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Ultrasonography evaluation of the normal ulnar nerve in adult: Comparison of the cross-sectional area at elbow extension and flexion

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ABSTRACT

Background: Cross-sectional area (CSA) measurement of the ulnar nerve in the adult population by using ultrasonography (US) at elbow extension and flexion has previously been reported, but not much evidence showed a significant difference between elbow extension and flexion position.
Purpose: To compare the ulnar nerve CSA between elbow extension and flexion position.
Methods: A comparative cross-sectional study was conducted by involving 36 healthy adults with normally functioning ulnar nerve proven by Nerve Conduction Study (NCS) or Electroneurography. The ulnar nerve CSA was measured on each elbow by using US at the level of the medial epicondyle, 2 cm distal and 2 cm proximal from the medial epicondyle.
Results: The average ulnar nerve CSA at the medial epicondyle, 2 cm distal and proximal to the medial epicondyle at elbow extension respectively were 5.95 ± 0.74 mm2, 6.27 ± 0.92 mm2, and 5.92 ± 0.73 mm2. At elbow flexion, the average ulnar nerve CSA at the positions was 5.70 ± 0.83 mm2, 5.23 ± 0.87 mm2, dan 5.73 ± 0.71 mm2 respectively. The CSA of the ulnar nerve at elbow extension was significantly larger compared to the flexion position in the three areas observed in this study ($p < 0.001$).
Conclusion: The CSA of the ulnar nerve at elbow extension position was larger compared to the flexion position. Elbow position should be considered in measuring CSA of the ulnar nerve.

1. Background

Ulnar nerve, as one of the unprotected nerves in the body, is located in the subcutaneous layer with minimal protection from muscle and skeletal structure adjacent to medial epicondyle of the humerus [1]. Therefore, ulnar nerve becomes prone to direct injury [2,3]. Electrodiagnosis (EDx) using a combined needle EMG and Nerve Conduction Study (NCS) or electroneurography is a medical diagnostic test commonly used to detect the abnormalities in ulnar nerve, especially nerve compression or entrapments [2,4,5]. One of the limitations of this diagnostic test is the inability to localize the level of nerve entrapment in around a quarter of cases [2,6,7]. This condition is further classified as non-localizing ulnar neuropathy (NL-UN) [8].

High-resolution ultrasonography (US) becomes the modality of choice in assessing ulnar nerve due to its capability in showing nerve morphology. In determining ulnar nerve abnormalities, cross-sectional area (CSA) measurement is one of the most useful indicators which could be obtained by US [9–11]. While most of the studies suggest CSA measurement performed with elbow in flexed position, some others suggest with elbow in extended position. Thoirs K et al. (2008) in their study showed that elbow position could significantly affect the ulnar nerve CSA measurement and suggested that elbow position as a confounding factor for the measurement [12]. Only a few studies had shown a difference in CSA value between those two positions, where extended elbow showed a larger CSA compared to flexed elbow [10–13]. Based on our experience in ulnar nerve US examination, there are some conditions

Abbreviations: US, Ultrasonography; NCS, Nerve Conduction Study; NL-UN, Non-localizing ulnar neuropathy; TR, Triceps brachii muscle; ME, Medial epicondyle; O, Olecranon; FCU, Flexor carpi ulnaris; CSA, cross-sectional area.

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where patients have a very limited range of motion of their elbow or shoulder. It is interesting to find out how significant the difference of CSA value between those two positions. If so, further study might be needed to find the normal CSA value of ulnar nerve in extended elbow, different from the one in flexed elbow.

2. Methods

A comparative cross-sectional study was conducted on 36 healthy subjects who were selected by consecutive sampling. The study was approved by the Ethical Committee for Research and Health Science of the Faculty of Medicine University of Indonesia. US examination was performed in Cipto Mangunkusumo National Central General Hospital, Jakarta from September to November 2019. The inclusion criteria were healthy individuals between 18–40 years old with normal NCS examination results (>50 m/second). Exclusion criteria were cubital tunnel syndrome, history of surgery, or other comorbidities related to the elbow region (trauma, neoplasm, inflammation, and polyneuropathy).

US examination was conducted using Philips US machine Affiniti 70 (Bothell, Washington - USA) with 15-MHz linear array transducer. The examination was performed by a musculoskeletal radiologist with more than 10 years of experience in musculoskeletal sonography. Other information such as age, gender, body height, body weight, dominant or nondominant side of the elbow, and body mass index was recorded and analyzed.

2.1. Measurement of ulnar nerve cross-section area

Flexion of the elbow was examined by positioning the subject's forearm in pronation and internal rotation with the palm on the examination table (crab position), and the elbow was flexed 90° degree. Extension of the elbow was examined by positioning the subject's shoulder and elbow in the extension position with the back of the hand on the examination table (Fig. 1).

The ulnar nerve CSA of each elbow was recorded by using US at three levels: the level of the medial epicondyle (Fig. 2), 2 cm distal (Fig. 3) and proximal to the medial epicondyle (Fig. 4) at the transverse plane, and the measurement of the ulnar nerve CSA were done manually using freehand tracing method at inner of the hyperechoic layer.

