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Ultrasound evaluation of ulnar neuropathy at the elbow: correlation with electrophysiological studies

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Objectives. To evaluate, in patients with ulnar neuropathy at the elbow (UNE), if ultrasonographic differences in ulnar nerve size correlate with severity score determined by electrodiagnostic studies.

Methods. We examined prospectively 38 patients (50 elbows) with UNE. Patients were classified into mild, moderate and severe groups according to electrodiagnostic studies. Cross-sectional areas (CSAs) of the ulnar nerve were measured 4 cm proximal to the medial epicondyle (CSA-prox), 4 cm distal to the epicondyle (CSA-dist) and at the maximum CSA (CSA-max) of the ulnar nerve found between these points. We used a control group of 50 normal elbows.

Results. The CSA-max in the patient group was highly correlated with the severity score obtained by electrodiagnostic studies: mild: $11.1 \pm 3.4\,mm^2$, moderate: $15.8 \pm 3.8\,mm^2$, severe: $18.3 \pm 5.1\,mm^2$ ($P < 0.001$). Patients with UNE had larger ulnar nerve CSAs than controls at all three levels ($P = 0.012$ for CSA-prox, $P < 0.001$ for CSA-max, $P = 0.003$ for CSA-dist). A cut-off point of $\geqslant 10\,mm^2$ for CSA-max yields both sensitivity and specificity of 88%.

Conclusions. Ultrasonography can have a role not only in the diagnosis, but also in the severity stratification of patients with UNE.

Key words: Ultrasound, Entrapment neuropathy, Ulnar neuropathy at the elbow, Ultrasound of peripheral nerves.

Introduction

Ulnar neuropathy is the second most common nerve entrapment neuropathy after median nerve compression in the carpal tunnel; the elbow is the most common site of ulnar nerve compression where the nerve passes through the cubital tunnel [1]. Ulnar neuropathy at the elbow (UNE) is traditionally diagnosed by a thorough history, physical examination and nerve conduction studies (NCSs) [2].

However, since the 1990s, the development and the continuing improvement of ultrasound (US) technology have provided precise, non-invasive diagnosis of musculoskeletal abnormalities in a variety of clinical settings. Current US equipment is able to confidently identify almost all the main nerve trunks running in the limbs [3].

In the last decade, several studies have been performed to investigate the US findings of UNE [4–13]. These studies have shown that enlargement of the ulnar nerve is a relevant component of UNE, thus the ability to assess this finding by US measurement may prove helpful as an adjunct to NCSs in detecting patients with UNE. However, no studies have yet investigated the relationship between the severity of UNE and US findings as a primary endpoint. The aim of this study was to evaluate and compare the US changes of the ulnar nerve in patients with different grades of neuropathy determined by NCSs.

Materials and methods

Patients

Between October 2006 and March 2008, we prospectively studied the usefulness of high-resolution sonography in patients with UNE referred to the outpatient clinic of Neurology of Sacro Cuore Hospital. The study was approved by the local medical ethical committee of the Sacro Cuore Hospital of Negrar. Informed consent was obtained from each subject prior to the investigation. All participants had both ulnar nerves examined sonographically and electrophysiologically, but we considered each nerve separately in clinical diagnosis. Thirty-eight consecutive patients with UNE were included in this study (27 men, 11 women; mean age, 59.2 ± 14.2 years; range, 25–83 years); 12 patients had bilateral symptoms, thus in total 50 pathological ulnar nerves were analysed in this study.

Inclusion criteria were weakness in ulnar nerve-innervated muscles and sensory changes in the fourth and fifth fingers, and abnormalities that met the electrodiagnostic criteria for UNE proposed by the American Association of Neuromuscular & Electrodiagnostic Medicine (AANEM) [14]. Patients were excluded if any of the following was found: (i) history of polyneuropathy; (ii) acute trauma involving the upper extremity, previous trauma in the region of the elbow (including previous surgery); or (iii) brachial plexus injury.

