Usefulness of clinical findings, nerve conduction studies and ultrasonography to predict response to surgical release in idiopathic carpal tunnel syndrome

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Abstract

Objectives

To assess the usefulness of clinical findings, nerve conduction studies and ultrasonography performed by a rheumatologist to predict success in patients with idiopathic carpal tunnel syndrome (CTS) undergoing median nerve release.

Methods

Ninety consecutive patients with CTS (112 wrists) completed a specific CTS questionnaire and underwent physical examination and nerve conduction studies. Ultrasound examination was performed by a rheumatologist who was blind to any patient's data. Outcome variables were improvement >25% in symptoms of the CTS questionnaire and patient's overall satisfaction (5-point Likert scale) at 3 months postoperatively. Success was defined as improvement in both outcome variables. Receiver operating characteristics (ROC) curves and logistic regression analyses were used to assess the best predictive combination of preoperative findings.

Results

Success was achieved in 63% of the operated wrists. Utility parameters and area under the ROC curve (AUC) for individual findings was poor, ranging from 0.481 of the nerve conduction study to 0.634 of the cross-sectional area at tunnel outlet. Logistic regression identified the preoperative US parameters as the best predictive variables for success after 3 months. The best predictive combination (AUC=0.708) included a negative Phalen maneuver, plus absence of thenar atrophy, plus less than moderately abnormalities on nerve conduction studies plus a large maximal cross-sectional area along the tunnel by ultrasonography.

Conclusions

Although cross-sectional area of the median nerve was the only predictor of success after three months of surgical release, isolated preoperative findings are not reliable predictors of success in patients with idiopathic CTS. A combination of findings that include ultrasound improves prediction.

Key words

Carpal tunnel syndrome, diagnosis, surgery, nerve conduction, ultrasonography, humans.

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Received on January 2, 2009; accepted in revised form on May 8, 2009.

Competing interests: none declared.

Introduction

Carpal tunnel syndrome (CTS), or compression neuropathy of the median nerve at the wrist, is the most common entrapment neuropathy (1). Patients with severe and persistent hand or arm paresthesias or chronic pain are candidates to carpal tunnel release performed as an endoscopic or as an open procedure. The success of such procedure is generally moderate at 3 months and similar to local steroid injection in the long-term (2). The correlation between findings on physical examination or nerve conduction studies (NCS) and outcome after surgical release of the median nerve is unclear (3-7), although NCS results are universally used as a guide to recommend surgery.

High-resolution real-time US of the carpal tunnel has shown to be a useful diagnostic tool in patients with suspected CTS (8-13). This rapid imaging technique is cheap (14), easy and pain-free. If we could demonstrate that US examination performed at the rheumatology clinic is useful in predicting the success of carpal tunnel release, inconveniences associated with NCS in candidates of carpal tunnel release may be avoided.

Tools that help physicians in guiding decisions on costly and painful procedures are most welcome in the current context of patient-oriented and cost-effective medicine. Therefore, we conducted a study to assess the usefulness of clinical findings, NCS and US, and their combinations for predicting success in patients with idiopathic CTS undergoing surgical release of the median nerve.

Material and methods

A prospective observational study was designed to assess the usefulness of clinical findings, NCS and US to predict the outcome of surgery in CTS.

Patients

Between May 2005 and December 2006, all consecutive adult patients with suspected CTS referred to the outpatient rheumatology clinic of Hospital Universitario Dr. Negrin, in Las Palmas de Gran Canaria (Spain) for diagnostic work-up studies and treatment who finally underwent CTS surgery were selected for the study. The study protocol was approved by the Institutional Review Board and all participants gave written informed consent.

