	**78.6** (48.8-94.2)	**80.4** (65.6-90.1)
Presence of at least two criteria	**8**	**2**	**40** (19.9-63.5)	**95** (81.7-99.1)	**80** (44.2-96.4)	**76** (61.5-86.4)

References are listed in brackets. CSA, cross-sectional area.

Table 4 Sensitivities, specificities, positive predictive values (PPV) and negative predictive values (NPV) in diagnosing CTS with abnormal nerve conduction studies (NCS) using most sensitive criteria found

	Abnormal NCS ($n = 20$)	Control ($n = 40$)	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	PPV (%) (95% CI)	NPV (%) (95% CI)
Palmar displacement >2.5 mm [10]	**17**	**4**	**85** (61.1-96)	**90** (75.4-96.7)	**80.9** (57.4-93.7)	**92.3** (78.0-97.9)
Middle CSA >9 mm^2 [8]	**20**	**3**	**100** (79.9-100)	**92.5** (78.5-98)	**86.9** (65.3-96.5)	**100** (88.2-100)
Swelling ratio ≥ 1.3 [11]	**18**	**3**	**90** (66.8-98.2)	**92.5** (78.5-98)	**85.7** (62.6-96.2)	**94.9** (81.3-99.1)
Presence of at least two criteria	**19**	**2**	**95** (73-99.7)	**95** (81.7-99.1)	**90.5** (68.1-98.3)	**97.4** (84.9-99.8)

References are listed in brackets. CSA, cross-sectional area.

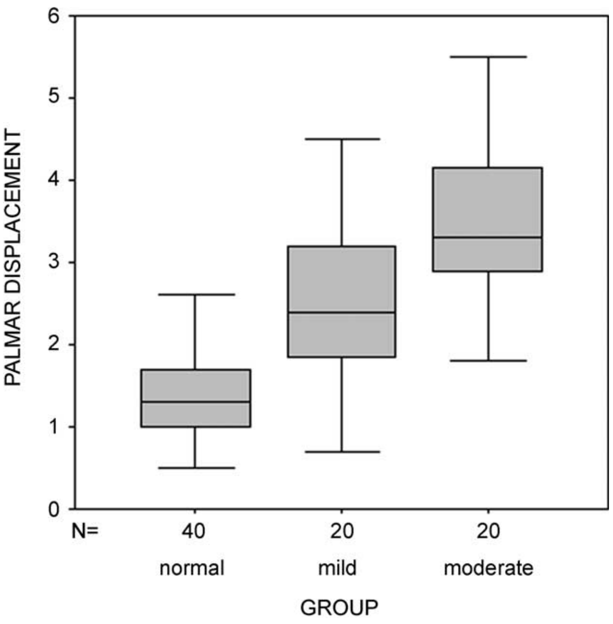


Figure 1 The distribution of palmar displacement for the normal and patient groups.

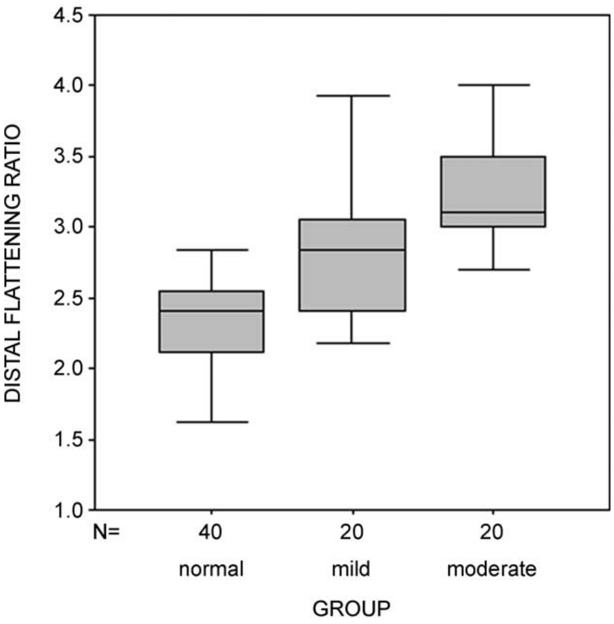


Figure 3 The distribution of the flattening ratio at distal level for the normal and patient groups.

combined. By combining these criteria, 90% of the controls, 65% of the mild cases and 90% of the moderate cases were correctly classified. Of the mild cases, 20% were incorrectly classified as normal, and 15% were incorrectly classified as moderate cases (Table 5).

