■ UPPER LIMB

The long-term post-operative electromyographic evaluation of patients who have undergone carpal tunnel decompression

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We present the electromyographic (EMG) results ten years after open decompression of the median nerve at the wrist and compare them with the clinical and functional outcomes as judged by Levine's Questionnaire. This retrospective study evaluated 115 patients who had undergone carpal tunnel decompression at a mean of 10.47 years (9.24 to 11.36) previously. A positive EMG diagnosis was found in 77 patients (67%), including those who were asymptomatic at ten years.

It is necessary to include both clinical and functional results as well as electromyographic testing in the long-term evaluation of patients who have undergone carpal tunnel decompression particularly in those in whom revision surgery is being considered. In doubtful cases or when there are differing outcomes, self-administered scales such as Levine's Questionnaire should prevail over EMG results when deciding on the need for revision surgery.

Decompression of the median nerve at the wrist is considered to be the best way to treat carpal tunnel syndrome (CTS).[1] However, as it is difficult to quantify the symptoms and signs of this condition, electrodiagnostic testing can be used as an objective way of evaluating it before and after treatment.[2-4] However, a normal sensory conduction velocity and motor latency of the median nerve does not exclude a diagnosis of CTS and conversely, abnormal values can be found in asymptomatic patients.[5] In addition, there have been discrepancies between the different methods of post-operative assessment based on complementary tests, such as electromyographic (EMG) or imaging studies, with respect to the clinical and functional diagnosis.[6]

To date, the longest published neurophysiological follow-up is 15 months.[4-8] The aim of this long-term study was to correlate the EMG results, ten years after open carpal tunnel decompression, with the clinical and functional outcome.

Patients and Methods

We carried out a retrospective study on all patients who had an open carpal tunnel decompression and who fulfilled the following criteria: 1) operation between 1999 and 2000; 2) no further surgery for recurrent symptoms; 3) a complete pre-operative clinical history, including data corresponding to items in Levine's Questionnaire[9]; 4) a positive pre-operative EMG diagnosis; 5) pre-operative clinical diagnosis according to Graham's criteria (CTS-6)[10], including numbness and tingling in the distribution of the median nerve, nocturnal numbness, weakness and/or atrophy of the thenar musculature, positive Tinel's sign, positive Phalen's test and loss of two-point discrimination; and 6) consent to EMG studies at ten years post-operatively. Of 152 patients who initially fulfilled the inclusion criteria, 37 declined to participate, leaving a total of 115 patients in the study. There were 18 male and 97 female patients with a mean age at operation of 56.02 years (41 to 63), and a mean body mass index at review of 27.08 kg/m^2 (22.06 to 35.12). Their mean duration of symptoms of CTS prior to surgery was 19.08 months (14.50 to 23.33). Other pathologies were present: diabetes in 12 patients (10.4%), rheumatoid arthritis in two (1.7%), previous ipsilateral wrist fracture in 16 (13.9%), and carpometacarpal arthritis of the thumb Eaton[11] grade I in 30 (26.1%), grade II in eight patients (7.0%) and grade III in nine (7.8%).

All operations were carried out by the same surgeon (MAMF) using a standard technique. A tourniquet was applied and a 4 cm slightly curved palmar incision was made in line with the ulnar edge of the nail of the ring finger, with the proximal interphalangeal joint in 90° of flexion. The transverse ligament was divided longitudinally on the ulnar side. The medium palmar fascia was sutured but not closed

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Table I. Clinical, functional and electromyographic (EMG) outcomes in all patients

Variable	Before surgery	10 years after surgery	p-value
Mean (SD) Levine clinical score (1, normal; 5, most abnormal)	3.35 (0.32)	1.49 (0.12)	< 0.001*
Mean (SD) Levine functional score (1, normal; 5, most abnormal)	2.44 (0.33)	1.43 (0.84)	< 0.001*
Mean (SD) sensitive conduction velocity (m/s)	37.05 (7.56)	44.02 (5.10)	< 0.001*
Mean (SD) sensitive action potential amplitude (mV)	8.21 (3.25)	12.80 (4.02)	< 0.001*
Mean (SD) motor latency (ms)	5.06 (1.01)	3.95 (0.78)	< 0.001*
Mean (SD) compound muscle action potential amplitude (mV)	7.43 (2.78)	9.22 (2.64)	0.001*
EMG diagnosis of carpal tunnel syndrome (n, %)			< 0.001†
Normal	0 (*0*)	38 (*33.04*)	
Mild	22 (*19.13*)	49 (*42.60*)	
Moderate	61 (*53.04*)	28 (*24.36*)	
Severe	32 (*27.83*)	0 (*0*)	
Very severe	0 (*0*)	0 (*0*)	

* paired *t*-test
† chi-squared test

totally, and the skin closed with an absorbable 5/0 suture. The arm was elevated for the first 24 hours after operation, and a short palmar splint was applied for the first two weeks after operation.