Suspected idiopathic CTS was defined by sensory symptoms over the distribution territory of the median nerve regardless of the results of Tinel nerve percussion and Phalen maneuver. Sensory symptoms included hypoesthesia, burning pain, tingling or numbness aggravated by sustained positions and relief by shaking or moving the hands, sleep disruption by symptoms, and daily complaints for at least 3 months. Patients were excluded if they had already undergone surgery, had suffered traumatic injuries at the target wrist, had received injections, presented ganglions or tenosynovitis, as were those with hypothyroidism, acromegaly, polyneuropathy, radiculopathy, fibromyalgia, rheumatoid arthritis or crystal arthritis. Pregnant women were also excluded.

Clinical assessment

Patients were initially assessed by a single rheumatologist (S.O.) who made the clinical history and the physical examination. Physical examination included responses to the Tinel and Phalen tests and assessment of the thenar eminence, looking specifically for thenar muscle wasting. In all patients, the following data were recorded: age, sex, duration and distribution of CTS symptoms, bilateral or unilateral involvement, and results of laboratory tests (complete blood count, coagulation tests, routine biochemical profile, serum thyroid hormones, rheumatoid factor, and C-reactive protein). Patients completed the Spanish validated version of the Boston-Levine CTS health-related quality of life questionnaire (Q-CTS) (15). The questionnaire consists of two sections, the first concerning symptoms and the other regarding functional status of the hand. The total score is given in two scales, symptoms (range 1–5) and function (range 1–5). If both hands were involved, patients fulfilled two questionnaires, one per hand.

Ultrasound

Sonographic examinations were performed by a single rheumatologist

experienced in musculoskeletal US studies (A.N.) who was unaware of the patient's symptomatology and results of NCS. All patients underwent high-resolution real-time sonography of the carpal tunnel using a General Electric Logic 5 Pro machine and 12 MHz linear array transducer. The carpal tunnel inlet was defined as the proximal margin of the flexor retinaculum between the scaphoid tubercle and the pisiform bone, and the tunnel outlet was the distal margin of the flexor retinaculum between the trapezium bone and the hook of the hamate bone. Measurements were performed at the carpal tunnel inlet proximally and at the carpal tunnel outlet distally by direct tracing with electronic callipers excluding the echogenic rim surrounding the nerve. We performed assessments twice and recorded the arithmetic mean. The flattening ratio, defined as the ratio of the major axis of the median nerve to its minor axis, was also assesses at the level of the hamate bone (16). A normal flattening ratio at the level of the distal carpal tunnel should be less than 3.0 (17). The maximum height or bowing of the retinaculum was measured above a line subtended between radial attachment in the trapezium and ulnar attachment in the hamate and the top of the flexor retinaculum. The normal palmar displacement of the retinaculum should not exceed 4.0 mm (17). Compression in longitudinal view was also recorded.

Nerve conduction studies

Electrodiagnostic tests were performed with the guidance of two neurologists following the American Academy of Neurology protocol (18). CTS severity by NCS criteria was classified as follows: (*1*) normal, no electrophysiological evidence of CTS; (*2*) mild, reduced nerve sensory conduction velocity; (*3*) moderate, increase in nerve motor conduction distal latency; and (*4*) severe, nerve sensory potential is not evoked, or motor conduction velocity, or motor conduction amplitude are reduced.

Surgery

Patients with typical symptoms and daily complaints for at least 3 months were candidate for median nerve release, except those with both normal or mild CNS and median cross-sectional area at tunnel inlet <11 mm^2.

All operations were performed by three experienced plastic surgeons with an open technique under local anaesthesia with tourniquet control to minimise vascular bleeding. If both hands were involved, the most symptomatic was operated first, but never both hands simultaneously.

Outcome measures

The outcome of surgery was evaluated by means of the Q-CTS and by the patient's overall satisfaction on a 5-point Likert scale (1 = worse, 2 = no change, 3 = better, 4 = much better, 5 = cured) at 3 months postoperatively. Patient's satisfaction was also evaluated at one year after operation. Assessment was performed by a single examiner blinded to the results from the NCS and US. The main outcome variable was success, which was defined as an improvement ≥25% in the symptoms score of the Q-CTS plus scores 4 or 5 in the Likert scale at 3 months after surgery.