Control group

Fourteen healthy age group-matched volunteers, five females and nine males, with no signs or symptoms of UNE were bilaterally studied as a control group (28 normal ulnar nerves). We also used the unaffected side of 22 patients as control nerves. Thus, in total 50 normal ulnar nerves were analysed; in all the cases a full neurological examination and NCSs were performed.

Electrodiagnostic evaluation

Electrodiagnostic studies were performed in all the enrolled subjects in agreement with the AANEM recommendations [14] using a Nicolet Viking IV electrodiagnostic system (Nicolet Instrument Corporation, Madison, WI, USA). All the tests were done in the same room with skin temperature kept $>33^{\circ}C$. The severity score adopted was chosen by an expert neurophysiologist before the beginning of the study in order to differentiate three stages: myelinic damage (mild involvement), mild assonal damage (moderate involvement) and severe assonal damage (severe involvement).

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The severity score was assessed on the following criteria:

(i) Mild involvement, presence of one of the following:
   (a) reduced motor conduction velocity (MCV) >10 m/s across the elbow (segment below-above elbow), compared with the more distal segment (wrist-below elbow), from the muscle I dorsal interosseus (IDI) or Abductor Digiti Minimi (ADM), plus increased F-wave (compared with the unaffected side or normative value);
   (b) reduced amplitude of sensory nerve action potentials (SNAPs) at IV and/or V finger (compared with the unaffected side or normative value).

(ii) Moderate involvement, presence of one of the following:
   (a) point 1 plus 2 of the previous grade;
   (b) motor conduction block from IDI or ADM at the elbow;
   (c) reduced amplitude of proximal compound muscle action potential (CMAP) across the elbow from IDI or ADM >20 but <50% and/or abnormal EMG of ulnar hand muscles (acute and chronic denervation potentials) and/or SNAPs absence.

(iii) Severe involvement, presence of one of the following:
   (a) complete motor conduction block alone across the elbow from IDI or ADM plus other abnormalities (point 3 of previous grade);
   (b) reduced amplitude of proximal CMAP across the elbow from IDI or ADM >50%;
   (c) severe axonal involvement of ulnar nerve with SNAPs abnormalities and abnormal EMG of ulnar hand muscles (acute and chronic denervation potentials).

Sonography

All patients underwent high-resolution real-time sonography of the ulnar nerve at the elbow using a Vivid 7 machine (General Electric, Milwaukee, WI, USA) with a 12-MHz matrix linear array transducer. To ensure unbiased examination, the examiner was requested not to inquire about symptoms and the patients were asked not to speak during examination. Sonographic examination was done either on the same day or within 7 days of the electrophysiological study.

The sonographic examination was performed by the same operator; the patient sat and faced the operator with the examined upper limb flexed to 90°, maximally intrarotated and with elbow flexed to 30°. A systematic scan to follow the nerve in transverse planes was performed; three measurements were taken: (i) 4 cm proximal to the medial epicondyle [cross-sectional area (CSA)-prox], (ii) 4 cm distal to the epicondyle (CSA-dist) and (iii) the maximum cross-sectional area (CSA-max) of the ulnar nerve found between these points. Three measurements were obtained at each level and the mean was considered for the statistical analysis. The examiner carefully placed the probe perpendicular to the nerve to obtain the minimum and thus most accurate CSA. The CSA of the ulnar nerve was measured using automatic manual 'tracing' just inside the hyperechogenic line that surrounds the nerve perineurium.

Statistical analysis

Statistical analyses were performed using the SPSS Version 11.0 (SPSS, Chicago, IL, USA). All the continuous variables were normally distributed as assessed by the Kolmogorow–Smirnov test. Statistical analysis was performed using the Student's *t*-test and one-way ANOVA to test the differences between groups' means. The χ^2 and Fisher's exact were used for testing the association between qualitative variables. The sensitivity and specificity of sonography were also studied by means of a receiver operating characteristic (ROC) curve. All statistical tests were two sided. A test result was considered statistically significant if the *P*-value was $\leqslant 0.05$.