Discussion

NCS and imaging techniques are used to support the diagnosis of CTS and revealing underlying pathologies. Each method has some particular advantages and disadvantages. NCS is useful in evaluating nerve dysfunction,[15] but its application is painful and it cannot assess the wrist anatomy. There is still a controversy about the real value of NCS for the diagnosis and therapeutic surveillance in CTS.[16,17]

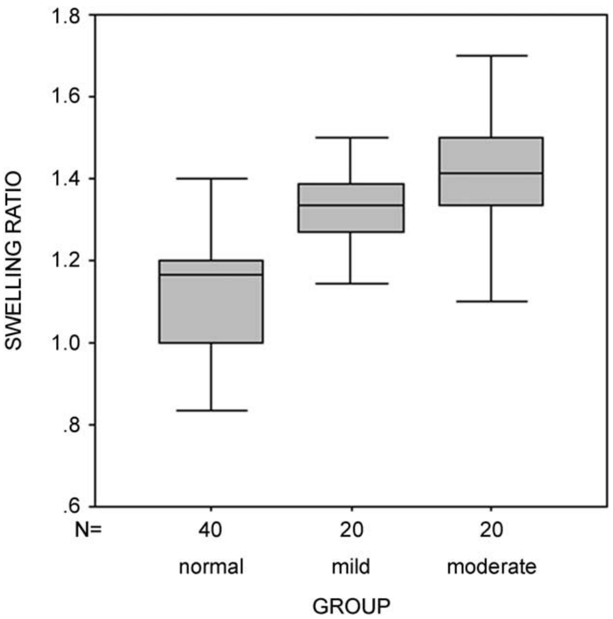


Figure 2 The distribution of the swelling ratio for the normal and patient groups.

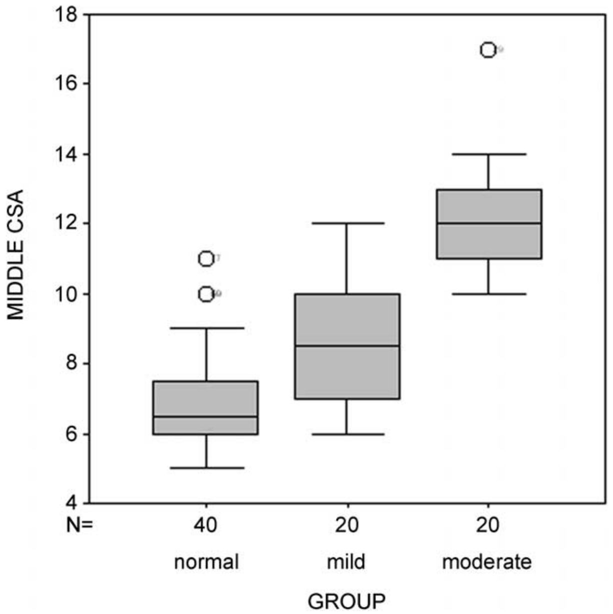


Figure 4 The distribution of CSA at middle level for the normal and patient groups.

Table 5 Classification results for the combination of middle cross-sectional area, palmar displacement and swelling ratio

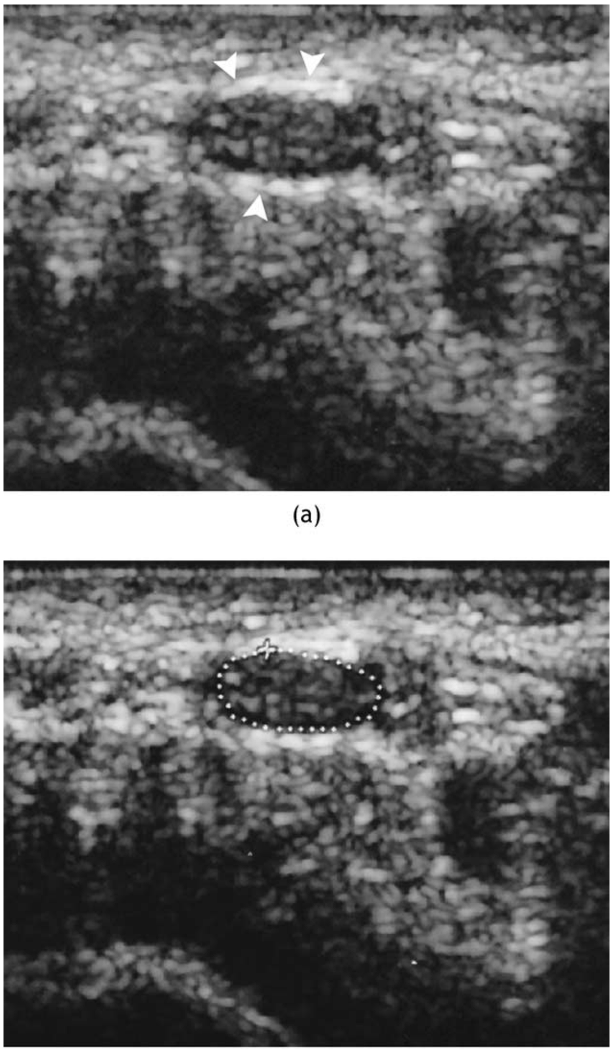
Groups		Predicted group membership		
		Normal	Mild	Moderate
Original group membership	Normal	90%	7.5%	2.5%
	Mild	20%	65%	15%
	Moderate	0%	10%	90%