Statistical analysis

We studied the distribution of preoperative variables in all patients and in those who responded and who did not respond to surgery at 3 months. Differences in the Q-CTS scores before and after surgery between groups were tested by the Student's t test for paired samples. Differences in the frequency of variables between groups were tested by chi-square (χ^2) test. Sensitivity, specificity, positive likelihood ratio, and area under the curve (AUC) for predicting success were obtained for all preoperative findings from receiver operating characteristics (ROC) curve and tables analyses. The best cut-offs for the US findings were obtained from ROC curves and were based on the positive likelihood ratios (LR+). We did not obtain cut-offs for US parameters in which the ROC curves were not explicative enough, depending on the figure. We then carried out logistic regression analyses and the post-estimation ROC curve to find the best predictive combination of preoperative findings. Since all sonographic cross-sectional areas were highly correlated (r>0.8), only one area was included in the models at a time. Cross-sectional areas were tested in the models as continuous variables and as dummy variables from the best cut-offs. Clinical findings (Tinel and Phalen tests, thenar atrophy) were tested individually, or as any present, or as all present. Multilevel mixed-effects logistic regression models had been previously used to test whether the patient had an influence on the result for the wrist. Since we did not find any effect, all regression models were run for the wrist without including the effect of the patient. A p-value below 0.05 was deemed statistically significant. Stata 10.0 (StataCorp LP, College Station, TX) statistical software package was used for the analysis of data.

Results

Between May 2005 and December 2006, 90 patients (112 wrists) fulfilled the inclusion criteria. They were 15 men and 75 women with a mean (SD) age of 50 (11) years. In 22 patients (24.4%), both hands were affected. The mean (SD) duration of clinical symptoms was 30 (31) months. Table 1 shows baseline characteristics of the study popuation.

Three months after carpal tunnel release, the mean Q-CTS symptoms score decreased significantly from 3.09 (0.77) to 1.76 (0.76) (p<0.001) and the Q-CTS function score from 2.84 (0.91) to 2.02 (0.98) (p<0.001). Overall satisfaction at 3 months after surgery on a 5-point Likert scale was rated as "cured" in 21 cases, "much better" in 60, "better" in 20, and "no change" or "worse" in 11. The proportion of success at 3 months (an improvement ≥25% in the Q-CTS symptoms score plus scores 4 or 5 in the Likert scale) was 71/112 (63%). Patient satisfaction was available from 82 operated wrists 12 months after surgery, in which the proportion of cured or much better was 67/82 (82%). No postoperative complications neither infection occurred. There were no differences in success at 3 months depending on patient characteristics (Table I). The only wrist findings that were associated with success at 3 months were two US measures: the cross-sectional area at tunnel outlet and the maximal cross-sectional

Table I. Description of the 90 patients with a diagnosis of CTS who had been consecutively included in the study, at baseline and after 3 months from surgery, by success of the first operated hand.

Characteristic	All	Success after 3 months*		*p*-value
		No (n=30)	Yes (n=60)	
Women, n (%)	75 (83)	24 (80)	51 (85)	0.549
Age, mean ± SD	50±11	52±11	49±11	0.135
Two hands affected, n (%)	22 (24)	6 (20)	16 (27)	0.488
Main activity				0.976
Low wrist risk, n (%)**	12 (14)	4 (14)	8 (14)	
High wrist risk, n (%)***	76 (86)	25 (86)	51 (86)	

*Success was defined as an improvement in the symptom scale of the Boston-Levine carpal tunnel syndrome Quality of Life questionnaire (Q-CTS) greater than 25% plus a satisfaction with surgery by a Likert scale greater than "a little bit better" ("much better" or "cured").
**Sales (3), Retired (3), Driver (2), Student (1), Official (1), Security (1), Social worker (1).
***Cleaning (39), Administrative (12), Nurse attendant (8), Farmer (4), Waiter (4), Technical mechanics (2), Beautician (2), Seamtress (1), Nurse (1), Painter (1), Technical electrician (1), Plaster (1).
SD: standard deviation.