Results

Fifty elbows with UNE were studied. Parasthesia in the fourth and fifth fingers was present in all the cases, whereas overt muscle wasting was present in five cases (10%). Table 1 shows the baseline characteristics of the patients included in this study.

There was no significant difference in CSA of ulnar nerve at the three levels between the healthy group and the normal side of patients. The mean ulnar nerve CSA (square millimetres) at all the three levels (-prox, -max and -dist) was significantly greater in UNE patients than in controls (*P*-values are 0.012, <0.001 and 0.003, respectively, Table 2).

The CSA-max in the patient group was highly correlated with the severity score obtained from NCSs: mild: $11.1 \pm 3.4\,mm^2$, moderate: $15.8 \pm 3.8\,mm^2$ and severe: $18.3 \pm 5.1\,mm^2$ ($P < 0.001$, Table 2). There was no significant correlation between CSA-prox and -dist and UNE severity.

A sensitivity analysis was performed to assess whether the CSA-max of the ulnar nerve measured by US may be used as an adjunct to clinical evaluation and NCSs. A cut-off point of $\geqslant 10\,mm^2$ for CSA-max yields sensitivity and specificity of 88% (44/50 elbows) each. The positive and negative predictive values were 88% (44/50 elbows) each. All the six pathological nerves that gave a normal result at US had a mild involvement at NCSs and all the six normal nerves that gave an abnormal result at US had a CSA-max at the lower limit ($10\,mm^2$ in two cases and $11\,mm^2$ in four cases).

Statistical analysis was done using the upper limit of 95% CI to calculate the cut-off point, its specificity and sensitivity, for a

TABLE 1. Baseline characteristics of the patients

Variable	Patients
Age, mean ± S.D., years	59.2 ± 14.2
Sex, male:female, *n* (%)	27:11 (71:29)
No. of patients/elbows examined	38/50
Duration of symptoms, mean ± S.D., months	11.1 ± 10.7
Side affected, *n* (%)	
Right	9 (23.7)
Left	17 (44.7)
Bilateral	12 (31.6)
NCSs severity, *n* (%)	
Mild	18 (36)
Moderate	19 (38)
Severe	13 (26)

TABLE 2. CSA of the ulnar nerve at the elbow in different groups

	Patients *vs* controls			UNE severity			
	Control nerves (*n* = 50)	Pathological nerves (*n* = 50)	*P*-value	Mild (*n* = 18)	Moderate (*n* = 19)	Severe (*n* = 13)	*P*-value
CSA-prox	5.9 ± 1.2	6.7 ± 1.6	0.012	7.1 ± 1.6	6.3 ± 0.9	6.8 ± 1.9	NS
CSA-max	7.1 ± 2.1	14.6 ± 5.0	<0.001	11.1 ± 3.4	15.8 ± 3.8	18.3 ± 5.1	<0.001
CSA-dist	5.7 ± 1.0	6.5 ± 1.5	0.003	6.2 ± 1.5	6.5 ± 1.5	7.2 ± 1.3	NS

Values are given as mean ± S.D., in square millimetres. NS: not significant.

TABLE 3. Sensitivity, specificity and κ-value of US cut-off points that discriminate between different grades of UNE severity as detected by US

	CSA-max, mm^2				
	<10	⩾10	κ (*P*-value)	Sensitivity, %	Specificity, %
Controls	44	6	0.76 (<0.001)	88	88
Patients	6	44			
	<15	⩾15			
Mild	16	2	0.53 (<0.001)	69	89
Moderate and severe	10	22			
	<20	⩾20			
Moderate	16	3	0.24 (0.15)	39	84
Severe	8	5			

pathological mean CSA of the ulnar nerve that discriminates between the cases *vs* the control group. This was identified as being 10 mm^2. The same analysis was done when choosing the cut-off point that discriminates between the different severity score groups; the study revealed that 15 and 20 mm^2 were the best cut-off points to discriminate between mild and moderate groups and between moderate and severe groups, respectively (Table 3). We found a good intra-observer reproducibility of CSA measurement ($k = 0.89$).

