Contribution of ultrasound in the assessment of nerve diseases

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Background and purpose: Recently, ultrasound (US) has been used to assess the peripheral nervous system; however, there is no real study about its possible significant role in routine practice. Our study aims to assess the contribution of US as a routine tool in a neurophysiological laboratory.

Methods: The study assesses 130 patients who presented clinical suspicion of peripheral nerve diseases, excluding motor neuron disease, radiculopathy, hereditary and acquired polyneuropathy. All patients were clinically, neurophysiologically and sonographically assessed in the same session by the same neurologist/neurophysiologist. To avoid interpretation bias, two independent and blinded clinicians, different than the examiners performing electrodiagnosis and US, reviewed clinical, neurophysiological and US findings (also data about follow-up, when available) and classified the contribution of US as follows: Contributive (US had influence on the diagnostic and therapeutic strategies), Confirming (US confirmed the clinical and neurophysiological diagnosis), Non-Confirming (US findings were normal) and Incorrect (US findings led to incorrect diagnosis).

Results: US impacted, namely modified the diagnostic and therapeutic path in 42.3% of cases (55 patients); US had a confirmatory role in 40% (52 patients); US did not confirm clinical and neurophysiological diagnosis in 17.7% (23 cases); no incorrect US findings were observed.

Conclusion: US complements neurophysiological assessment even in routine practice, and this confirms the increasing interest in US for a multidimensional evaluation of peripheral nerve system diseases.

Introduction

Electrodiagnosis is the main tool in assessing nerve function and hence is crucial in the diagnosis of nerve involvement. An improved resolution, an increased portability and a wider access of ultrasound (US) instruments have made this tool useful in assessing nerve entrapment and other kind of nerve abnormalities (as tumours, extrinsic compression) [1–6]. A growing body of literature supports the use of US in the assessment of nerve diseases.

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In 2007, we assessed the outcome of adding US to electrodiagnosis in 77 patients who presented an atypical clinical and neurophysiological condition [7]. Results showed that US may be useful for the diagnosis and determination of an appropriate therapy.

In an editorial response to our study, F.O. Walker affirmed that by combining electrodiagnosis evaluation to US the approach to nerve and muscle diseases may be redefined [8].

Considering our preliminary encouraging results [7], Walker's suggestions, emerging literature [9,10] and because US studies are not particularly time-consuming, they are painless and are very well tolerated by patients, we decided to always add US evaluation to routine neurophysiological practice in peripheral nerve lesion assessment.

The aim of this study was to evaluate whether the routine use of US in a neurophysiological laboratory can modify the diagnostic and therapeutic approach to patients with suspect peripheral nervous system diseases, and, if so, how this comes about.

Methods

We prospectively included in our study 130 patients who referred in our laboratory between January and July 2009 with clinical history, symptoms and neurological examination that suggested peripheral nerve diseases. We excluded from this study patients with motor neuron disease, radiculopathy, hereditary and acquired polyneuropathy.

All patients were clinically, neurophysiologically and sonographically assessed in the same session according to the above reported order/timing. The neurologist/neurophysiologist (LP, CP, GG) who performed US evaluation was also the same one who performed neurophysiological assessment.

Concerning the assignment of the US contribution, in order to avoid biases, the following procedure was followed: two independent clinicians (GL, ADP), different than the examiners performing electrodiagnosis and US, reviewed clinical, neurophysiological and US reports (also data about follow up, when available) and determined which value US provided. The results of the two authors were compared and, in case of divergent opinions and lack of agreement, a third opinion was obtained.

Main outcome measure

Electrophysiological examinations

Neurophysiological evaluation was performed using Medelec Oxford Synergy equipment (Surrey, England). Routine nerve conduction studies and electromyography were performed according to conventional procedures [11–14].

Sonographic examinations

After performing clinical and neurophysiological evaluation, US of the nerve with suspect damage was performed on the basis of the results provided by the previous assessments. An Esaote Lab 25 Gold (Genoa, Italy) equipped with a broadband (frequency band 10–18 MHz) linear transducer was used.

Sonographic criteria for nerve identification were based on detection of the fascicular echotexture, according to criteria described in literature. We used quantifiable measurements such as cross sectional area (CSA) and longitudinal diameter [15].

The longitudinal diameter was measured directly on the screen by means of the electronic callipers provided with the equipment software; by the ellipse function, or trace area, CSA was traced inside the hyperechoic rim of the nerve.

US results are based on the localization of nerve abnormality (for example, increased CSA in compression site or related to extrinsic compression), extension of abnormal findings, (focal or diffuse increased CSA) and its shape and echogenicity. Hypoechogenicity was considered pathological only when associated with increased CSA.