2.2. Statistical analysis

The quantitative data were analyzed statistically using Statistical Package for Social Sciences (SPSS) version 20.0 software. The bivariate analysis using the paired T-test was conducted to compare the ulnar nerve CSA of each position and considered to have a significant difference if the p-value < 0.05.

3. Results

3.1. Characteristics of individuals

From a total of 36 subjects, 13 men were included in this study. The average age of the participant was 29.6 years and dominated with normal body mass index (the average of the BMI was 23.6 kg/m^2). A total of 25 participants were examined for both elbows and the rest was examined for only one elbow. From 61 elbows examined, 35 of which was the dominant arm and the rest was non-dominant (Table 1).

CSA of the ulnar nerve at the extension position was significantly larger compared to the flexion position in all three level ($p < 0.001$). CSA at the level of medial epicondyle has the largest difference between extension and flexion position (Table 2).

4. Discussion

In determining abnormalities in the ulnar nerve, CSA measurement is one of the most useful indicators which could be obtained by US, especially in the detection of ulnar nerve entrapment. A meta-analysis conducted by Chang et al. [14] showed the CSA of ulnar nerve as an indicator for ulnar nerve abnormality, but not specifically explained the influence of flexion and extension position of the elbow during the examination. Although it is quite rare, some patients may have limited range of motion in the elbow or shoulder that made them unable to do crab position.

CSA of the ulnar nerve at the extension position was significantly larger compared to the flexion position in all three levels observed in this study. Based on Table 2, the average ulnar nerve CSA at the level of the medial epicondyle has the largest difference between extension and flexion position, consistent with the previous studies by Roodt et al. [10], Ozturk et al. [11], and Kutlay et al. [13]. The difference between flexion and extension position is likely due to narrowing of the cubital tunnel in the flexion position, results in stretched and flattened ulnar nerve and smaller CSA [9,11,15,16].

Compression of the ulnar nerve could be taking place between the arcade of Struthers and aponeurosis of deep flexor-pronator, but usually found in the area around the cubital tunnel. Based on this phenomenon, the measurement of ulnar nerve CSA was set at the medial epicondyle, 2 cm proximal, and 2 cm distal to medial epicondyle. Previous studies showed that ulnar nerve diameter was found to be bigger at the distal or proximal portion which explained the compression of the ulnar nerve at the outlet of the cubital tunnel [10,14,17,18]. The measurement of the CSA was done by observing the inner side of the hyperechoic layer, known as epineurium since epineurium could be thickened at chronic subluxation or dislocation in soft tissue abnormalities, therefore, overestimation of the CSA could happen. [19,20] Besides, the nerve has inconsistent characteristics of shape, from circular, oval, to other shapes, which could affect the accuracy of measurement of the CSA. Hence, the measurement of the inner side could make the observed area to become

Fig. 1. Elbow position in the examination process. Left: Elbow flexion position; Right: Elbow extension position with transducer in transversal projection.

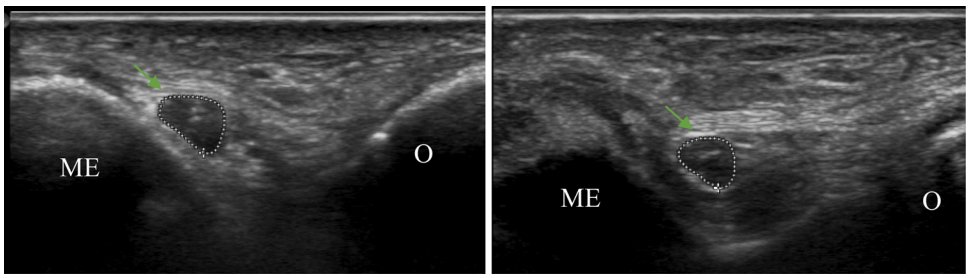

Fig. 2. US examination of ulnar nerve at the level of the medial epicondyle. Left: extension position; Right: flexion position. ME = medial epicondyle, O = olecranon.

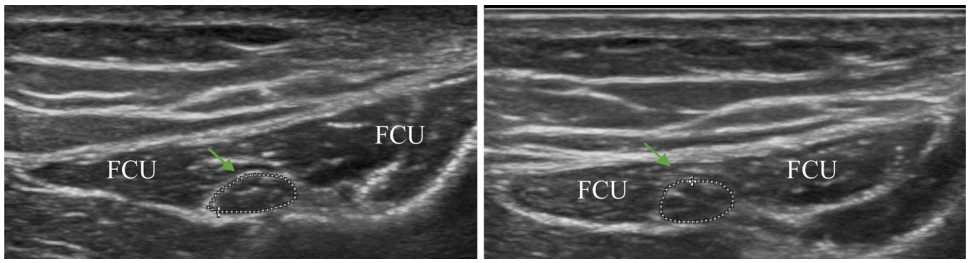

Fig. 3. US examination of the ulnar nerve at the level of 2 cm distal from the medial epicondyle. Left: extension position; Right: flexion position. FCU = flexor carpi ulnaris.