At review in 2010, patients were evaluated in the following manner.

EMG evaluation. This was undertaken using a Medelec electromyograph (Medelec, Woking, United Kingdom) with bipolar percutaneous electrodes. All studies were carried out by specialists in neurophysiology, under the same conditions, and the following data were analysed: sensory conduction velocity from the middle finger to the wrist, and sensory action potential amplitude; distal motor latency of the median nerve from wrist to thenar eminence, at an interval of 7 cm; compound muscle action potential, measured from onset to peak of the initial monophasic negative muscle response.

The criteria of the American Society of Electrodiagnostic Medicine[12] were used to classify the condition as: 1) mild (pathological sensory conduction velocity with normal motor values); 2) moderate (pathological sensory conduction velocity with prolonged motor latency); 3) severe (pathological sensory conduction values and prolonged motor latency, with low or absent motor or sensory action potential); and 4) very severe (thenar motor or sensory response absent, with or without lumbrical response).

A sensory velocity < 48 m/s and a motor latency > 4.2 ms at an interval of 7 cm were considered to be the pathological cut-off value. Sensory action potential amplitude and compound muscle action potential amplitude were considered low when < 7.7 mV and < 5.6 mV, respectively.

Levine Questionnaire. Clinical and functional assessment was measured using the two scales in the Levine Self-Administered Questionnaire.[9] The Levine symptom score was determined by 11 questions regarding different attributes of pain, tingling and numbness, with each answer scoring between 1 (normal) and 5 (most abnormal). The Levine functional score looks at eight daily activities and evaluates the ability to perform each one, from 1 (normal) to 5 (most abnormal). The results are expressed as a mean score of the questions answered.

The study had ethical approval and informed consent was obtained from all patients. In 2010 the patients were divided into two subgroups: those who reported symptoms that merited a review (44 patients), and those without symptoms (71 patients). All patients underwent EMG evaluation and assessment using the Levine Questionnaire.

Statistical analysis. For statistical analysis we used the chi-squared test for qualitative variables, a paired *t*-test for quantitative variables, and Pearson's correlation coefficient. A sample size of 42 patients was necessary to detect differences of 20% in clinical and EMG outcomes of each evaluation. Statistical significance was set at a p-value < 0.05.

Results

The EMG review of the 115 patients took place at a mean of 10.47 years (9.24 to 11.36) after operation. The EMG results at the ten-year review compared favourably with the pre-operative results for sensory conduction velocity of the median nerve, distal motor latency, amplitude of sensory and compound muscle potential and EMG diagnosis. However, the mean sensory conduction velocity remained below the cut-off point considered normal in the neurophysiologic laboratory where this study was carried out (p < 0.001). A positive EMG diagnosis of CTS was found in 77 patients (67.0%), even with a moderate degree of disease, ten years after surgery, in spite of the favourable data provided by the Levine Questionnaire (Table I) (Figs 1 and 2).

Moreover, in the subgroup of 71 asymptomatic patients, 41 (57.7%) had a positive EMG diagnosis for the condition, with a pathological value of sensory conduction velocity, with or without prolonged motor latency (Table II). The rate of positive diagnosis in the symptomatic subgroup was 81.8% (36 of 44 patients) (Table III). Independent of the test result, patients in the symptomatic subgroup were offered surgical revision if, after four weeks of conservative

Table II. Clinical, functional and electromyographic (EMG) outcomes at ten years after surgery in the asymptomatic subgroup of 71 patients

