Study of Normal Cross-sectional Area of Upper Limb Peripheral Nerves by High-resolution Ultrasonography

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ABSTRACT

In the present study, we have tried to establish reference value of cross-sectional area (CSA) of upper limb nerves. Three hundred normal subjects were studied and CSAs of median, radial, and ulnar nerves were measured at anatomical sites, such as median nerve at palmar aspect of wrist ventral to flexor retinaculum, ulnar nerve medial–posterior aspect of medial epicondylo, and radial nerve in spiral groove of humerus bone. Earlier also Cross sectional area reference values by HRUS has been studied. We have correlated CSAs with age, gender, and height. Cases we studied were between the age group of 20 and 50 years, and most of them were 20 to 40 years. There were 179 males and 121 females in our study.

The mean CSA of median nerve was 8.27 mm² among males and 8.04 mm² among females with p-value < 0.05, hence the difference between male and female is statistically significant. Mean CSA of ulnar nerve of right hand was 6.39 mm² among males and 6.08 mm² among females, with p-value <0.05, hence the difference between male and female is statistically significant. The mean CSA of ulnar nerve of right hand was 6.39 mm² among males and 6.08 mm² among females, with p-value <0.05 and the difference between males and females is significant.

Mean CSA of radial nerve of right hand was 3.76 mm² in males and 3.86 mm² in females and of the left hand was 3.78 mm² in males and 3.79 mm² in females with p-value >0.05 mm, hence the difference between males and females is insignificant.

In our study, our aim was to obtain reference values for cross-section of upper limb nerves, such as median nerve, radial nerve, and ulnar nerve of normal individuals, and we have studied correlation and variation with respect to age, sex, height, and handedness found. High-resolution ultrasonography (HRUS) being noninvasive, relatively cheaper, easily available, and portable modality has become highly dependable modality in the study of peripheral nerves. With continuous improvement in the USG technology, we are able to see nerves up to fascicular level.

Nerve imaging has become an important and essential diagnostic tool to know the anatomy, morphology, and pathology of nerves. High-resolution ultrasound and magnetic resonance imaging depict changes in nerves in the cases of trauma, tumor, and neuropathologies and are most important methods for visualizing nerves and adjoining soft tissues.12 Computed tomography scan has limitations in this aspect, but is very useful in evaluating coexisting trauma.34

INTRODUCTION

Earlier neurological examination and nerve conduction studies, recording of late response F waves and needle electromyography were done for peripheral nerves disorders.

Ultrasonography (USG) being noninvasive, relatively cheaper, easily available, and portable modality has become highly dependable modality in the study of peripheral nerves. With continuous improvement in the USG technology, we are able to see nerves up to fascicular level.

In our study, our aim was to obtain reference values for cross-section of upper limb nerves, such as median nerve, radial nerve, and ulnar nerve of normal individuals, and we have studied correlation and variation with respect to age, sex, height, and handedness. For superficial nerves, 12 to 18 MHz frequency probe is recommended. However, 12 MHz frequency is sufficient but for fine details in cases of injury, very high frequency probe up to 22 MHz is useful.

MATERIALS AND METHODS

The cross-sectional study of peripheral nerves was carried out in the Department of Radiodiagnosis of Sarojini Naidu Medical College, Agra, Uttar Pradesh, India, in normal individuals with no neurological problems.

Three hundred cases were studied randomly along with well-informed consent between age group 20 and 45 years. Sonographic equipment used was Sonocx × 8 Medison and Sonosite (Micromax), with high-frequency 7 to 14 MHz linear probe.
Scanning was done in both lying down and sitting positions. Bilateral upper limb nerves were traced. Median nerve at wrist, Ulnar nerve at cubital tunnel, and Radial nerve at 4 cm above lateral epicondyle and in spiral groove region of humerus. After investigating anatomical structures, such as bones muscles and blood vessels, peripheral nerves were traced. Cross-sectional area was taken by one measurement within hyperechoic rim surrounding the nerve. In USG machine, CSA was taken at the level of maximum enlargement by eclipse mode.

Peripheral nerves comprise numerous parallel fascicles of varying thickness. The fascicles contain multiple axons with myelin sheath and Schwann cells. The individual nerve fibers are surrounded by the endoneurium and the fascicles by perineurium (fatty and collagen-rich sheaths of connective tissue). The epineurium between the individual fascicles is referred to as the interfascicular epineurium, and the epineurium on the outer edge of the outer fascicles, i.e., the outer sheath of the nerve, is referred to as the outer or epifascicular epineurium. The epineurium contains the vasa nervorum.