Table II. Preoperative clinical characteristics in 112 hands from 90 patients with a definite diagnosis of CTS, at baseline and after 3 months from surgery, by success. Results are expressed as mean ± standard deviation unless otherwise indicated.

Characteristic	All	Success after 3 months*		*p*-value
		No (n=41)	Yes (n=71)	
Clinical findings, n (%)				
Positive Tinel' sign	70 (63)	26 (63)	44 (62)	0.980
Positive Phalen' sign	87 (78)	36 (88)	51 (72)	0.146
Thenar atrophy present	10 (9)	6 (15)	4 (6)	0.233
Nerve conduction studies, n (%)				0.606
Normal	13 (12)	6 (15)	7 (10)	
Mild	17 (16)	4 (10)	13 (18)	
Moderate	44 (39)	17 (42)	27 (38)	
Severe	38 (34)	14 (34)	24 (34)	
Ultrasound findings				
Cross-sectional area at tunnel inlet	13.7±3.7	12.8±2.2	14.2±4.3	0.065
Cross-sectional area at tunnel outlet	14.2±4.5	12.8±3.0	15.0±5.0	0.021
Maximal cross-sectional area along the tunnel	15.0±4.9	13.4±3.5	15.8±5.3	0.017
Flattening ratio	2.8±0.6	2.8±0.4	2.8±0.6	0.518
Bowing of flexor retinaculum	3.7±1.2	3.7±1.3	3.7±1.1	0.945
Nerve compression in long view, n (%)	17 (16)	4 (10)	13 (18)	0.454

*Success was defined as an improvement in the symptom scale of the Boston-Levine carpal tunnel syndrome Quality of Life questionnaire (Q-CTS) greater than 25% plus a satisfaction with surgery by a Likert scale greater than "a little bit better" ("much better" or "cured").

area along the tunnel (Table II). Neither the results from the physical exam nor the nerve conduction studies were associated with success at 3 months.

The analysis of the usefulness of the different findings for predicting the success of surgical release after 3 months yielded very modest results (Table III). Most positive likelihood ratios were under 2.0, and the areas under the ROC curve (AUC) were mostly under 0.500. US findings had better utility parameters overall (Table III), especially the cross-sectional area at tunnel outlet (AUC=0.634) and the maximal cross-sectional area along the tunnel (AUC=0.617).

Performance of the individual preoperative parameters, including the best cut-offs of the US measurements, on the improvement after surgery in terms of symptoms, function, and satisfaction (after 3 and 12 months) is presented in Table IV. There are no clear differences between parameters.

Logistic regression identified the preoperative US parameters as the best predictive variables for success after 3 months (Table V). Of note, a cross-sectional area at tunnel inlet ≥16.5 mm was associated with success with an odds ratio of 8.14, and a cross-sectional area at tunnel outlet ≥20 mm predicted success perfectly. The multivariate logistic regression for success at 3 months yielded a best model (AUC=0.708) that included a negative Phalen, plus absence of thenar atrophy, plus NCS less than moderately altered, plus a large maximal cross-sectional area along the tunnel by US (Table V and Fig. 1).

Despite the lower number of wrists available at 12 months we run different models to predict satisfaction with surgery after one year. The best predictive model (AUC = 0.729) included absence of thenar atrophy, plus NCS less than moderately altered, plus a large maximal cross-sectional area along the tunnel by US (Fig. 1).

Discussion

The main finding of our prospective study is that US measurement of the cross-sectional area of the median nerve and NCS have limited value for predicting success of carpal tunnel release. Neither type of test will change considerably the pretest probability. However, the only findings that were associated with success at 3 months in our study were the median nerve cross-sectional measurement by US.