Discussion

In patients with UNE, the CSA-max of the ulnar nerves at the elbow correlates with severity estimated by NCSs. In the last decade, many studies have been carried out on the utility of US in the diagnosis of compressive neuropathies. Compared with NCSs, US has several advantages such as ready accessibility, portability, quick scan time and better patient tolerability. More importantly, US allows complete evaluation of the anatomic structures that surround the nerve. The initial studies focused on the use of US in the carpal tunnel syndrome, the most frequent compressive neuropathy, showing an important role in the diagnostic process of this condition [15–17]. More recently, similar studies have been carried out on the second most frequent compressive neuropathy, UNE, with good results. In particular, it has been convincingly demonstrated that in patients with UNE, there is an enlargement of the ulnar nerve at the elbow [4, 5, 8–11].

Our study confirms that UNE is associated with the enlargement of the ulnar nerve at the elbow but mainly shows that the nerve enlargement, evaluated by CSA-max, is strictly linked to UNE severity. This association was previously studied, but the results were discordant. Some authors found a positive correlation between CSA and NCSs, mainly with one parameter of the electrodiagnostic evaluation like MCV [7, 8, 10, 11], whereas Park *et al.* [9] did not. Limitations of these studies were the small sample (on average 23 symptomatic elbows) and the fact that this correlation was not the primary end point. In addition, we believe it to be crucial to consider the result of the whole NCS and not to limit the correlation with a single NCS parameter.

Our aim was to assess UNE by US similarly to the study performed by El Myedani *et al.* [15] on carpal tunnel syndrome, which allowed identification of cut-off points that stratify patients. Therefore, a large sample of patients and a severity score with a limited number of stages were necessary. Different US methods can be used to assess structural alterations of the nerve in compressive neuropathies: the measure of short/long nerve axis, the antero–posterior diameter and the ratio between two different measures. Two main reasons induced us to choose CSA as the most important US parameter. First, on the grounds of previous studies concerning both carpal tunnel syndrome and UNE, CSA seemed to be the most effective and reliable method to estimate the nerve swelling. Secondly, this evaluation is easy to perform. In this study, we paid particular attention to CSA-max, which was almost always found at the level of epicondyle and seemingly represented the most useful point to establish the severity of UNE.

We found three cut-off points that may define the severity of UNE: mild ⩾10 mm^2, moderate ⩾15 mm^2 and severe ⩾20 mm^2. The first two cut-off points showed a very good diagnostic performance, whereas it was poor for the severe stage. The same statistical analysis performed by El Myedani *et al.* [15] for carpal tunnel syndrome was remarkably better. We believe that this difference is principally due to the heterogeneous aetiology and pathogenesis and the anatomical complexity of UNE, which prevents a single parameter of being indicative of the whole disorder. Actually, unlike carpal tunnel syndrome, UNE is a heterogeneous group of focal neuropathies of the ulnar nerve in the region of the elbow and there are at least four potential sites where the nerve may be damaged [7]. We believe that in order to improve US evaluation of UNE other aspects, together with CSA-max, should be evaluated such as the extension of nerve swelling or a swelling ratio such as that like Yoon *et al.* [13] have recently proposed.

A severity classification may affect the choice of treatment. We believe that especially for UNE, this process needs a composite evaluation that takes into account clinical evaluation as well as NCSs and US. With respect to US, we suggest that for CSA-max values >13 mm^2 surgery could be the therapeutic option; whereas a conservative approach should be preferred for values below this cut-off. In our study, none of normal ulnar nerves showed a CSA-max >13 mm^2; therefore, nerves with such swelling have a high probability to be compressed and, in the end, to benefit from surgery.