We used as CSA normal value data obtained from our laboratory. In particular, for entrapment syndrome, we used the following normal CSA values: median nerve at the wrist < 11 mm^2, ulnar nerve at the elbow < 11 mm^2 and peroneal nerve at the fibular head < 13 mm^2. In all other cases, particularly in traumatic cases and in tumours, we used the opposite side value, normal values, when available, and the value of CSA in the proximal and distal segments to damage. Being entrapment often bilateral in the suspect of entrapment, we never used comparison with the contralateral site.

The contribution of US was assessed according to the classification reported in our previous study on 2007, with a few modifications: [7].

- Contributive: 'The US findings enhanced diagnostic information, treatment or follow-up. In detail, the contributive group included three subgroups:
  - Diagnostic: when US mainly helped to identify the cause and site of the nerve lesion that was not possible with routine electrophysiology tests alone;
  - Therapeutic: when US findings mainly influenced therapeutic approach;
  - Follow-up: in this group, we included the follow-up of traumatic nerve lesion and tumours because the visualization of the nerve and its surroundings provides spatial information that was a useful adjunct to traditional electrophysiology studies. In other words, US was included in this group because it was useful in following the size and extent of the lesion over time, and its involvement or sparing of nearby tissues.
  - Confirming: US findings confirmed the clinical and neurophysiological diagnosis. In this case, US did not modify the diagnostic path; rather diagnosis was reinforced by additional evidence and information.
- Non-contributive: US findings were normal.
- Incorrect: US findings led to incorrect diagnosis. This group included misinterpreted findings, or findings not confirmed by surgical exploration.

The Institutional Review Board of the Neuroscience Department of the Catholic University approved the research protocol and patients gave informed consent.

Results

We examined 130 patients. The main features of the sample were as follows: 73 patients with clinical suspicion of compression/entrapment, 46 patients were admitted to our laboratory for traumatic nerve lesion, six patients with the suspect of nerve tumour, four with clinical suspicion of thoracic outlet syndrome. Note that we include another patient, with the clinical suspicion of carpal tunnel syndrome (CTS), who refused electrodiagnosis examination (both EMG and nerve conduction studies).

Contributive group

US strongly modified the diagnostic and therapeutic path in 55 cases (42.3%), providing the following information regarding therapeutic approach, diagnosis and follow-up according to the above-mentioned subgroups:

- As regards *diagnostic contribution*, US results allowed us to reach diagnosis in 9 of 55 cases (16.4%). In six cases, normal neurophysiological findings were not able to confirm clinical suspicion while diagnosis was made by US (two cases of ulnar nerve entrapment at the elbow: UNE; 1 tarsal tunnel syndrome and thre femoro-cutaneous neuropathy); in two cases with traumatic nerve lesions, US showed the exact site of the damage, while electrodiagnosis was not able to determine it precisely. Moreover, in one patient, diagnosis was reached only through US because he refused to perform electrodiagnosis (final diagnosis: CTS).
- As regards *therapeutic contribution*, US provided information in 35 cases (63.6% of the contributive group). There were 17 cases of traumatic nerve lesions, 12 cases of UNE and 6 cases of CTS. In all these cases, the neurophysiological findings suggested a clear diagnosis but US added information useful to take therapeutic decision between different approaches (for example in traumatic cases, US distinguished neurotmesis from axonotmesis and this was crucial to proceed to surgical exploration or to have a conservative and waiting approach) or to better target the therapy (for example, when neurophysiological evaluation was not able to identify the precise site of nerve lesion when US provided this information allowed to limit the extension of surgery) or to anticipate unexpected findings (for example in case of anatomical variation as presence of bifid median nerve, accessory muscle, ulnar luxation), presence of neuroma, etc). In these cases and in other (as nerve relationship with bone fragments and screw in fractures, presence of neuroma, etc), US was able to provide information useful to better treat the patient.
- As regards *follow-up contribution*, 11 patients (20%) were included. There were six cases of nerve tumours, where US helped to evaluate the evolution; five cases of traumatic nerve lesions where US allowed following critical relationship with surroundings (as bone fragments).

Confirming group

US had a confirmatory role in 52 patients (40%). US confirmed electrodiagnosis in 39 entrapment cases (24 CTS, 13 UNE, 1 femoral neuropathy, 1 peroneal nerve neuropathy) and in 13 traumatic nerve lesions.

