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A comparison of ultrasonographic and electrophysiologic 'inching' in ulnar neuropathy at the elbow

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HIGHLIGHTS

- Ultrasound changes in ulnar neuropathy at the elbow may not be maximal at the site of electrophysiological nerve dysfunction.
- Ultrasound changes in healthy ulnar nerve and ulnar neuropathy share a similar anatomical distribution.
- Findings from this study suggest that ulnar neuropathy may represent decompensation of chronic subclinical nerve injury.

ABSTRACT

Objective: The present study aimed to clarify the relationship between structural ulnar nerve changes and electrophysiological nerve dysfunction in patients with ulnar neuropathy at the elbow (UNE).
Methods: High-resolution ultrasonography of the ulnar nerve was performed on 17 limbs with clinically and electrophysiologically confirmed UNE, and 52 control subjects at four standardised sites proximal and distal to the medial epicondyle (P2, P1, D1, D2), corresponding to segments of ulnar short-segment nerve conduction studies ("inching studies").
Results: Ulnar nerve cross-sectional area (CSA) and hypoechoic fraction were significantly increased in patients with UNE immediately distal (D1) and proximal (P1) to the medial epicondyle ($p < 0.01$). In patients with UNE, hypoechoic fraction was similar in asymptomatic and symptomatic limbs. Motor nerve conduction velocity across the elbow correlated with CSA_{max} and the maximum hypoechoic fraction ($R = 0.6$, $p < 0.05$). CSA and hypoechoic fraction of individual segments did not correlate with corresponding latencies on inching studies, but latencies across the D1 segment correlated with CSA at P1 ($R = 0.80$, $p < 0.0001$) and D2 ($R = 0.65$, $p < 0.01$).
Conclusions: Sonographic abnormalities in UNE may not be maximal at the site of electrophysiological nerve dysfunction.
Significance: Sonographic abnormalities may reflect secondary pathophysiological changes in segments adjacent to regions of nerve compression.

1. Introduction

High-resolution ultrasound studies have become increasingly important as an adjunct investigation in the electrodiagnostic clinic. Ulnar neuropathy at the elbow (UNE) may be difficult to localise on electrodiagnostic studies alone, and hence novel diagnostic methods such as MRI (Britz et al., 1996; Keen et al., 2012; Vucic et al., 2006) and ultrasound imaging (Beekman et al., 2004a; Boom and Visser, 2012; Park et al., 2004; Volpe et al., 2009; Yoon et al., 2008, 2010) have been employed to increase diagnostic sensitivity. In patients with UNE, changes in ulnar nerve cross-sectional area (CSA) and echogenicity appear to

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correlate with the severity of the lesion (Bayrak et al., 2010; Boom and Visser, 2012; Scheidl et al., 2013; Volpe et al., 2009). However, the precise pathophysiological implications of nerve enlargement and reduced echogenicity have not been fully elucidated.

The present study was undertaken to identify the distribution of changes in CSA and echogenicity of the ulnar nerve in normal elbows and those with UNE, in order to clarify the relationship of structural changes in the ulnar nerve to electrophysiological nerve dysfunction in patients with clinically and electrodiagnostically confirmed UNE.

2. Methods

We prospectively studied the ultrasound characteristics of the ulnar nerve in patients with UNE and healthy control subjects, at standardised locations across the elbow corresponding to segments on short-segment nerve conduction studies (“inching studies”). Quantitative ultrasound measurements were compared with electrodiagnostic parameters in patients with UNE. All subjects provided written informed consent. The study was approved by the University of California, San Francisco, Committee on Human Research.

2.1. Ultrasound examinations

Ultrasound studies of the ulnar nerve were performed prior to electrodiagnostic studies by a neurologist (NGS), who was blinded to the clinical history and neurological examination. A Mindray M7 ultrasonic imaging system was used with a linear array transducer (L14-6s, Mindray, Shenzen, China; nominal frequency range 6–14 MHz). The ultrasound device was set to ‘General Nerve’ factory preset (acoustic power 98%, line density set at medium, dynamic range set at 1, persistence set at 1, iClear set at 4) for each patient and maintained for all images. Focus settings were adjusted at each imaging location in individual patients to obtain optimum images, such that a single focal point was positioned at the level of the ulnar nerve.

Patients were studied while lying supine, with the elbow flexed to 90°, with the shoulder abducted and externally rotated approximately 30°. Marks were made on the skin overlying the ulnar nerve at the level of the medial epicondyle, and 2.5 cm and 5 cm proximal and distal to the medial epicondyle to produce four 2.5 cm segments spanning the elbow (proximal to distal – P2, P1, D1, and D2; Fig. 1). In patients with UNE, both upper limbs were studied. In control subjects, a single limb was studied, with the side chosen at random.