The fascicular structure of nerve is visualized by HRUS. In the transverse section, the nerve is oval to round and has a hyperechoic outer contour corresponding to the outer epineurium. The echotexture has a typical honeycomb pattern. The hyperechoic “honeycomb chambers” corresponds to the individual fascicles and the hyperechoic “honeycomb walls” to the interfascicular epineurium. The hyperechoic epineurium is additionally often surrounded by hyperechoic, perineural fatty tissue and connective tissue so that the outer contour of the outer nerve sheath usually cannot be precisely defined with sonography. The CSA of the nerve, therefore, must be measured on the inside of the epineurium, i.e., on the boundary surface between the hypoechoic fascicular structures and the hyperechoic nerve sheath.

The peripheral nerve is visualized in the longitudinal section as a minimally hypoechoic cable-like cord compared with the surrounding soft tissue (Fig. 1).

**Median Nerve**

The median nerve is traced in the palmar aspect of the wrist and is located ventral to the flexor retinaculum, dorsal to the flexor digitorum tendons, and medial to the flexor carpi radialis tendon. Figure 1A showing probe at wrist joint. Figure 1B shows the normal median transverse section, and Figure 1C shows lon scans of normal median nerve as (arrows). The median nerve can be traced from the wrist, between the flexor retinaculum and flexor digitorum tendons, to the forearm level, between the flexor digitorum superficial and profundus muscles, anterior to the brachial artery at mid arm level, and crossing lateral to the brachial artery at the upper arm level. The median nerve enters the forearm from the cubital fossa, between the two heads of the pronator teres muscle, called the pronator teres tunnel.

**Ulnar Nerve**

The ulnar nerve can be traced from the posterior aspect of the medial epicondyle, both proximally and distally.
The nerve is located between the flexor carpi ulnaris and flexor digitorum profundus muscles at the forearm level and is accompanied by the ulnar artery in the lower part of the forearm.9 Near the wrist level, the ulnar nerve runs lateral to the flexor carpi ulnaris tendon and crosses superficially to the flexor retinaculum tendon and lateral to the ulnar artery, which is also called the Guyon tunnel.

Normal ulnar nerve (epicondyle level) (Fig. 2C, right) shows the area scanned. Figures 2A and B show cord like hypoechoic structure in longitudinal view (arrow) above medial epicondyle.

**Radial Nerve**

The radial nerve is easily traced from the spiral groove of the humeral bone proximally to an area between the medial and lateral heads of the triceps muscle, then distally to the lateral part of the cubital fossa, where it divides into superficial and deep branches. Figure 3 shows the normal radial nerve in transverse and long US scan, nerve
in the spiral groove region of the humerus. Figure 4 shows radial nerve above lateral epicondyle.

**RESULTS**

A total of 300 healthy subjects were recruited for our study and divided into three age groups: 20 to 30, 31 to 40, and 41 to 50 years.

In the first group (20–30 years), there was a total of 128 subjects (42.67%) among which 74 subjects were males (41.34%), with a mean age of 25.73 years, and 54 subjects were females (44.63%), with a mean age of 25.54 years. In the second group (31–40 years), there was a total of 127 subjects (42.33%) among which 70 subjects were males (39.11%), with a mean age of 35.87 years, and 57 subjects were females (47.11%), with a mean age of 35.13 years. In the third group (41–50 years), there was a total of 54 subjects (18.00%) among which 35 subjects were males (19.55%), with a mean age of 42.89 years, and 19 subjects were females (15.70%), with a mean age of 43.13 years. There was a total number of 179 males with a mean height of 5.19 ft [standard deviation (SD) ± 0.52] and 121 females with a mean height of 5.10 ft (SD ± 0.48) with a p-value >0.05.

**Median Nerve**

Mean CSA of median nerve of the right hand was 8.25 mm² among males and 8.09 mm² among females with a p-value >0.05. Mean CSA of median nerve of the left hand was 8.27 mm² among males and 8.04 mm² among females with a p-value <0.05, hence the difference between male and female is statistically significant (Table 1).