Until the recent past the NCS were used as a gold standard for the diagnosis of this entity.[18,19] However, similar treatment outcomes were presented for patients who had negative and positive electrophysiological test results.[20] Therefore, a growing number of researchers now believe that the diagnosis must be primarily based on the clinical findings.[21-23] However, NCS are still being employed routinely in many centres, especially for legal reasons in work-related cases.

MRI and USG are painless diagnostic techniques. By imaging the carpal tunnel anatomy, they can also discriminate pathological changes such as synovitis, tumours, and anatomic malformations from idiopathic causes. In our referral group, these changes were encountered in four patients, and they were all excluded from the final analysis to ensure the homogeneity of the patient group. MRI provides an excellent tissue contrast and a clear presentation of the soft-tissue abnormalities. In addition, nerve oedema can be easily depicted as it cause increased signal intensity on MRI.[3-5] Conversely, the principal advantages of USG are its low cost, short study time, availability, and the possibility of the dynamic imaging. Despite these advantages, operator dependency and absence of standardized parameters prevents the widespread use of USG in CTS.

There has been increased interest in the use of USG for evaluating CTS since the development of small high-frequency transducers. As USG evaluation of CTS is not standardized, different measurement techniques and patient groups have been variously used.[6-14] These variances influenced the observed values and hence the determination of the cut-off points to differentiate normal and CTS patients. The cut-off values were higher in studies that used NCS as the gold standard than those that mainly relied on clinical measures.[6,7,10-12] Mild symptomatic patients were excluded from the more numerous former trials. Therefore, the validity of these criteria in detecting the early stages of this disease is a matter of contradiction that requires further clarification. In order to answer this question, the present study group was intentionally consisted of mild and moderate cases.

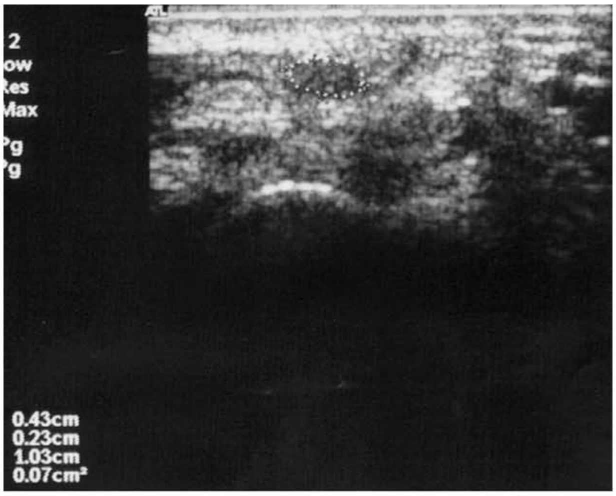
Measurement techniques are particularly important when calculating the CSA of the median nerve. The use of the direct (continuous boundary trace, ellipsoid) or indirect [area $= \pi$ (D1 $\times$ D2)/4] methods influence the results.[8] Inclusion of the perineurium in the measurement, as preferred by Sarria et al.,[10] also affects the measurements. In the present study continuous boundary trace was used to calculate the CSA. The perineurium was excluded because of the difficulty in defining its outer borders, hence causing poor reproducibility of the measurements (Fig. 5).