Ultrasound images were acquired with the transducer placed over the mid-point of each segment, and an additional image was acquired of the ulnar nerve at the mid-point of the arm. The transducer was held perpendicular to the skin with minor angle adjustments performed to ensure that the transducer was perpendicular to the nerve. Minimal pressure was applied to the transducer to avoid extrinsic nerve compression. Images were saved in TIFF format with a file name consisting of a randomly generated 5 number string, such that individual images were not labeled with site, subject, or group information.

The CSA was measured just within the hyperechoic rim of the nerve using the ‘trace area’ function of the ultrasound system. The ulnar nerve swelling ratio (UNSR; (Pompe and Beekman, 2013) was calculated using the CSA measured from the mid-point of the arm and the maximum CSA value recorded around the elbow (CSA_{max}).

2.2. Offline image analysis

Nerve ultrasound may show loss of the normal fascicular pattern of nerve and reduced echogenicity in nerve pathology

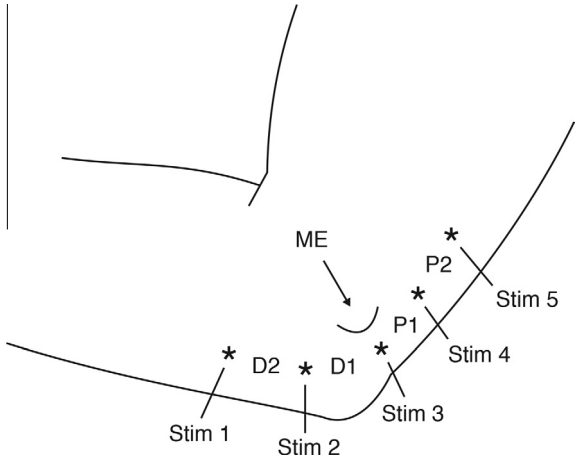

Fig. 1. Sites of ulnar nerve stimulation and locations of ultrasound images relative to the medial epicondyle (ME). Short-segment nerve conduction studies of the ulnar nerve were performed by stimulating five sites across the elbow: 5 cm distal to the ME (Stim 1); 2.5 cm distal to the ME (Stim 2), at the ME (Stim 3); 2.5 cm proximal to the ME (Stim 4); and 5 cm proximal to the ME (Stim 5), resulting in 4 nerve segments D2, D1, P1 and P2. D2 corresponded to the segment of the ulnar nerve deep to the flexor carpi ulnaris muscle. D1 corresponded to the segment of the ulnar nerve between the entrance of the cubital tunnel and the medial epicondyle. P1 corresponded to the segment of the ulnar nerve immediately proximal to the ME, and P2 was 2.5 cm proximal to that. Ultrasound images were acquired at the midpoint of each nerve segment. A fifth ultrasound image was acquired of the ulnar nerve at the mid-point of the arm (not shown).

(Suk et al., 2013), possibly reflecting nerve oedema. However, qualitative approaches for measurement of echogenicity (Jain et al., 2009) may introduce bias and may not be ideal in research studies. Quantitative approaches have been developed (Tagliafico et al., 2010; Watanabe et al., 2010) and expert panels have recommended further research on the use of nerve echogenicity in the diagnosis of nerve disease (Cartwright et al., 2012; Hobson-Webb et al., 2012).

Measurement of hypoechoic fraction has been suggested as an objective measurement of echogenicity of the nerve and can distinguish between normal and abnormal ulnar nerves at the elbow (Boom and Visser, 2012). Hypoechoic fraction is calculated by thresholding an image resulting in regions above the threshold that are white and regions below threshold that are black (Figs. 2 and 3). The proportion of the nerve that is below threshold can thus be calculated. Image thresholding can be performed automatically using the open-access software ImageJ (National Institutes of Health, Bethesda, Maryland, USA).

To perform this analysis, a region of interest was selected in each image by tracing just within the hyperechoic rim of the nerve. Images were converted to 8-bit and the ‘MaxEntropy’ automatic thresholding method was applied (Kapur et al., 1985). The MaxEntropy method was selected as it was one of three most reliable thresholding methods described (along with RenyiEntropy and Yen methods) but was the most specific for abnormal nerve (Boom and Visser, 2012). Hypoechoic fraction was calculated using the ‘Measure Area Fraction’ function with ‘Limit to Threshold’ selected.

2.3. Clinical examination

A neurological history and examination was recorded in each subject. Clinical criteria for the diagnosis of ulnar neuropathy included two or more of the following: symptoms of numbness of the medial hand or digits 4 and 5; subjective weakness or clumsiness of ulnar innervated muscles; objective evidence of sensory loss in the ulnar nerve distribution as assessed using pin-prick,