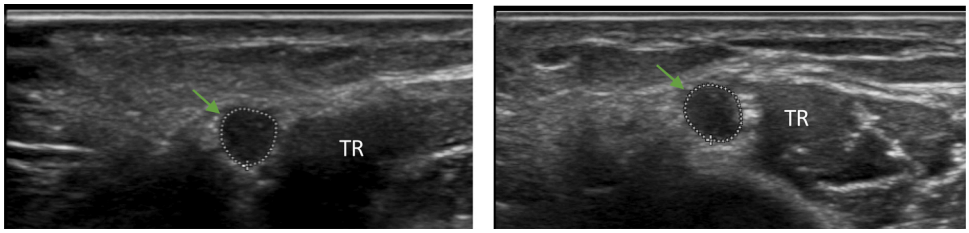

Fig. 4. US examination of the ulnar nerve at the level of 2 cm proximal from the medial epicondyle. Left: extension position; Right: flexion position. TR = triceps brachii muscle.

Table 1
Characteristics of the subjects.

Subject Characteristics	Frequency N (%)
Age Groups	
20–29 years old	18 (50.0)
30–39 years old	18 (50.0)
Nutritional Status	
Normal (BMI 18.5–24.9 kg/m^2)	26 (72.2)
Overweight (BMI 25.0–29.9 kg/m^2)	4 (11.1)
Obese (BMI > 30.0 kg/m^2)	6 (16.7)
Involvement of Arm	
Unilateral	11 (30.6)
Bilateral	25 (69.4)

Table 2
The average and standard deviation of ulnar nerve cross-sectional area.

Location of Ulnar Nerve Examination	Mean ± SD (mm^2)		*p-value*
	Flexion	Extension	
Level of 2 cm proximal from medial epicondyle	5.7 ± 0.8	6.0 ± 0.7	<0.001
Level of the medial epicondyle	5.2 ± 0.9	6.3 ± 0.9	<0.001
Level of 2 cm distal from medial epicondyle	5.7 ± 0.7	5.9 ± 0.7	<0.001

more accurate [13].

Previous studies demonstrated that there was a significant difference between the area of ulnar nerve CSA based on age group, notably between the group with age below 40 years old and more than 40 years old. [11,14,21,22] Based on this result, to homogenize the subject, this study set the age criteria of the included subject, from 18 to 40 years old. The age below 40 years old become a consideration due to high prevalence of external compression of the ulnar nerve, while in other hand, the population with age above 40 years old was more susceptible to suffer the cubital tunnel syndrome. [23] An et al. [24] conducted a study on patients with cubital tunnel syndrome in the United States and found that the average participant age was 46 ± 15.7 years old showing that the ulnar nerve entrapments distal to the medial epicondyle was more common in older patients. Another study by Linda et al. [25] which included fishermen along the coast of Manado found that cubital tunnel syndrome was more frequent in subjects with age below 50 years old and worked for over 10 years.

Based on the result of this study, we found that extended elbow position with the palm facing upward and elbow facing to the operator provides better stability compared to the palm touching the examination table. The ulnar nerve is also easier to identify in extended position because in flexed elbow position there is a possibility of nerve displacement from its original location. [9] For this matter, a dynamic examination is important to evaluate ulnar nerve displacement, as stated by the European Society of Musculoskeletal Radiology [26]. We also found that US examination of the ulnar nerve in flexed elbow position is more challenging to perform because in flexed elbow the field of the examination is not in a straight plane but rather in the angulated condition. To anticipate this condition, we suggest starting the US examination from the distal portion, which is easier for the operator to identify

the ulnar nerve between two muscle belly of the flexor carpi ulnaris.

There are several limitations in this study. The age of the subject included in this study ranges only between 24–35 years old which does not represent the size of adult ulnar nerve cross-sectional in general. This study also does not consider confounding factors such as body height, body weight, body mass index, and physical activities of the subject. Further studies are needed to validate the data in larger populations.

5. Conclusion

Ulnar nerve CSA at the extended elbow position is significantly larger compared to flexed elbow position. Elbow position needs to be considered when calculating CSA of the ulnar nerve, since its normal value is significantly different between flexed and extended elbow position. Further study with larger sample size may be considered to evaluate CSA cut off value for ulnar nerve compression/entrapment in extended elbow position.

Ethical statements

This study was approved by the Research and Ethics Committee from the Faculty of Medicine Universitas Indonesia (Ethics number: 89/UN2.F1/ETIK/2019) and Dr. Cipto Mangunkusumo Hospital. Each of the participants was given written informed consent and the patient data were kept anonymously and confidential. Patient data used in this study were kept anonymously and confidential.

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CRediT authorship contribution statement

Marcel Prasetyo: Conceptualization, Methodology, Writing - review & editing, Visualization, Software, Supervision, Project administration, Validation. **Reiner Reza Rahardja:** Conceptualization, Data curation, Investigation, Writing - original draft. **Ahmad Yanuar:** Conceptualization, Methodology, Investigation, Supervision. **Joedo Prihartono:** Conceptualization, Methodology, Formal analysis, Software, Supervision. **Stefanus Imanuel Setiawan:** Data curation, Writing - review & editing, Project administration.

Declaration of Competing Interest

The authors declare no conflict of interest.

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