Original Research

Sonographic Measurements of the Ulnar Nerve at the Elbow With Different Degrees of Elbow Flexion

Prutha Patel, MD, John W. Norbury, MD, Xiangming Fang, PhD

Objective: To determine whether there were differences in the cross-sectional area (CSA) and the flattening ratio of the normative ulnar nerve as it passes between the medial epicondyle and the olecranon at 30° of elbow flexion versus 90° of elbow flexion.
Design: Bilateral upper extremities of normal healthy adult volunteers were evaluated with ultrasound. The CSA and the flattening ratio of the ulnar nerve at the elbow as it passes between the medial epicondyle and the olecranon were measured, with the elbow flexed at 30° and at 90°, by 2 operators with varying ultrasound scanning experience by using ellipse and direct tracing methods. The results from the 2 different angles of elbow flexion were compared for each individual operator. Finally, intraclass correlations for absolute agreement and consistency between the 2 raters were calculated.
Setting: An outpatient clinic room at a regional rehabilitation center.
Participants: Twenty-five normal healthy adult volunteers.
Main Outcome Measurement: The mean CSA and the mean flattening ratio of the ulnar nerve at 30° of elbow flexion and at 90° of elbow flexion.
Results: First, for the ellipse method, the mean CSA of the ulnar nerve at 90° (9.93 mm^2) was slightly larger than at 30° (9.77 mm^2) for rater 1. However, for rater 2, the mean CSA of the ulnar nerve at 90° (6.80 mm^2) was slightly smaller than at 30° (7.08 mm^2). This was found to be statistically insignificant when using a matched pairs *t* test and the Wilcoxon signed-rank test, with a significance level of .05. Similarly, the difference between the right side and the left side was not statistically significant. The intraclass correlations for absolute agreement between the 2 raters were not very high due to different measurement locations, but the intraclass correlations for consistency were high. Second, for the direct tracing method, the mean CSA at 90° (7.26 mm^2) was slightly lower than at 30° (7.48 mm^2). This was found to be statistically nonsignificant when using the matched pairs *t* test and the Wilcoxon signed-rank test with a significance level of .05. There was no significant difference in the average flattening ratio between the 2 angles for the left arm (0.54 at 30° vs 0.56 at 90°; $P = .619$ for the matched pairs *t* test and .274 for the Wilcoxon signed-rank test). However, for the right arm, the flattening ratio at 90° was significantly higher than that at 30° (0.58 at 90° vs 0.50 at 30°; $P = .007$ for both the matched pairs *t* test and the Wilcoxon signed-rank test).
Conclusions: The mean CSA of the ulnar nerve at the elbow at 30° was not significantly different than at 90°. However, the average flattening ratio at 90° was found to be significantly higher than at 30° for the right arm.

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INTRODUCTION

Ulnar nerve neuropathy at the elbow (UNE) is the second most frequent entrapment of the ulnar nerve in the upper limb [1]. Trauma from repeated elbow flexion that increases pressure on the ulnar nerve is thought to cause damage to the nerve [2,3]. It usually is diagnosed with nerve conduction studies and electromyography. These studies are painful, invasive (the use of a needle during electromyography), and uncomfortable. Also, the sensitivity of electrodiagnosis for UNE ranges only from 37% to 80% [4], which is much lower than for carpal tunnel syndrome. This is likely due to technical problems, including improper elbow positioning, which gives inaccurate nerve length measurements [5,6].

P.P. Department of Physical Medicine and Rehabilitation, Brody School of Medicine, 925-10 Spring Forest Road, Greenville, NC 27834. Address correspondence to: P.P.; e-mail: patelprutha13@gmail.com
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J.W.N. Department of Physical Medicine and Rehabilitation, Brody School of Medicine, Greenville, NC
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X.F. Department of Biostatistics, East Carolina University, Greenville, NC
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Given the low sensitivity of electrodiagnostics for UNE, we need other methods that would improve the reliability of its diagnosis.

Ultrasound (US) is a diagnostic modality that is noninvasive, painless, and affordable. The use of US in the diagnosis of UNE will become an excellent tool for a rapid and painless diagnosis [7]. Analysis of research results showed that there is a positive correlation between an increase in the cross-sectional diameter of the ulnar nerve and entrapment neuropathy. Recently, studies that used US also established normal values for the cross-sectional area (CSA) of several peripheral nerves, including the ulnar nerve [8]. However, the measurements were not done at different degrees of elbow flexion, nor did they take into account the morphologic changes that occur in the ulnar nerve.