Carpal tunnel release surgery should be considered in patients with persistent symptoms that do not respond to conservative measures and in those with severe nerve entrapment as evidenced by nerve conduction studies, thenar atrophy, or motor weakness. Standard open carpal tunnel release is just as effective as the alternatives, but is technically less demanding, so incurs a lower risk of complications and of added costs (19, 20). The percentage of improvement after surgical treatment ranges between 66% and 93% (3-5, 18, 21-23), which agrees with our results. Improvement is maintained or increases with a follow-up longer than 6 to 9 months (3, 24). In the present series, 71% of patients reported being completely satisfied with the outcomes of surgery at 3 months postoperatively. Postoperatively, the

Table III. Usefulness of clinical, neurological and of different cut-offs of ultrasound findings for identifying patients with success of surgery after 3 months. For ultrasound parameters, cut-offs with best positive likelihood ratios (LR) are shown with AUC.

Finding	Sensitivity (%)	Specificity (%)	AUC	LR+	LR-
Positive Tinel's sign	66	33	.495	0.99	1.03
Positive Phalen's sign	80	8	.437	0.86	2.64
Tenar atrophy	6	85	.454	0.40	1.11
Any clinical finding from above	82	12	.469	0.93	1.50
All clinical findings present	3	88	.453	0.23	1.11
Cross-sectional area at tunnel inlet (mm^2)			.575		
(≥ 9.5)	96	7		1.04	0.40
(≥ 10)	92	10		1.01	0.87
(≥ 10.5)	89	12		1.01	0.92
(≥ 11)	85	17		1.02	0.91
(≥ 11.5)	80	29		1.14	0.67
(≥ 12)	70	34		1.07	0.87
(≥ 12.5)	63	41		1.08	0.88
(≥ 13)	52	61		1.34	0.79
(≥ 13.5)	45	68		1.42	0.80
(≥ 14)	37	76		1.50	0.84
(≥ 14.5)	31	78		1.41	0.88
(≥ 15)	30	88		2.43	0.80
(≥ 15.5)	24	93		3.27	0.82
(≥ 16)	18	95		3.75	0.86
(≥ 16.5)	17	98	.572	6.93	0.85
(≥ 17)	14	98		5.77	0.88
(≥ 18)	13	98		5.20	0.90
(≥ 19)	11	98		4.62	0.91
(≥ 20)	8	98		3.46	0.94
Cross-sectional area at tunnel outlet (mm^2)			.634		
(≥ 9.5)	95	11		1.07	0.44
(≥ 10)	90	19		1.12	0.50
(≥ 10.5)	87	28		1.21	0.46
(≥ 11)	84	33		1.26	0.48
(≥ 11.5)	81	42		1.38	0.46
(≥ 12)	74	42		1.27	0.62
(≥ 12.5)	66	47		1.25	0.72
(≥ 13)	63	56		1.42	0.67
(≥ 13.5)	55	61		1.41	0.74
(≥ 14)	45	75		1.81	0.73
(≥ 14.5)	42	78		1.89	0.75
(≥ 15)	32	81		1.66	0.84
(≥ 16)	27	83		1.65	0.87
(≥ 17)	24	86		1.74	0.88
(≥ 18)	19	94		3.48	0.85
(≥ 19)	15	94		2.61	0.91
(≥ 20)	13	97	.537	4.65	0.90
Maximal cross-sectional area along the tunnel (mm^2)			.617		
(≥ 9)	97	3		1.00	1.11
(≥ 9.5)	97	6		1.03	0.55
(≥ 10)	95	6		1.01	0.83
(≥ 10.5)	95	17		1.14	0.28
(≥ 11)	91	19		1.13	0.47
(≥ 11.5)	88	28		1.21	0.44
(≥ 12)	85	31		1.22	0.50
(≥ 12.5)	78	33		1.18	0.65
(≥ 13)	71	47		1.34	0.62
(≥ 13.5)	63	47		1.20	0.78
(≥ 14)	54	64		1.49	0.72
(≥ 14.5)	49	67		1.48	0.76
(≥ 15)	43	75		1.72	0.76
(≥ 15.5)	37	78		1.66	0.81
(≥ 16)	34	81		1.74	0.82
(≥ 16.5)	31	81		1.58	0.86
(≥ 17)	28	83		1.66	0.87
(≥ 17.5)	26	83		1.57	0.89
(≥ 18)	20	92		2.40	0.87
(≥ 18.5)	18	94		3.32	0.86
(≥ 19)	15	94		2.77	0.90
(≥ 20)	12	94		2.22	0.93
(≥ 20.5)	12	97	.548	4.43	0.90
(≥ 21)	11	97		3.88	0.92
Flattening ratio			.423		
Bowing of flexor retinaculum			.512		
Nerve compression in long view	22	88	.548	1.79	0.89
Moderate to severe nerve conduction studies	72	24	.481	0.95	1.15