Variable	Before surgery	10 years after surgery	p-value
Mean (SD) Levine clinical score (1, normal; 5, most abnormal)	3.36 (0.31)	1.27 (0.08)	< 0.001*
Mean (SD) Levine functional score (1, normal; 5, most abnormal)	2.47 (0.38)	1.22 (0.44)	< 0.001*
Mean (SD) sensitive conduction velocity (m/s)	37.25 (7.54)	44.46 (5.03)	< 0.001*
Mean (SD) sensitive action potential amplitude (mV)	8.23 (3.15)	13.82 (4.32)	< 0.001*
Mean (SD) motor latency (ms)	5.02 (0.99)	3.73 (0.69)	< 0.001*
Mean (SD) compound muscle action potential amplitude (mV)	7.41 (2.76)	9.52 (2.74)	< 0.001*
EMG diagnosis of carpal tunnel syndrome (n, %)			< 0.001†
Normal	0 (*0*)	30 (*42.25*)	
Mild	13 (*18.31*)	22 (*30.99*)	
Moderate	38 (*53.53*)	19 (*26.76*)	
Severe	20 (*28.16*)	0 (*0*)	
Very severe	0 (*0*)	0 (*0*)	

* paired *t*-test
† chi-squared test

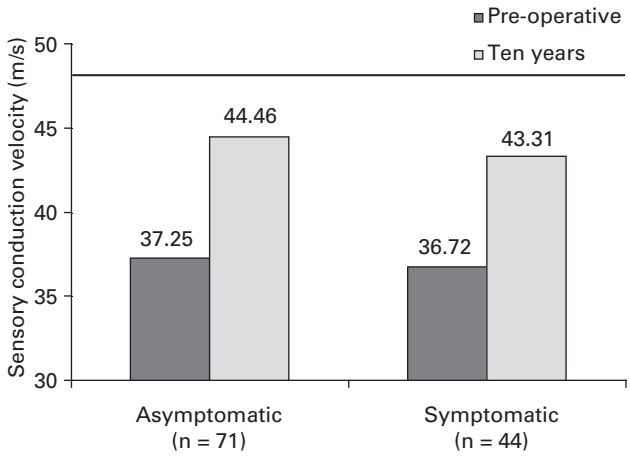

Fig. 1

Bar chart showing the mean sensory conduction velocity pre-operatively and at ten years for patients who were asymptomatic and symptomatic at the ten-year assessment. The continuous horizontal line is the cut-off value of 48 m/s, below which our laboratory considers abnormal.

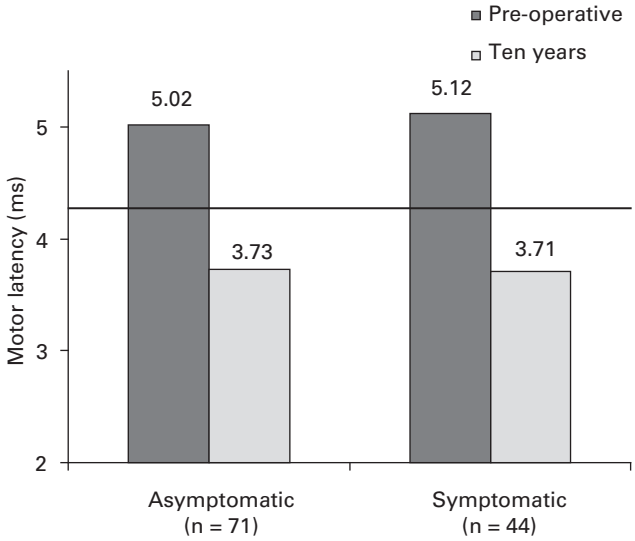

Fig. 2

Bar chart showing the mean motor latency pre-operatively and at ten years for asymptomatic and symptomatic patients at the ten-year assessment. The continuous horizontal line is the cut-off value of 4.2 ms, above which our laboratory considers abnormal.

treatment with non-steroidal anti-inflammatory drugs and ultrasound, no improvement in the symptoms was achieved (13 of 44 patients).

The Levine Self-Administered Questionnaire was undertaken at a mean of 10.38 years (9.16 to 11.54) after operation. The results showed on both scales that most patients reported a favourable outcome, obtaining a global mean between the absence of symptoms and the slightest degree of discomfort (Table I).

The correlation between the EMG results and the Levine Questionnaire revealed a significant and direct relationship between the motor latency of the median nerve and the clinical scale, and an inverse relationship between this score and the sensory conduction velocity, and the amplitude of the sensory and compound muscle action potentials. Also, a significant correlation was found between both scales of the questionnaire (functional and clinical) (Table IV).