Note that, in all traumatic nerve lesions, US provided additional information compared with neurophysiological findings. However, it was decided to include some cases of traumatic nerve lesions in the confirmatory group when fulfilling the following criteria: partial nerve lesion neurophysiologically confirmed (in this case US information on nerve continuity was not contributive) or when identification of the exact site of the nerve lesion was possible by electrodiagnosis alone.

Non-contributive group

In 23 cases (17.7%), US results were normal and did not modify the diagnostic path. In these cases, US was unable to show abnormalities. We divided this group into two subgroups. One where neurophysiological assessment confirmed the clinical suspicion: seven traumatic lesions, two CTS and one UNE. The other group included cases, where either electrodiagnosis or US did not confirm the clinical suspicion: two traumatic lesions, three CTS, three Tarsal tunnel syndrome, one lateral femoral cutaneous syndrome, four thoracic outlet syndrome.

Incorrect group

No cases with incorrect US findings were observed. To provide data on the US contribution in the three more common nerve lesions, three tables summarize results at disease level: Table 1 on traumatic lesion group, Table 2 on carpal tunnel syndrome cases and Table 3 on ulnar neuropathy at elbow cases.

Comment section

On the basis of previous results concerning the usefulness of US in atypical cases [7] and of clinical practice,

Table 1 Contribution of US in traumatic nerve lesion cases

	Contributive									
	Therapeutic [71% of contributive]		Diagnostic [8% of contributive]		Follow-up [21% of contributive]		Total	Confirmatory	Non-contributive	Total
Traumatic lesions (n = 46)	17 (37%)	US showed unexpected nerve impairment and allowed to hypothesize the mechanism of lesion otherwise no explainable (five cases): one case of median nerve lesion; one case of sciatic nerve lesion; one case of PIN lesion; two cases of peroneal nerve lesion. US showed nerve interruption: three cases of peroneal nerve neuropathy US showed the presence of traumatic aneurism that 'contact' the nerve: entrapment of ulnar nerve at the Guyon tunnel (one case) US showed the relationship between nerve-bone fragments or screw (seven cases): three cases of peroneal nerve lesions; three cases of radial nerve lesions; one case of ulnar lesion US showed good outcome after surgery of nerve grafting (nerve continuity) despite the clinical failure: one case of radial nerve lesion	2 (4%)	US identified the exact site of nerve lesion that was difficult to detect with electrophysiology: one case of avulsion root of plexus lesions and one case of PIN lesion	5 (11%)	US allowed to follow critical relationship with surroundings and nerve condition: sciatic nerve lesion (one case); peroneal nerve lesion (one case); radial nerve lesion (one case); PIN lesion (one case); brachial plexus lesion (one case)	**24 (52%)**	13 (28%)	9 (20%)	**46 (100%)**

Bold values indicate the absolute values and the percent values of the total no. of patients and in the subgroups.

Table 2 Contribution of US in carpal tunnel syndrome cases

	Contributive							
	Therapeutic [100% of contributive]		Diagnostic	Follow-up	Total	Confirmatory	Non contributive	Total
Carpal tunnel syndrome (n = 35)	6 (17%)	US identified: Bifid median nerve with persistent median artery: three cases Accessory muscle: one case Tenosynovitis of flexor tendons: two cases	–	–	**6** (17%)	24 (69%)	5 (14%)	**35** (100%)

Bold values indicate the absolute values and the percent values of the total no. of patients and in the subgroups.

Table 3 Contribution of US in Ulnar neuropathy at elbow cases

	Contributive							
	Therapeutic [86% of contributive]		Diagnostic [14% of contributive]		Follow-up	Total	Confirmatory	Non-contributive	Total
UNE (n = 28)	12 (43%)	US showed ulnar nerve luxation/subluxation: five cases and one cases with triceps muscle US showed anatomic alteration of cubital tunnel: For arthrosic deformities in one case and post-elbow fracture in one case US showed displacement of ulnar nerve in cubital tunnel (this was superficial on the epicondyle bone): one case after surgical decompression US showed an accessory muscle (anconeus epitrochlearis muscle): two cases US showed relationship between ulnar nerve and bone fragment: one case post-surgery	2 (7%)	US showed ulnar impairment in patients with normal neurophysiological findings: two cases	–	**14 (50%)**	13 (46%)	1 (4%)	**28 (100%)**

Bold values indicate the absolute values and the percent values of the total no. of patients and in the subgroups.

we decided to quantitatively and qualitatively assess the contribution of US as a routine tool in a neurophysiological laboratory. This had never been assessed before.