**Ulnar Nerve**

Mean CSA of ulnar nerve of the right hand was 6.39 mm² among males and 6.08 mm² among females with a p-value <0.05, hence the difference between male and female is statistically significant. Mean CSA of ulnar nerve of the left hand was 6.33 mm² among males and 6.09 mm² among females with a p-value >0.05 (Table 2).

**Radial Nerve**

Mean CSA of radial nerve of the right hand was 3.76 mm² among males and 3.83 mm² among females; the left side was 3.78 mm² among men and 3.79 mm² among women with a p-value >0.05 (Table 3).

**DISCUSSION**

The present study was undertaken to establish reference values using HRSG in healthy subjects for the most frequently examined nerve segments on the upper extremities. We established a set of normal CSA values for several upper limb nerves, at predefined anatomical sites, and assessed whether CSAs correlated with age, gender, and height. The study comprised total of 300 cases referred from other departments without neurological signs and symptoms. The sonographic evaluation was conducted in all the cases as per protocol.

**Age Distribution**

Majority of the patients were between 20 and 50 years of age and the predominant age group in the study was 20 to 40 years. In the first group (20–30 years), there were a
total of 74 males with mean age of 25.73 years, 54 females with mean age of 25.54 years. In the second group (31–40 years), there was 70 males with mean age of 35.87 years, 57 females with mean age of 35.13 years. In the third group (41–50 years), there was 35 males (19.55%) and 57 females (47.11%). In the third group, there were 35 males (19.55%) and 19 females (15.70%). Very few studies have been done till now that have assessed the mean CSA of major peripheral nerves and its correlation with physiological factors like age, height, and sex.

Therefore, in the present study, we report the correlation of age, height, and sex with the reference values for CSA in 300 healthy subjects. In our study CSA of major upper limb peripheral nerves found is given in Table 4.

The CSA of most nerves, as in our study, ranges from 1 to 10 mm. Our study subjects represented a broad range of age and a balanced gender distribution in Indian population. Mean CSA of median nerve of the left hand was 8.27 mm² among males and 8.04 mm² among females with a p-value <0.05, hence the difference between male and female is statistically significant; means men have a higher value than women in left hand.

Mean CSA of ulnar nerve of the right hand was 6.39 mm² among males and 6.08 mm² among females with a p-value <0.05, hence the difference between male and female is statistically significant; means men have a higher value than women in right hand.

Mean CSA of radial nerve of the right hand was 3.76 mm² among males and 3.83 mm² among females; left hand was 3.78 mm² among males and 3.79 mm² among females with a p-value >0.05, hence the difference between male and female is statistically insignificant.

The CSA reference values obtained in our study seem to differ significantly from previously reported values from Cartwright et al [3] in the literature (Student’s t-test for CSA of the median nerve in carpal tunnel p = 0.034; ulnar nerve in Guyon’s canal p = 0.021; radial nerve in spiral groove p < 0.001).

This discrepancy could be due to the fact that our participants differed significantly from the population studied from Cartwright et al [3] regarding age (Student’s t-test, p = 0.0038) and height (Student’s t-test, p < 0.0001).

An additional reason could be that the previously reported studies included only unilateral measurements of the nerves, which can likely have an impact on the variance of the values reported. Cartwright et al [3] found that females had smaller nerves than males. Another essential feature of Kerasnoudis et al [6] study is its independence to height in most of the peripheral nerves. In our research also, there is no correlation between CSA and height.

### SUMMAR Y

In our study, among males and females, males had significantly larger values than females in bilateral upper limbs in median nerve in the left hand, ulnar nerve in right hand.

In our study, no difference in nerve size parameters was found when dominant and nondominant sides were compared and also no significant difference found when we correlated with height. However, ulnar nerve in medial epicondyle and radial nerve in spiral groove showed decrease in diameter with increasing age.

The use of predefined anatomical landmarks is essential to obtain comparable data. The excellent reliability of our measurements serves as a basis for the acceptance of the normal values provided by our study.

Nonetheless, it is important to note that sonographic measurements of peripheral nerves should be put in the context of clinical and electrophysiological data, and caution is advised when interpreting minor deviation from normative data. For future ultrasound studies involving pathologic nerves, caution is advised concerning the difficulty of differentiating between normal and pathologic heterogeneity of CSA variation in peripheral nerves, especially in the case of immune-mediated neuropathies.

### REFERENCES