AUC,: area under the ROC curve; LR: likelihood ratio

mean change of Q-CTS symptoms score was 1.33 and the mean change of Q-CTS function score was 0.82, which is similar to data reported in other prospective studies (3, 25-28).

A few prospective studies have assessed the factors predictive of the outcomes of carpal tunnel release. In a community-based study, worse scores on patient-reported measures of upper extremity functional limitation, worse mental health status, tobacco and alcohol use, forceful repetitive work, and the involvement of an attorney were the strongest predictors of less favorable outcomes of carpal tunnel release (3). Other prospective studies were focused on only one variable, such as age (18), gender (25), duration and severity of symptoms (13) or electrophysiological changes after surgery (4). However, an association between outcome after surgery for CTS and gender (25), age (18), bilateral involvement (3), Tinel and Phalen signs or thenar atrophy (3) were not found. In the present study, none of the clinical parameters examined were individually associated with a favourable outcome. The relationship between duration or severity of symptoms (5, 6, 21, 26) and outcome of surgical decompression is unclear. It has been reported that good response to steroid injection is an excellent diagnostic and prognostic sign (24).

Different studies have shown that preoperative results of NCS had no effect on the outcome of carpal tunnel decompression (4-7, 18, 29), although in a study of 1268 surgical procedures patients with middle-grade abnormalities had better results than those with either very severe or no abnormality (21). In the present study, we also found that cases with less than moderately altered findings on NCS showed a tendency towards a better outcome in the logistic regression analysis. Other authors have shown that between 8% and 13% of patients with surgical success had normal preoperative NCS (7, 30, 31). Improvement of symptoms after carpal tunnel decompression or resumption of work activities do not appear to be different in patients with normal or abnormal NCS (7, 23, 30, 32, 33).

High-resolution sonography has em-

Table IV. Results of carpal tunnel release according to preoperative findings.

