ORIGINAL ARTICLE

# Usefulness of combination of grey-scale and color Doppler ultrasound findings in the diagnosis of ulnar nerve entrapment syndrome

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**Background:** Ulnar nerve entrapment (UNE) has been diagnosed with clinical examination and electrodiagnostic studies. This study was designed to determine the value of a combination of grey-scale and color Doppler ultrasound findings in the diagnosis of patients with UNE. **Materials and Methods:** During May to August 2013 41 patients with UNE (proven by electrodiagnostic studies) and 44 healthy volunteers were evaluated by ultrasound study. Three cross-sectional area (CSA) of ulnar nerve around cubital fossa was determined and measured in both groups. The maximum and minimum diameter of ulnar nerve was measured for calculating flattening ratio index (FRI). Vascularity of ulnar nerve around cubital fossa was also examined in proper color Doppler setting. **Results:** The mean CSA of nerve at all proximal, middle and distal levels were greater in patients with UNE than in controls ($P = 0.02$, <0.001 and 0.34 respectively). A cut-off point of 10.5 $mm^2$ for CSA (in the level of the cubital fossa) yielded a sensitivity and specificity of 92.7% and 93.2%, respectively. Mean FRI was 3.1 ± 0.6 in patients with UNE group and 1.4 ± 0.2 in the control group with a significant difference ($P < 0.001$). FRI with cutoff point 2.15 has been shown as an important parameter for the detection of UNE. The vascularity in UNE has a sensitivity and specificity of 66% and 93.2%, respectively, and has a higher probability of being positive in severe UNE. **Conclusion:** Combination of grey-scale and color Doppler ultrasound may provide valuable diagnostic criteria and severity assessment of UNE.

**Key words:** Color Doppler, cubital tunnel syndrome, neuropathy, ultrasound

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## INTRODUCTION

Ulnar neuropathy at cubital tunnel is the most common form of ulnar nerve entrapment (UNE) and the second common entrapment neuropathy of the upper extremity after carpal tunnel syndrome.[1-3] The elbow is the most common site of ulnar nerve compression where the nerve passes through the cubital tunnel. The incidence of cubital tunnel syndrome is about 7/100,000 individuals.[4] The diagnosis of this syndrome is based on assessing signs and symptoms, orthopedic testing, and also electrodiagnostic studies.[1,2,4] Electrodiagnostic studies have traditionally main role in diagnosis and management of cubital tunnel syndrome, because of their ability to determine disease grading and the level of compression. However, these studies cannot evaluate the architecture of nerve and peripheral soft tissue. Moreover, they are accompanied with substantial rate of false negative and false positive results.[5-8]

Since the 1990, improved ultrasound imaging has provided an alternative, non-invasive diagnostic tool for musculoskeletal abnormalities in a variety of clinical setting. Nowadays, ultrasound is able to identify successfully almost all main nerve trunks running in the limbs.[9-11]

Some studies have been performed to evaluate the ultrasound findings of ulnar neuropathy.[11-14] These studies have shown that enlargement of ulnar nerve is a relevant component of UNE and thus can be helpful as an adjunct evident to electrodiagnostic studies in detecting patients with cubital tunnel syndrome. This study was designed to determine the value of grey-scale and color Doppler combination in diagnosis of UNE.

## MATERIALS AND METHODS

### Study population

This study was a case-control study performed during May to August 2013 in Isfahan, Iran. Forty-one patients with definite UNE referred to Radiology Department from Orthopedic Clinic of Alzahra Hosptial (a Tertiary Referral Center in Isfahan, Iran) were enrolled in the

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study, consecutively. A written informed consent was obtained from each patient. Inclusion criteria were clinical manifestation of cubital tunnel syndrome confirmed by standard electrophysiologic criteria. Clinical manifestation included weakness of the ulnar nerve-innervated muscle and sensory changes in fourth and fifth fingers.[3] Patients with a history of polyneuropathy, chronic illness such as diabetes mellitus and chronic kidney disease, surgery and trauma in the region of the elbow, and brachial plexus injury were excluded.

Furthermore, 44 healthy volunteers with no symptom of cubital tunnel syndrome were studied as a control group. Patients in control and case groups were matched in baseline characteristics including age, sex and body mass index.