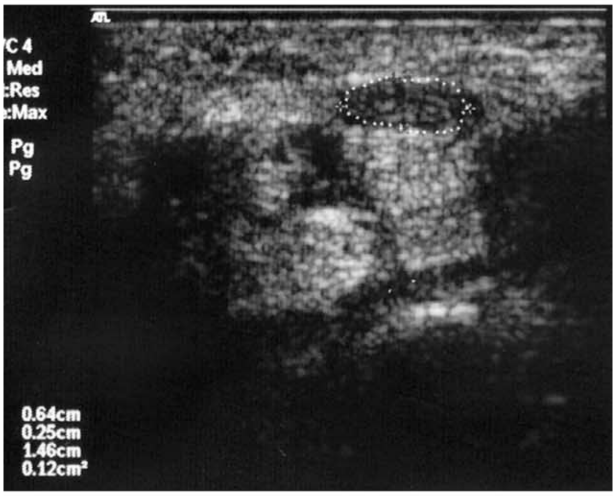
(a)

(b)

Figure 5 Transverse sonogram of median nerve. (a) An echogenic rim indicating the perineurium (arrowheads) is not always present and its outer margin is difficult to define. (b) Continuous boundary trace (dotted) was used to calculate the area of median nerve just within the perineurium.



(a)



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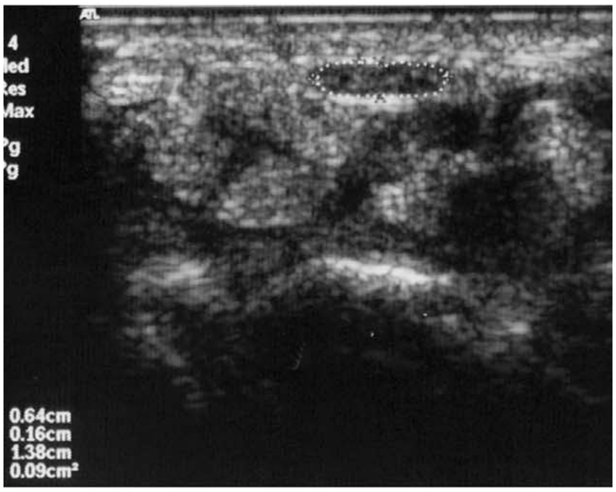

(c)

Figure 6 Sonograms of a symptomatic CTS patient. (a) The median nerve of normal size at the proximal level (7 mm^2). (b) At the pisiform level the size of the median nerve was larger (12 mm^2) compared with the proximal level. The swelling ratio was 1.7. (c) Increased flattening of the median nerve at distal level.

In the present study, mean median nerve areas and palmar displacements were lower for both patient and control groups than found in other studies.[6-14] For the patient group, this observation was thought result from the exclusion of severe cases. For the normal group, exclusion of participants with occupations requiring repetitive wrist and hand motions was thought to cause lower figures as these occupations may affect carpal tunnel anatomy. The lower figures for normal group was thought to be the factor responsible for the higher USG parameter specificity figures in detecting CTS when compared with past studies.[10,11,13]

In this study, the highest sensitivity in diagnosing CTS was obtained using the swelling ratio (Fig. 6). This parameter was initially defined by Buchberger et al.,[6,7] but it has not received general acceptance. Recently, Keberle et al.,[11] using a cut-off value of ≥ 1.3, reached to 100% sensitivity with multi-dimensional linear array and 66.7% sensitivity with conventional linear array transducers. In our study, a transducer of the latter type was used, and the sensitivity was found to be 72.5%, a value slightly higher than the one found by Keberle et al.[11] Only three of 40 normal wrists showed this sign whereas 29 wrists with CTS showed this sign. Eleven of 29 were mild cases and 18 of 29 were moderate cases. Although swelling ratio also had the highest sensitivity (55%) in detecting mild cases, this was not the case in moderate CTS. Therefore, we think that the swelling ratio is especially important in detecting mild cases. The authors interpret the higher sensitivity of this criterion to be the result of the better depiction of nerve swelling. As CSAs of the median nerve have a natural variability in different patients, the use of the swelling ratio probably provides better results than the absolute values in any level.

In the relevant literature, the cut-off value for middle CSA usually varies between 9 and 11 mm^2.[6-10] The highest value defined is 15 mm^2.[12] This figure may be the result of the authors' exclusion of the cases with mild electrophysiological abnormalities. Therefore, in this study, a set of cut-off values between 9 and 11 mm^2 was used. This produced an overall sensitivity of 30 to 65% in detecting CTS patients, the highest figure being for 9 mm^2 (Fig. 6(b)). In the control group, the middle CSA was larger than 9 mm^2 in only three out of 40 (7.5%) wrists. Twenty-six of 40 (65%) wrists with CTS had showed this sign,