For performing conduction studies, it has been well established that the position of the elbow strongly influences the calculated conduction velocity. Ulnar nerve conduction studies performed in the extended elbow position often show artifactual slowing of conduction velocity due to underestimation of the true nerve length. This is because, in the extended elbow position, the ulnar nerve is slack, with some redundancy. It is important to determine whether the CSA of the ulnar nerve varies with the position of the elbow as well just as its length [9]. In addition, calculating the flattening ratio by using short-axis and long-axis radii gives information regarding morphologic changes. If variations are found in the CSA and the flattening ratio due to elbow positioning, then establishing normal values for the CSA at different elbow positions will be helpful in determining normal versus abnormal conditions at a given degree of elbow flexion.

Previous studies that used indirect measures of the CSA by means of the ellipsoid formula showed lower diagnostic accuracy (Fig 1) [10]. Because the shape of the ulnar nerve around the elbow is not round but rectangular, most literature indicates that measurement of the CSA is best assessed by direct tracing (Fig 2) [11]. Similarly, although a few studies have included the hyperechoic epineurium in the CSA measurements, there is consensus in the literature that more precise measurement of the CSA is obtained along the inner hypoechoic border [12,13]. The goal of this study was to determine whether there were differences in the CSA and the flattening ratio of the normative ulnar nerve at 30° of elbow flexion versus 90° of elbow flexion when using US as a diagnostic tool. The CSA was obtained by 2 operators (P.P., J.W.N.) by using the ellipse method and the direct tracing method.

METHODS

The study protocol was approved by the institutional review board, and all participants gave written informed consent. We enrolled 25 healthy adult participants who were >18 years old and who volunteered to participate in the study (18 women and 7 men). Participants were considered only if they exhibited no symptoms of neuropathy. Exclusion criteria included signs or symptoms in the upper extremities that resemble peripheral nervous system dysfunction (paresthesias, numbness, weakness), any history of risk factors for polyneuropathy (including but not limited to diabetes mellitus), previous elbow surgery, medial elbow pain, and acute trauma to the elbow. For each participant, we obtained a transverse scan of the ulnar nerve at the elbow as it passes between the medical epicondyle and the olecranon to calculate CSA measurements by using the ellipse method and the direct tracing method. We performed US evaluation of the ulnar nerve CSA at 30° of elbow flexion and at 90° of elbow flexion of both upper extremities for all the participants. Measurements were done while the subjects were in

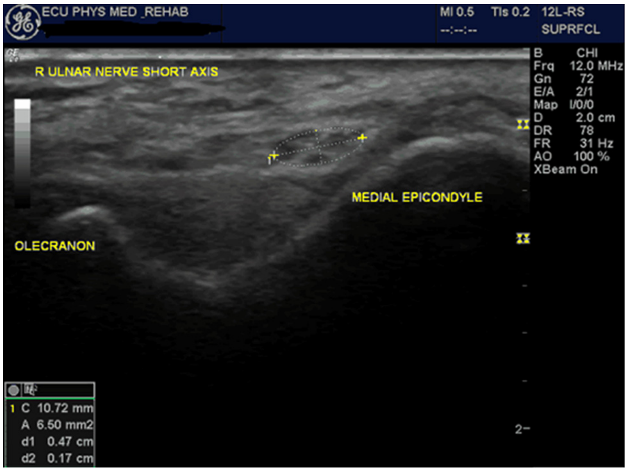

Figure 1. Transverse scan of the ulnar nerve at the retroepicondylar groove. CSA measured with ellipse method.

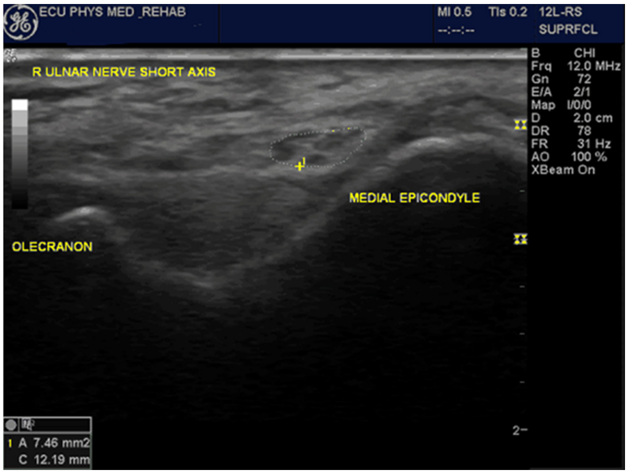

Figure 2. Transverse scan of the ulnar nerve at the retroepicondylar groove. CSA measured using direct tracing excluding the epineurium.