In the sample of patients with clinical suspicion of nerve diseases (excluding radiculopathy, motor neuron diseases and polyneuropathy), in 4 of 10 cases, US allowed us to define the diagnosis or to modify the therapeutic path, thus the role of US was contributive. In these cases, US mainly helped to give surgical indications (Figs 2 and 3), precisely identifying the site of nerve lesion, revealing iatrogenic findings (e.g. the presence of screws; Fig. 4), pathological conditions (e.g. the presence of an accessory muscle or inflammatory process) and dynamic abnormalities (ulnar nerve luxation). Furthermore, in cases of tumours and in the course of post-traumatic lesions, US provided useful information about the evolution of the pathologies. In these cases, US showed the evolution of nerve size and surroundings and implemented clinical –

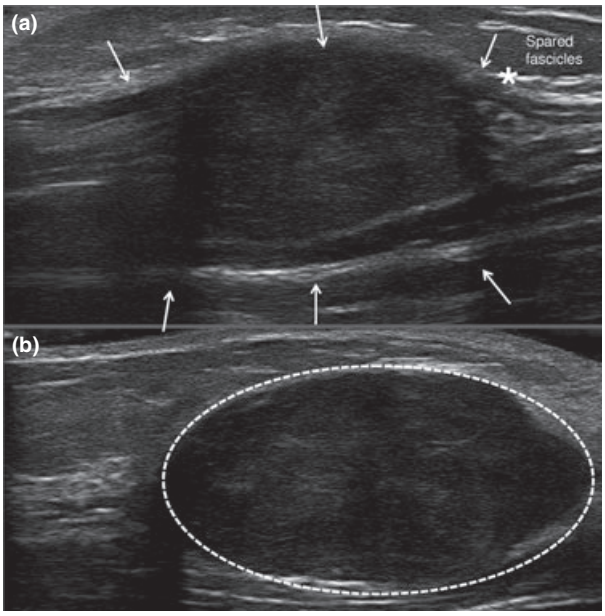

Figure 1 Diagnostic ultrasound image of a neuroma of the ulnar nerve (a) the nerve neuroma has an oval shape, well-defined margins, some fascicles displaced on its marginal site (longitudinal scan). (b) marked increased in nerve size (cross sectional area 189 mm^2; transversal scan).

neurophysiological information. In some patients, US helped to reach a diagnosis when neurophysiological evaluation did not clearly define the site of the lesion or gave negative results. US was useful when one patient refused to undergo neurophysiological tests.

In 4 of 10 cases, US confirmed clinical and neurophysiological diagnosis providing more evidences: information on nerve morphology and surrounding structures completed the electrophysiological data providing a different point of view of nerve impairment (Fig. 4).

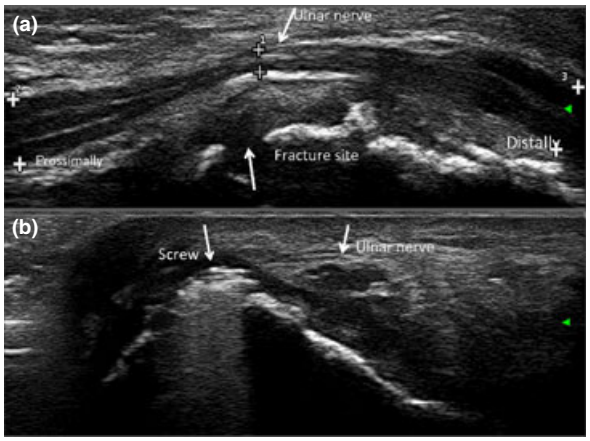

Figure 2 Diagnostic ultrasound image of the ulnar nerve in traumatic lesion (a) at the fracture site, the nerve showed a narrowing of its diameter to the proximal and distal site (longitudinal scan). (b) the relationship between the nerve and the screw.

In about 2 of 10 cases, US was normal. In these cases, the role of US was defined 'not contributive', but the term may not be completely appropriate. The fact that a US shows that there is no morphological alteration of the nerve and its surroundings is in itself a 'contributive' information excluding tumours or either pathologies.

As regards the risk of equivocal results and misinterpretations, in the previous study, we diagnosed a nerve tumour, confirmed by magnetic nuclear resonance (MNR), while it was actually an inflammatory lesion. In the current study, probably for the operators' greater familiarity with the US technique, there were not cases of equivocal US results.

Further notes should be done on the current study. First, because of the inclusion/criteria criteria, this study focused primarily on the use of US for identifying nerve lesions. We are aware that by excluding patients with motor neuron disease we may have excluded other kind of contributions of US (for example, US imaging of muscle, particularly fasciculations or atrophy, could contribute to a diagnosis). Secondly, being the study performed in a tertiary referral centre, it may not be representative of other electrodiagnostic laboratories.