### Ultrasonography assessment

All patients underwent high-resolution ultrasound study of ulnar nerve at the elbow by 5-7 MHz matrix linear array transducer (Mindray unite, DC7). To reduce the bias of examination, the examiner was requested not to ask patient symptom, and the patients were request not to speak during examination. The ultrasound study was performed on both groups in the supine position with the arm abducted by the same operator. A systemic scan to follow the nerve in transverse planes was performed and three cross-sectional area (CSA) were determined including level of medial epicondyle, 2 cm proximal to medial epicondyle (CSA-prox), 2 cm distal to epicondyle (CSA-dis), and the maximum CSA (CSA-max) of ulnar nerve between these points. At each level, three measurements were taken, and the mean was recorded for the statistical analysis. The examiner carefully placed the probe perpendicular to the nerve to obtain the most accurate CSA. The CSA of the ulnar nerve was measured by automatic manual tracing inside the hyperechogenic line, which surrounds the nerve. The maximum and minimum diameters of ulnar nerve were measured for calculating flattening ratio index (FRI) defined as maximum diameter of the nerve to its minimum diameter. The vascularity of nerve was examined in the longitudinal plane while the pulse repetition frequency (PRF) was set as low as possible to obtain good signal without artifact. The presence of the color signal was recorded as positive, and absence of the color signal recorded as negative.

### Statistical analysis

Statistical analysis was performed using SPSS version 20.0 (SPSS Inc., Chicago, Illinois, USA). The Chi-square and Fisher's exact test were used for testing the association between categorical variables. The Student's *t*-test and Mann-Whitney U-test was used to test the differences between quantitative variables. Receiver operating characteristic (ROC) curve analysis was used for determination of the cut-off point of CSA and FRI. $P < 0.05$ was considered as the significant.

## RESULTS

A total of 41 patients with UNE were entered in this study (26 men, 15 women; mean age 38.8 years ranged 29-48 years). Duration of disease in the study patients range from 6 months to 11 years, with the mean of 2.45 ± 1.39 years. Based on electrodiagnostic findings, degree of disease severity was mild in 19 patients (46%), moderate in 9 persons (22%) and severe in 13 (31%). Control group included 44 healthy volunteers (27 men, 17 women; mean age 39.5 years ranged 27-49 years).

The mean ulnar nerve CSA in group of patients with UNE and control group is shown in Table 1. The mean CSA of nerve at all proximal, middle and distal levels were greater in UNE patients than in controls ($P = 0.02$, <0.001 and 0.34, respectively) indicating a significant difference at proximal and epicondylar sites.

Using the ROC curve, a cut-off point of 10.5 $mm^2$ or higher for CSA in the level of the cubital fossa has area under the curve of 0.983 (confidence interval 0.962-1.00). This cutoff point yields a sensitivity of 92.7% and a specificity of 93.2%. The positive and negative predictive values were 92.7% and 93.2%, respectively. Of 41 elbows with UNE, 38 were identified using the 10.5 $mm^2$ criterion, but 3 cases of UNE was missed. Furthermore, 41 control nerves were correctly classified, whereas 3 were incorrectly classified as having UNE by this criterion.

Mean FRI was 3.1 ± 0.6 in case group and 1.4 ± 0.2 in the control group with a significant difference ($P < 0.001$). Using the assessment of the area under the ROC curve, FRI with cutoff point 2.15 has been shown as an important parameter for detection of UNE with a sensitivity of 100% and a specificity of 100%.

The vascularity was detected in 27 patients with a sensitivity of 66% and a specificity of 93.2%. Meanwhile, 36.8% of patients with mild disease, 88.9% with moderate disease and 92.3% with severe disease had vascularity in their ulnar nerves.

In the control group vascularity was evident in 3 persons (6.8%), so statistical difference was significant ($P < 001$).

*T*-test exam showed CSA and FRI of ulnar nerve in vascularity positive individuals (in both control and

**Table 1: Mean CSA in three levels of ulnar nerve**

| Mean ulnar nerve CSA | Patients | Control |
|---|---|---|
| Cubital tunnel | 17/1±5/6 $mm^2$ | 7/2±1/7 $mm^2$ |
| Superior condyle | 9/3±2/1 $mm^2$ | 8±1/4 $mm^2$ |
| Inferior condyle | 9/2±2/7 $mm^2$ | 7/8±1/4 $mm^2$ |

CSA = Cross sectional area

case groups) were significantly greater in comparison to vascularity negative subjects.

Furthermore Mann-Whitney test shows a significant difference between the vascularity by electrodiagnostic findings ($P < 001$).

## DISCUSSION

High-resolution ultrasonography is a non-invasive technique in the evaluation of entrapment neuropathies.[1,15] UNE is the second most common entrapment neuropathy after carpal tunnel syndrome.[2,3] Previously, several ultrasound studies have investigated the median nerve at the wrist,[6,7,12,14] but a limited number of studies have investigated ulnar nerve.[1,2,4,9] In this study, a significant difference was revealed in the CSA of ulnar nerve between the affected and control groups. A cut-off point of 10.5 $mm^2$ or higher for CSA yielded a sensitivity of 92.7% and a specificity of 93.2%. This cutoff point has area under the ROC curve of 0.983 which is responsible for the significant sensitivity and specificity and providing high diagnostic value.