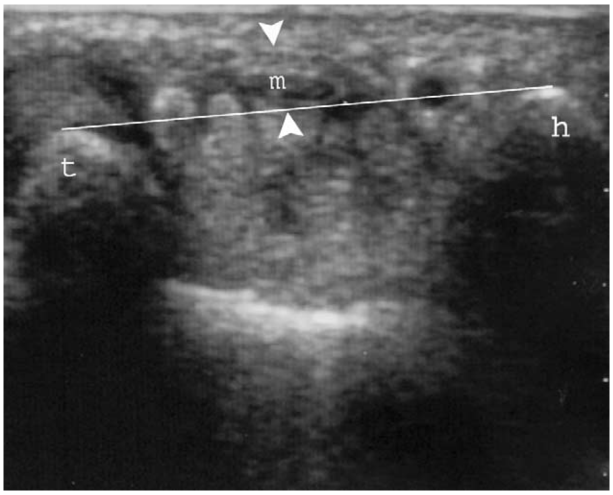

Figure 7 Palmar displacement (arrowheads) of a symptomatic CTS patient (m: median nerve, t: trapezoid, h: hook of hamate). Flattening of the median nerve was also present.

in which 20 of them had belonged to the moderate cases. Although it was not useful in detecting the mild cases, the middle CSA had the highest sensitivity (100%) among the USG parameters in detecting moderate cases when a cut-off value of 9 mm^2 was used. The above-mentioned finding parallels findings of past studies of moderate and severe cases. In those studies the measurement of median nerve area was implicated as the most consistent finding.[7,8,10,13]

Palmar displacement ranks third in sensitivity among the USG criteria used. According to Buchberger et al.,[3,6,7] this is a less reliable criteria of CTS on USG than MRI. Sarria et al.[10] found the sensitivity of this criterion to be 81.3% using a cut-off value of 2.5 mm. In the present study, the overall sensitivity of palmar displacement was 62.5% using the same cut-off value (Fig. 7). When considering only the moderate cases this figure improves to 85.0%, a value slightly higher than the one found by Sarria et al.[10] This criterion showed the lowest specificity (90%) among all of our criteria, but still higher than the values of relevant literature.[7,10]

Buchberger et al.[6,7] have initially emphasized the diagnostic value of the flattening ratio at distal level by using a cut-off value of 4.2. However, Duncan et al.[8] found a low sensitivity (38%) by using a value of 3.3, whereas Sarria et al.[10] found no difference between patients and control groups using flattening ratios at proximal, middle or distal levels. None of the present patients had a flattening ratio higher than 4.2 at the distal level. Therefore the cut-off value proposed by Duncan et al. was used in the present study.[8] The overall sensitivity of this criterion was 25.0%, a value even less than the one that was being found by Duncan et al.[8] (Fig. 6(c)). This was probably the result of the presence of milder cases than the ones included in the cited study.[8] Poor standardization of the flattening ratio measurements may be an additional contributing factor. As stated by Duncan et al.[8] the recognition of the median nerve at distal level is relatively difficult, and probe compression may further affect measurements.

Nakamichi and Tachibana[13] recommended USG as the initial test if thenar atrophy had already occurred. They recommended the combination of NCS and USG for other conditions. Some authors have proposed USG as the initial step in all conditions because of its advantages and sensitivity.[10,12] Similarly, we suggest the use of USG instead of electrophysiological studies if the referring physician needs an additional confirmation. However, the present study has some limitations that should be recognized. We have intentionally excluded severe cases and the number of patients employed was relatively small. The inclusion of severe cases would provide more comparison and would increase the number of total participants. Another potential limitation of the study is the investigation of both wrists from each participant in the control group. Although the wrists are separate from each other, it is highly likely that as they are from the same person they share some characteristics, and will behave more similarly than two wrists from different people. However, the strong significance of the test results suggests that in practical terms this did not affect the conclusions drawn. The use of single ultrasonographer and absence of repeated measurements is another weakness of the present study, because the average of the multiple values might have been more accurate. It should be noted that the present patients were selected by an experienced physician, and the present results may not be similar in the general population.[14] Therefore these criteria must be cautiously applied beyond a specialized reference source.

In conclusion, USG plays an important role in diagnosing mild and moderate CTS. This method may be easily performed by obtaining single measurement at each level (CSA at proximal and middle levels and palmar displacement at distal level). The detection of at least two of three above-defined criteria (median nerve CSA >9 mm^2 at pisiform level, swelling ratio ≥ 1.3, and palmar displacement >2.5 mm) may be helpful for the verification of the diagnosis.

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