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Ultrasonography of ulnar neuropathy at the elbow: Axonal involvement leads to greater nerve swelling than demyelinating nerve lesion

Erika Scheidl [a], Josef Böhm [b], Zsófia Farbaky [c], Magdolna Simó [a], Dániel Bereczki [a], Zsuzsanna Arányi [a,*]

[a] Department of Neurology, Semmelweis University, Budapest, Hungary
[b] Freiberg County Hospital, Department of Neurology, Freiberg, Germany
[c] Budai Irgalmasrendi Hospital, Department of Radiology, Budapest, Hungary

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HIGHLIGHTS

- High-resolution ultrasound shows pronounced focal morphological abnormalities of the ulnar nerve at the elbow in UNE, which may be of significant diagnostic help particularly in nerve lesions with non-localizing axonal loss.
- Nerve size parameters, such as the largest cross sectional area (CSA_{max}) of the ulnar nerve around the elbow and the cubital-to-humeral nerve area ratio (CHR) show significantly larger nerve swelling in axonal lesions, as compared to predominantly demyelinating lesions.
- The subtype of axonal lesion also affects nerve size parameters: CSA_{max} values in patients with sensorimotor axonal lesion were significantly higher than in those with pure sensory axonal involvement.

ABSTRACT

Objective: To evaluate nerve size parameters measured by ultrasound in patients with ulnar neuropathy at the elbow (UNE) and to correlate them with the type of nerve lesion.
Methods: The largest cross sectional area (CSA_{max}) of the ulnar nerve around the elbow and the cubital-to-humeral nerve area ratio (CHR) were measured in 50 elbows with UNE and in 87 elbows of 50 healthy subjects. CSA_{max} and CHR were compared between controls and patients with predominantly demyelinative and axonal nerve involvement. Subgroups of patients with pure sensory and mixed sensorimotor axonal lesion were also compared.
Results: In patients with axonal nerve involvement, a significantly larger CSA_{max} and CHR were found when compared to those with predominantly demyelinating nerve lesion; both groups differed significantly from healthy controls. CSA_{max} values in patients with sensorimotor axonal lesion were significantly higher than in those with pure sensory axonal involvement.
Conclusion: CSA_{max} and CHR highly correlate with the type of nerve pathology in UNE, with a significantly larger nerve swelling seen in axonal lesions, as compared to demyelinating lesions.
Significance: In addition to helping in the localization of nerve lesion, ultrasonography may also reflect the type and degree of nerve lesion as assessed by electrophysiological means.

1. Introduction

High resolution ultrasonography (HRUS) is an emerging technique for the investigation of peripheral nerves, and it is increasingly being used in the diagnosis and localization of entrapment neuropathies. Ultrasound shows nerve swelling just proximal to the sites of compression and also depicts a change in echotexture: edematous nerves have indistinct outer margins and show a homogenous hypoechoic appearance due to the loss of the normal fascicular pattern. On longitudinal scans, an abrupt caliber change and a spindle-like swelling of the compressed nerve segment can be seen (Beekman and Visser, 2004; Peer and Bodner, 2008). Measured on transverse scans, the cross sectional area

* Corresponding author. Address: Department of Neurology, Semmelweis University, Balassa u. 6, Budapest 1083, Hungary. Tel.: +36 1 210 0337; fax: +36 1 210 1368.
E-mail address: aranyi.zsuzsanna@med.semmelweis-univ.hu (Z. Arányi).

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(CSA) and the distal-to-proximal swelling (nerve area) ratios are the most frequently used quantitative parameters for the ultrasound investigation of nerve compression (Chiou et al., 1998; Beekman and Visser, 2004; Beekman et al., 2004a; Peer and Bodner, 2008; Yoon et al., 2008; Zaidman et al., 2009; Gruber et al., 2010; Beekman et al., 2011).

The question naturally arises how these nerve size parameters measured by HRUS correlate with the underlying type of focal nerve pathology (i.e. demyelinating or axonal), as assessed by electrophysiological means. We have used ulnar neuropathy at the elbow (UNE) as a 'model' of focal nerve compression to carry out such an analysis. UNE is the second most common entrapment neuropathy, where ultrasound may be of particular diagnostic help if electrophysiological results are non-localizing (Beekman et al., 2004a; Wiesler et al., 2006; Yoon et al., 2007). There have been previous reports on the correlation of electrophysiological and ultrasonographic results in UNE (Beekman et al., 2004a,b; Mondelli et al., 2008; Volpe et al., 2009; Bayrak et al., 2010), and these studies point in the direction that the degree of nerve enlargement depends on the electrophysiological severity of nerve lesion. However, these studies focused on 'electrophysiological severity', where the delineation between demyelinating and axonal nerve lesions was not always clear, as for example both a high-degree conduction block and a severe axonal lesion may be considered in the same group of severe electrophysiological findings. In our study, we grouped patients according to nerve pathology, and nerve size parameters on HRUS were compared between patients with predominantly demyelinating and patients with axonal nerve involvement. Furthermore, subgroups of patients with pure sensory axonal and mixed sensorimotor axonal involvement were also analyzed.