Previous studies showed that the measurement of CSA of nerve was preferred instead of maximal nerve diameter.[2,4] Our prior experience with ultrasonography in the diagnosis of carpal tunnel syndrome has shown that the critical cutoff value of the measurement vary considerably within the literature.[11] 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.[6,15] Based on our experience, the CSA is a more reliable measurement than the diameter because nerves have variable shapes from round to oval or even triangular in their courses, and thus the enlargement of nerve can be measured at many points and different measurement can be mathematically valid. Furthermore, with modern ultrasonography, the epineural limits of the nerve are much easier to define on a cross-section and the area calculation is simple using the continuous trace mode on this instrument.[1] We believe that in order to improve ultrasound evaluation of UNE, other aspects such as FRI and vascularity should be evaluated along with CSA-max. In this study, we paid particular attention to CSA-max, which almost always found at the level of epicondyle and seemingly represented the most useful point to establish the severity of UNE.

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 electrodiagnostic findings and ultrasonography. With respect to ultrasonography, researchers have suggested 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.[13]

Our study showed that the diagnostic cut-off for UNE of 10.5 $mm^2$ has a sensitivity of 92.3% and specificity of 93.2%. Wiesler *et al*.[1] also introduced cut-off 10 $mm^2$, but with different sensitivity and specificity (sensitivity 93% and specificity 98%). Although the introduced cutoff point was nearly similar to our study, but they found significance only in epicondylar site while, in our study, the difference was in epicondyle and supracondylar sites. This disparity may be due to the difference in selection of site for the ulnar nerve ultrasonography. We examined the nerve at 2 cm below the condyle, but most investigations were performed at 4 cm and 5 cm below the condyle.[1,2] More proximity to the epicondyle in our study may be the reason for this difference.

This study also introduced FRI to identify the patients affected by ulnar UNE. We found a sensitivity of 100% and a specificity of 100% for involved nerves with index greater than 2.15. These significant percentages for the cutoff point are because the ranges of FRI in patients and control group were 2.20-4.35 and 1-2.10, respectively. Hence, there was no overlap between FRI in two groups.

Our logic for measurement of this index was variable shape and size of nerves in their entire course. Furthermore, the affected nerve became elliptical in the site of involvement. Hence, the measurement of maximum to a minimum diameter of the nerve could be helpful. Clinically, the nerve in UNE is observed as compressed and therefore it would be reasonable to expect narrowing on ultrasonography instead of enlargement. In this series and in other reports, however, it was found that where the nerve looked compressed clinically, it was actually still homogenously swollen on ultrasonography. We speculate that one of the possible reasons why ultrasonography cannot identify a specific compression point on the nerve in the great majority of the patients is because the nerve moves (slides back and forth) under the compression, so there is no discrete area of thinning, but a zone of compression. There is currently no convincing explanation that accounts for the aforementioned finding. Further studies are needed to understand why swelling tends to occur over a specific area of the nerve, often without a clear area of maximal compression.[1,15]

Instead electrodiagnostic criteria for classification of patients to mild, moderate and severe category, we introduced "vascularity" as a severity indicator. Previous studies showed that vascularity can be a good diagnostic criteria in patients with carpal tunnel syndrome.[6,16]

Our study showed a significant difference in vascularity of nerve in case and control groups. Moreover, the vascularity was related to the severity of UNE and was more prominent in severe and moderate cases (89% in moderate and 92.3% in severe cases in comparison to 36.8% of mild cases). In Mallouhi *et al*. research the vascularity was detected in 95% of patients with carpal tunnel syndrome whereas in this study vascularity was presented in 66% patients with UNE that could be due to difference in sensitivity of units.[6]

This study shows that ultrasonography can provide several advantages as an adjunct to NCV. First, it is quick, painless, noninvasive technique for screening purposes. Second, ultrasonography can determine a possible anatomic etiology of UNE such as an occult ganglion or nerve dislocation. Third, ultrasonography may have a prognostic value in treated patients.

There are some study limitations that have to be considered. A clear limitation is the small sample for both patients and controls. Next, the examiner performing ultrasonography knew UNE symptoms (such as muscle atrophy) which carries bias risk. Another limitation was difference in sensitivity of units and the lack of standardization gray scale and Doppler ultrasonography techniques for imaging patients. It should be also mentioned that high sensitivity and specificity of FRI in this study may because of the small sample for both patients and controls or due to the presence of patients with severe UNE in this study. Further studies are needed to support our findings and correlate them with acuity of illness.

Ultrasound is a cost-effective, noninvasive and reliable modality for imaging of peripheral nerves and could be a good adjunct to NCV for grading of UNE. Combination of grey-scale and color Doppler ultrasound may provide valuable diagnostic criteria and severity assessment of UNE.

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## AUTHORS' CONTRIBUTION

MK and AZ designed the study and aided in diagnosis of patients.MEG and AHS participated in collecting the data and writing the article.

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