Discussion

Previous studies reflect the current controversy regarding the validity of EMG testing in determining the severity of nerve compression in patients with CTS.[13,14] Rates of sensitivity and specificity up to 85% and 87%, respectively, have been reported after complete EMG testing.[15] Uchiyama et al[16] showed significant improvement in the neurophysiology results of 66 patients at one year after carpal tunnel decompression. In our study, it is striking to observe that two-thirds of the asymptomatic patients had positive EMG changes com-

Table III. Clinical, functional and electromyographic (EMG) outcomes at ten years after surgery for the subgroup of 44 symptomatic patients

Variable	Before surgery	10 years after surgery	p-value
Mean (SD) Levine clinical score (1, normal; 5, most abnormal)	3.35 (0.30)	1.85 (0.09)	< 0.001*
Mean (SD) Levine functional score (1, normal; 5, most abnormal)	2.39 (0.37)	1.77 (0.47)	< 0.001*
Mean (SD) sensitive conduction velocity (m/s)	36.72 (7.52)	43.31 (5.05)	< 0.001*
Mean (SD) sensitive action potential amplitude (mV)	8.18 (3.14)	11.15 (4.29)	< 0.001*
Mean (SD) motor latency (ms)	5.12 (0.97)	3.71 (0.67)	< 0.001*
Mean (SD) compound muscle action potential amplitude (mV)	7.46 (2.77)	8.74 (2.68)	< 0.001*
EMG diagnosis of carpal tunnel syndrome (n, %)			< 0.001†
Normal	0 (*0*)	8 (*18.18*)	
Mild	9 (*20.45*)	27 (*63.36*)	
Moderate	23 (*52.27*)	9 (*20.46*)	
Severe	12 (*27.28*)	0 (*0*)	
Very severe	0 (*0*)	0 (*0*)	

* paired *t*-test
† chi-squared test

Table IV. Results of the correlations between methods of evaluation at ten years after surgery (Pearson's coefficient and p-value)

	Clinical Levine	Functional Levine	Sensory velocity	Motor latency	Sensory action potential	Compound muscle action potential
Clinical Levine	1	0.501 (< 0.001)	-0.519 (< 0.001)	0.400 (0.001)	-0.498 (< 0.001)	-0.521 (0.001)
Functional Levine	0.501 (< 0.001)	1	-0.039 (0.749)	0.009 (0.940)	-0.412 (0.749)	-0.021 (0.940)
Sensory velocity	-0.519 (< 0.001)	-0.039 (0.749)	1	-0.750 (< 0.001)	0.614 (< 0.001)	0.682 (< 0.001)
Motor latency	0.400 (0.001)	0.009 (0.940)	-0.750 (< 0.001)	1	-0.762 (< 0.001)	-0.632 (< 0.001)
Sensory action potential	-0.498 (< 0.001)	-0.412 (0.749)	0.614 (< 0.001)	-0.762 (< 0.001)	1	0.748 (< 0.001)
Compound muscle action potential	-0.521 (0.001)	-0.021 (0.940)	0.682 (< 0.001)	-0.632 (< 0.001)	0.748 (< 0.001)	1

patible with the presence of CTS, even with only a moderate degree of severity on EMG diagnosis. This confirms that resolution of symptoms after operation may not be accompanied by recovery of median nerve function judged by motor latency values and sensory conduction velocity. However, the presence of comorbidities among our sample of patients, such as diabetes[17] or carpo-metacarpal arthritis of the thumb,[18] could have influenced these results.

Senda et al[5] evaluated the post-operative EMG results at six months in 26 patients following endoscopic release of the transverse carpal ligament. Their results confirmed the absence of complete recovery of sensory and motor parameters in the post-operative period, despite adequate clinical resolution.

Our findings suggest that in the long term different cut-off points should be taken into account when evaluating EMG results after carpal tunnel decompression. It is possible that the disparity between the clinical improvement and the lack of neurophysiological recovery may be due to the long-term effects of the initial median nerve compression. Although surgery may decompress the median nerve, intraneural fibrosis could result in nerve ischaemia[19-21] and produce the persistent EMG changes.

We found a significant correlation between the clinical scale used in the Levine Questionnaire and the EMG results, as the most pathological values of sensory conduction velocity and distal motor latency of the median nerve were found in those with the worst clinical outcome. This is consistent with the findings of You et al,[22] who showed a significant correlation pre-operatively between the EMG results and the clinical scale of Levine's Questionnaire. This raises the question as to whether a self-administered questionnaire could make EMG testing redundant.

We conclude from this study that clinical and functional outcomes should be considered in conjunction with EMG evaluation when assessing the long-term results of the treatment of carpal tunnel syndrome and the need for revision surgery. In doubtful cases self-administered assessments such as Levine's Questionnaire should prevail over EMG studies when the specialist makes a decision.

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