2. Patients and methods

2.1. Patients

Between November 2010 and August 2011, 50 elbows of 46 patients were diagnosed with UNE and included in the analysis. All patients were investigated with electrophysiological means and high resolution nerve ultrasound, as part of their routine clinical assessment. Inclusion criteria were the following: (1) Typical clinical signs and symptoms indicating ulnar nerve lesion (i.e. paresthesia and/or sensory loss on the fourth and fifth digits of the hand, weakness and atrophy of ulnar innervated hand muscles, Tinel sign at the elbow). All patients had complaints lasting for less than 6 months, but for more than 4 weeks. (2) Absence of the following: previously operated UNE, UNE due to trauma, complaints or signs suggesting the presence of polyneuropathy or conditions potentially associated with polyneuropathy, and complaints or signs suggesting lower trunk plexopathy or C8-Th1 radiculopathy (e.g. weakness of extensor indicis muscle). (3) Electrophysiological findings localizing ulnar nerve lesion to the elbow (i.e. focal slowing with or without conduction block) or non-localizing electrophysiological findings of ulnar nerve lesion (i.e. pure axonal damage) and focal nerve enlargement at the elbow on HRUS.

Based on the electrophysiological findings, patients were classified into groups of predominantly demyelinating nerve lesion and axonal nerve lesion, and the latter into subgroups of pure sensory and sensorimotor axonal nerve lesion (see below). Eighty-seven ulnar nerves of 50 control subjects were also investigated by ultrasound. None of the control subjects had symptoms or signs suggesting UNE, or any systemic diseases potentially associated with polyneuropathy, nor a history of neuromuscular disease.

2.2. Electrophysiological work-up

Electrophysiological investigation of UNE patients included motor and antidromic sensory nerve conduction studies of the ulnar nerve, inching across the elbow, and electromyography (EMG) of one or two ulnar-innervated hand muscles, such as the abductor digiti minimi (ADM) and the first dorsal interosseus (FDI) muscle. The studies were performed using a Nicolet Viking EMG device. The recording site for the motor nerve conduction study and for inching across the elbow was the ADM muscle using surface electrodes in the conventional muscle belly-tendon arrangement. Stimulation sites included the wrist, 4 cm below the elbow, 4 cm above the elbow, upper arm, and Erb point. For the inching technique, the nerve was stimulated at 5 cm and 2.5 cm below the line connecting the epicondyles, at the line connecting the epicondyles, and 2.5 cm and 5 cm above this line. The antidromic sensory nerve conduction study of the ulnar nerve was carried out using ring electrodes placed on the fifth finger. Stimulation sites were the wrist, and 4 cm below and above the elbow. All nerve conduction studies were performed with the elbow flexed in a 90° angle. Patients were classified as having predominantly focal demyelinating type UNE (demyelinating group) when significant slowing of motor conduction velocity ($\geqslant$10 m/s in comparison to the forearm; Kothari and Preston, 1995) was seen across the elbow or at any site in the inching study across the elbow, with or without motor conduction block (amplitude reduction $\geqslant$20% of the compound muscle action potential [CMAP] across the elbow), and the amplitude of the sensory nerve action potential (SNAP) and the CMAP was within normal limits with distal (wrist) stimulation. Patients were classified into the axonal group if the SNAP amplitude was low (<10 μV, indicating sensory axonal lesion) or both SNAP and CMAP amplitudes were low (<10 μV and <4 mV, respectively, indicating sensorimotor axonal lesion) when stimulated at the wrist. Electromyographic results were not used for the demyelinative-axonal classification, as the degree of axonal lesion is best shown by the distal CAMP/SNAP amplitude. All patients were classified as 'axonal' who had SNAP/CMAP amplitudes below cut-off values, irrespective of whether they had additional focal demyelinative signs at the elbow or not. The axonal group of patients was further divided into subgroups of pure sensory axonal and mixed sensorimotor axonal involvement.

2.3. Ultrasound examination

For ultrasound examinations, a Philips HD11XE ultrasound device with a small part imaging software and a 15 MHz 3 cm linear array transducer were used. Ultrasound examination was performed within 10 days after the electrophysiological assessment. The physician performing the electrophysiological examination and the ultrasonography was in many instances the same, which prevented blinding of the ultrasonographer. The patient was seated and with the arm placed on the examining table. The elbow was in a slightly flexed (10–20°) position. The ulnar nerve was first scanned in the transverse plane from the wrist to the axilla to exclude pathology at other sites than the elbow. The CSA of the ulnar nerve was then determined with manual tracing on transverse scans at three levels around the elbow (at the level of the medial epicondyle and 2 cm distal and proximal to this point), and on the mid-upper arm. Measurements were taken within the hyperechoic rim surrounding the nerve with the resolution of one tenth of a square millimeter. The probe was held at an angle where the nerve appeared the brightest with the best discernible outer margins. Color Doppler was used when differentiation between nerve fascicles and blood vessels proved difficult. Three measurements were averaged at each nerve site. The largest CSA out of the three values around the elbow (CSA_{max}) was used for statistical analysis. The ratio of CSA_{max} of the ulnar nerve around the elbow and the CSA on the mid-upper arm (CHR = CSA-