	Q-CTS symptom*			Q-CTS function*			Satisfaction†	
	Before	3 mo.	Difference‡	Before	3 mo.	Difference§	3 mo.	12 mo.
Clinical findings								
Tinel +	3.1 ± 0.7	1.8 ± 0.8	-1.4 ± 0.9	2.8 ± 0.9	2.1 ± 1.0	-0.7 ± 1.0	4 (3-4)	4 (4-5)
Phalen +	3.2 ± 0.7	1.8 ± 0.8	-1.4 ± 0.9	2.9 ± 0.9	2.1 ± 1.0	-0.8 ± 1.1	4 (3-4)	4 (3-5)
Thenar atrophy	3.5 ± 0.8	2.3 ± 1.0	-1.1 ± 0.8	3.6 ± 0.6	2.8 ± 1.1	-0.8 ± 0.8	4 (3-4)	3.5 (2-5)
Any + from above	3.2 ± 0.7	1.8 ± 0.8	-1.4 ± 0.9	2.9 ± 0.9	2.1 ± 1.0	-0.8 ± 1.1	4 (3-4)	4 (3-5)
All +	3.9 ± 0.6	2.6 ± 1.1	-1.3 ± 0.8	3.9 ± 0.4	3.2 ± 1.1	-0.7 ± 0.9	4 (2-4)	2 (2-4)
Nerve conduction studies								
Normal-slightly altered	3.2 ± 0.9	1.8 ± 0.8	-1.4 ± 0.9	2.9 ± 1.0	2.0 ± 1.0	-0.9 ± 1.1	4 (3-4)	4 (4-5)
Moderate-severely altered	3.0 ± 0.7	1.8 ± 0.8	-1.3 ± 0.9	2.8 ± 0.9	2.0 ± 1.0	-0.8 ± 1.0	4 (3-5)	4 (3-5)
Ultrasound findings								
Cross-sectional area at tunnel inlet ≥16.5 mm^2	3.1 ± 0.8	1.8 ± 0.8	-1.3 ± 0.9	2.9 ± 0.9	2.0 ± 1.0	-0.8 ± 1.1	4 (4-5)	4 (4-5)
Cross-sectional area at tunnel outlet ≥20 mm^2	3.0 ± 0.4	1.3 ± 0.4	-1.8 ± 0.5	2.6 ± 0.8	1.4 ± 0.6	-1.2 ± 1.0	4 (4-4.5)	4 (4-5)
Maximal cross-sectional area along the tunnel ≥20.5 mm^2	2.9 ± 0.4	1.7 ± 0.7	-1.5 ± 0.9	2.8 ± 0.9	2.0 ± 1.0	-0.8 ± 1.1	4 (4-4)	4 (4-5)

*Score, mean ± SD
† Median (25^{th}-75^{th} percentile).
‡ All differences are statistically significant.
§ All differences but the one by cross sectional area at tunnel outlet ≥20 mm are statistically significant.
Q-CTS: Boston-Levine carpal tunnel syndrome Quality of Life questionnaire; mo.: months.

erged as feasible, non-invasive imaging tool for evaluating the median nerve in the carpal tunnel (8, 17, 34). The main objective findings in CTS are swelling of the median nerve (increase in cross-sectional area). Sonography also provides information about the possible cause of CTS such as ganglion or rheumatoid arthritis tenosynovitis or synovitis of the wrist joint. A number of authors have reported the accuracy of sonography criteria of median nerve entrapment (8-12) and several studies have addressed the quantification of the nerve cross-sectional area and its role in diagnosing CTS (6-14, 35-41).

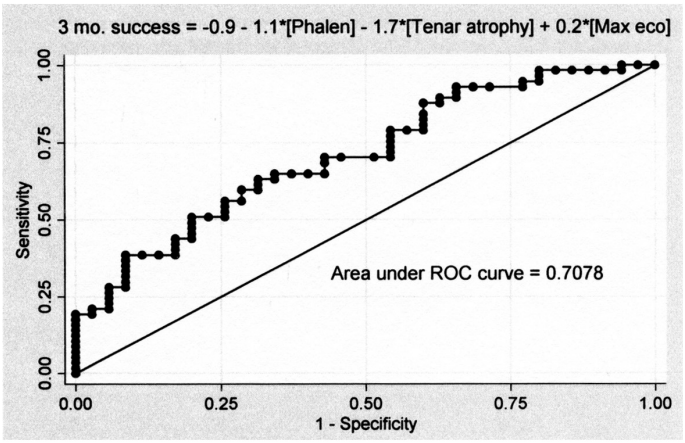
Nerve conduction studies are usually performed to confirm the diagnosis of CTS, particularly in candidates to surgical treatment. Moreover, NCS are time-consuming and expensive (40). Different studies have shown that sonographic detection of pathological swelling of the median nerve has a lower sensitivity than NCS but a higher specificity.(10, 11, 34, 35, 37-39, 42, 43). When surgical success was used as the gold standard, sonography had also a lower sensitivity than NCS but a higher specificity (12). The study of Mondelli *et al*. (44) concluded that the cross-sectional area of median nerve at tunnel inlet was predictor of postsurgical clinical and sonographic improvement. Sonography is probably preferable because it is painless, easily accessible and preferred by the patients. In addition, sonography is an accessible procedure in routine rheumatology consultation, requires minimal training and can be perform in less than 5 minutes. The advantages of sonography together with the present results and a previous study of sensitivity and specificity (13) support the recommendation of this approach as the diagnostic technique of choice in patients with symptoms of CTS, with electrodiagnostic studies as a second choice in patients with suggestive clinical symptoms and non-diagnostic US findings.