As a secondary but relevant result, we found that the diagnostic cut-off for UNE of 10 mm^2 has both a sensitivity and a specificity of 88%. Wiesler *et al.* [10] found the same cut-off point with a greater diagnostic performance (sensitivity 93% and specificity 98%). However, that study had a possible bias in recruiting patients, as acknowledged by the authors themselves; the mean CSA of patients was 19 mm^2, a value similar to that of our more severe cases. In our study, the mean CSA-max in case of mild involvement (11.1 mm^2) was very close to the diagnostic cut-off point of 10 mm^2; Fig. 1 shows that several mild cases fell below the value of 10 mm^2. This finding is not surprising. We thus agree with Mondelli *et al.* [7] that in patients with mild UNE (typical symptoms without any objective deficit and with only a slight MCV slowing across the elbow), it would have been reasonable to expect normal or only slightly altered CSA.

We found that in patients with UNE, not only CSA-max, but also CSA-prox and -dist were significantly greater than those of in controls. These data were similar to those of Chiou *et al.* [6], although in their study they did not reach statistical significance probably because of the small sample size. However, unlike CSA-max, in the case of CSA-prox and CSA-dist the differences were too small in quantitative terms and neither allowed a clear distinction between patients and controls nor did they show a correlation with severity. We believe that this result is partially due to some UNE patients who presented a diffuse nerve swelling. Park *et al.* [9] described this kind of nerve involvement as associated to retrocondylar compression syndrome, whereas they found focal swelling mainly associated with cubital tunnel syndrome. In our study, we did not differentiate UNE by aetiology but we also noted that there are patients with focal and with diffuse nerve swelling.

There are some limitations of our study that have to be considered. First, we used as a control group not only healthy subjects, but also the asymptomatic side of patients; in addition, the sample of healthy controls was small. But our purpose was

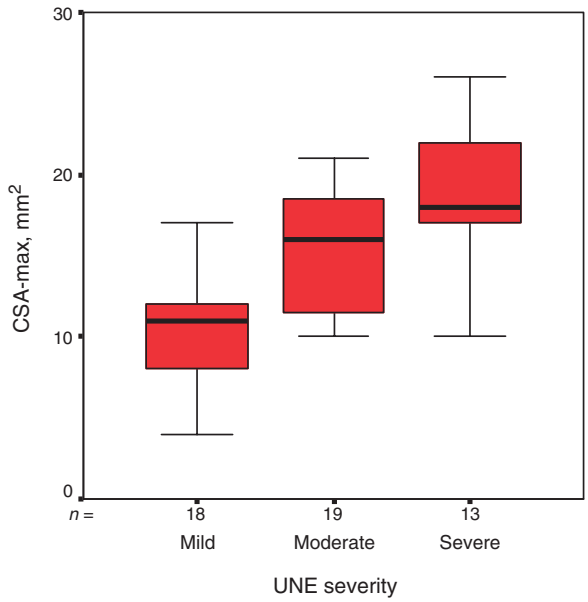

FIG. 1. On the *y*-axis of box plot, the ulnar nerve CSA (square millimetres) is reported. On the *x*-axis, the grade of severity of UNE estimated by nerve conduction studies is plotted.

mainly to analyse the patients and the relation between US and NCS severity. Moreover, our study confirmed the previous observation of Chiou *et al*. [6] that US features of ulnar nerve of the asymptomatic side of patients with UNE were similar to that of the control group.

Another limitation was that we did not consider different forms of ulnar entrapment such as cubital tunnel syndrome and retrocondylar compression syndrome. Moreover, we did not evaluate the interobserver variability of the method, but we may presume it was quite low. We underline that the method used is simple to perform as the high intra-observer reproducibility proves (0.89); moreover, the differences we observed between controls and patients (CSA-max of 7.1 and 14.6 mm^2, respectively) were strictly comparable with those of Chiou *et al*. [6], who used a similar method (area of ulnar nerve at epicondyle, 6.8 and 13.9 mm^2, respectively). The correlation we have found between nerve swelling measured by CSA-max and NCSs strengthens the role of US not only in the diagnosis but also in the treatment choice for patients with UNE.

Rheumatology key messages

- US can be confirmed as being accurate in the diagnosis of UNE.
- Maximum CSA of the ulnar nerve at the elbow is the most important ultrasonographic finding.
- US allows estimation of the severity of UNE.

Disclosure statement: The authors have declared no conflicts of interest.

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