Conclusion

In conclusion, our study shows that US complements neurophysiological assessment even in routine practice in a consistent amount of patients. US and electrodiagnosis together give information that is impossible to obtain if we use them separately [1]. This paper, along with a body of rapidly accumulating literature, confirms the increasing interest in a multidimensional evaluation of peripheral nerve system diseases [2,10,15–20]. Looking at neuro-imaging through US, the neurophysiologist can benefit from diagnostic precision and therapeutic accuracy [21–24].

Note that clinical neurophysiologists, by training, are well suited to rapid acquisition of the skills needed to perform US.

Further studies should evaluate cost-effectiveness, the comparison between magnetic nuclear resonance and US and the relationship between neurophysiological and US results. Eventually, it could be very interesting to assess whether, and in which cases, US study could be quite sufficient to reach a diagnosis without needing electrodiagnosis. Our special feeling and by definition, even if in some cases diagnosis could provide by US alone, neurophysiological assessment is the only tool to assess severity of the nerve functional involvement. The methodology to deal with this topic is complex but

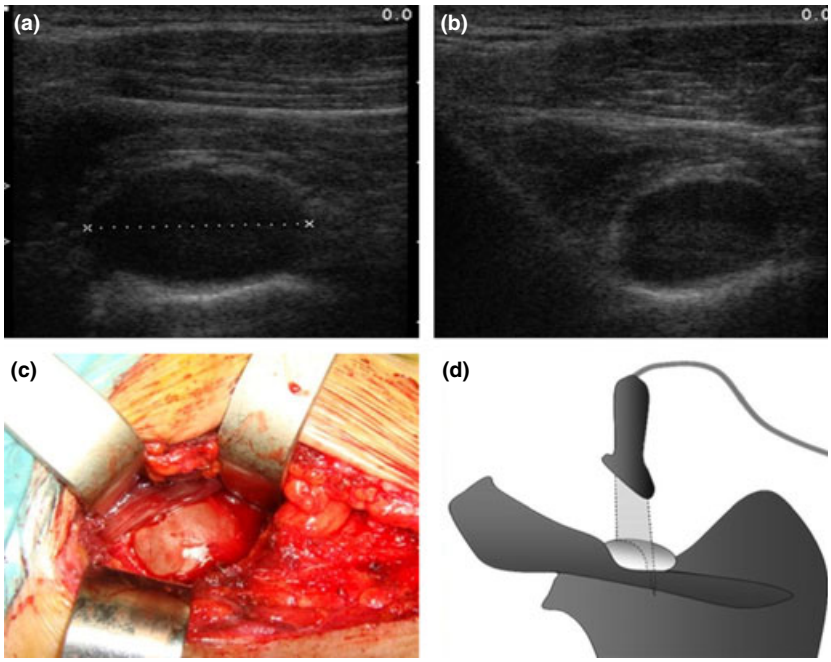

Figure 3 Diagnostic ultrasound image of a cyst that caused the compression of suprascapular nerve. (a) long axis cyst ultrasound view (b) short axis cyst ultrasound view (c) surgical view of the cyst (d) probe position for short axis cyst view.

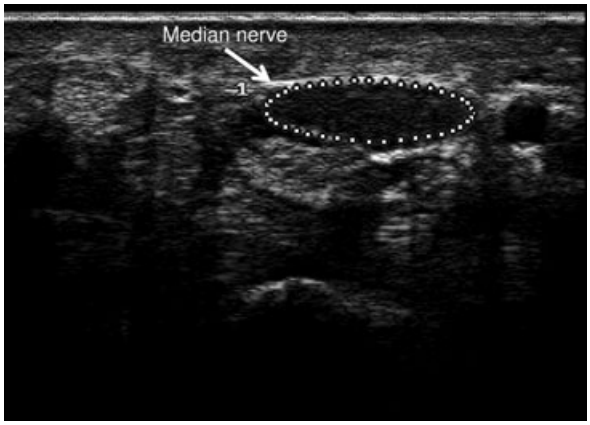

Figure 4 Example of confirmatory role of US. In a patient with symptoms and electrodiagnosis of carpal tunnel syndrome, US confirmed the diagnosis, showing a median nerve swelling and hypoechoic at the wrist (cross sectional area = 18 mm^2 n.v. < 11 mm^2).

perhaps a wide multicentric and multidisciplinary task force could provide this crucial information.

However, in the light of the above data, we can safely say that US should be used, whenever possible, not only to improve assessment of nerve impairment, but above all, to assist neurologists/neurophysiologists in deciding on a therapeutic course.

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Disclosure of conflict of interest

The authors report no conflicts of interest.

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