In summary, isolated preoperative findings (physical tests, US and NCS) are not good predictors of success after

Table V. Logistic regression analyses for predicting success after three months of surgery from baseline findings.

	Odds ratio for success* (95% confidence interval)	
	Bivariate	Multivariate AUC = 0.708
Clinical findings		
Tinel +	0.96 (0.41–2.21)	-
Phalen +	0.33 (0.09–1.23)	0.35 (0.08–1.45)
Thenar atrophy	0.36 (0.09–1.37)	0.18 (0.04–0.89)
Any + from above	0.62 (0.20–1.88)	–
All +	0.21 (0.04–1.13)	–
Nerve conduction studies		
Normal-slightly altered	1 (referent)	
Moderate-severely altered	0.82 (0.34–1.98)	–
Ultrasound findings		
Cross-sectional area at tunnel inlet ≥16.5 mm^2	8.14 (1.02–65.06)†	–
Cross-sectional area at tunnel outlet ≥20 mm^2	NA‡	–
Maximal cross-sectional area along the tunnel ≥20.5 mm^2	4.91 (0.59–40.97)	1.19 (1.03–1.37)§

*Success was defined as an improvement in the symptom scale of the Boston-Levine carpal tunnel syndrome Quality of Life questionnaire (Q-CTS) greater than 25% plus a satisfaction with surgery by a Likert scale greater than "a little bit better", "much better" or "cured".
†$p<0.05$; ‡ Predicts success perfectly; §The odds ratio is per increment in the maximal cross-sectional area along the tunnel.



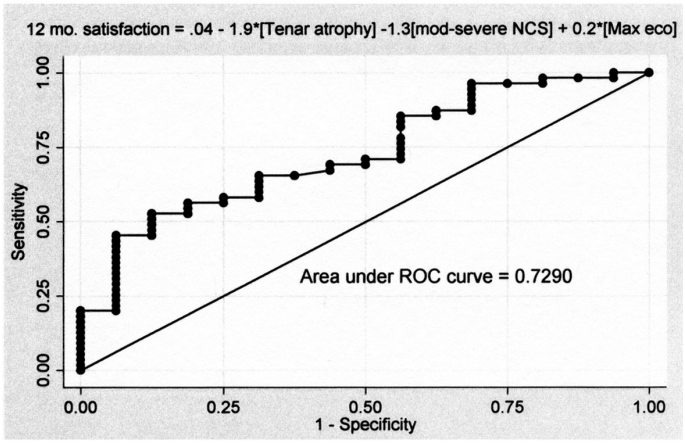


Fig. 1. ROC curve of best models to predict success after 3 months and satisfaction after 12 months.

3 months in patients with persistent symptoms of CTS. The cross-sectional area of the median nerve was the only diagnostic study with predictive value of a favourable surgical outcome at 3 months. Preoperative US studies are of value because prediction of success improved with the combination of negative Phalen maneuver, absence of thenar atrophy, NCS less than moderately altered and a large maximal cross-sectional area along the tunnel by US.

Acknowledgements

We thank Marta Pulido, MD, for editing the manuscript and editorial assistance, and Drs J.C. Quevedo, C. Erausquin, F. Francisco and D. Mendoza for their collaboration in patient recruitment.

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