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Ultrasound Reference Values Estimation for the Upper Limb Peripheral Nerves in Adult Females: A hospital-based Study

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Abstract

***Background*: Newer high-frequency probes make superficial ultrasonography (USG) an excellent cost-effective modality in imaging upper limb peripheral nerves. Aim: To estimate the reference values for the upper limb peripheral nerves in adult females in the community attending our hospital. *Subjects and Methods*: One hundred Sixty healthy adult female volunteers free from any neuromuscular disease, from 20 to 49 years old, were included in our study from November 2018 to March 2020. Age, height, and weight were recorded. Cross-sectional area (CSA) of upper limb peripheral nerves including median, ulnar, and radial nerves measured in mm^2 at 8 scanning sites bilaterally were taken by US using a linear transducer (L12-5). It was measured by circumferential tracing inside the hyperechoicrim of each upper limb peripheral nerve. *Results:* The mean age of included subjects was 28.33± 12.13 years. The mean height was 154.48± 7.8, and the mean weight was 79.11±15.4. A significant positive statistical correlation with age was found for the median nerve at the carpal tunnel in addition to all four scanned sites for the ulnar nerve (total of 5 sites). A significant positive statistical correlation with patient weight was found for the median nerve at the carpal tunnel in addition to all scanned sites for the ulnar nerve except for the Guyon canal (total of 4 sites). However, no significant correlation was noted in relation to patient height. *Conclusion:* Our work data can be used as reference values to help in the diagnosis of peripheral nerve abnormalities in our community. We recommend further work on more subjects with different demographic data to increase the efficiency and spectra of our database.**

Keywords: *Upper extremity nerve, reference values, Median nerve, Radial nerve, Ulnar nerve. Ultrasonography*

Introduction

MRI is superior and accurate in soft tissues and nerve imaging; however, it is expensive, takes more time, and is not practical for imaging several nerves that need to be examined over its long course[(1)]. During the past decade, high-resolution ultrasound gained more popularity, as a promising imaging modality used in the diagnosis of different peripheral nerve disorders. Some studies reported the cross-sectional area reference values for different peripheral nerves[(2-6)]. In our developing countries, USG remains an underutilized modality as most of the population is unable to afford costly diagnostic tests. Using appropriate techniques, peripheral nerves

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can readily be scanned throughout their courses from proximal to distal or vice versa, so knowledge of reciprocal anatomy between the scanned nerves and adjacent structures is needed for its proper visualization[7]. A normal nerve in the transverse section gives a "honeycomb like" appearance and reveals small hypoechoic areas representing nerve fascicles separated by hyperechoic septae representing inter fascicular perineurium[8]. The longitudinal sections reveal the fascicular architecture, leading to a "bundle of straws" appearance. The nerve is more echogenic as compared to the muscle which shows hypoechoic muscle fiber bundles with intervening echogenic perimysium[9]. Although the US has a few limitations like a small field of view, limited penetration, and an anisotropic effect when imaging nerves[10], major nerves in the upper extremity including median, ulnar, and radial nerves can usually be visualized without much difficulty, and requires the use of transducers with high insonation frequencies (7-12 MHz or more)[11]. Also, the European Society of Musculoskeletal Radiology stated that musculoskeletal sonography is the first-choice technique for peripheral nerve evaluation[12]. The aim of our hospital-based study is to estimate the reference values for the upper limb peripheral nerves in adult females in our community hoping that our data can help in future diagnoses of upper limb peripheral nerve disorders.

Subjects and Methods

One hundred Sixty healthy adult female volunteers free from any neuromuscular disease, 20 to 49 years old, were recruited from November 2018 to April 2020 at the Radiology department in our hospital. The local institutional review board committee of our hospital approved the study protocol and all participants provided informed consent before enrollment. For each female participant, the age, height, and weight were recorded before the ultrasound scanning of the nerves of the upper limb cross-sectional area.

Technique

The ultrasound scanning of the upper limb nerves was carried out using Philips ultrasound diagnostic (HD II XE Ultrasound 2006, Philips medical system, Nederland B.V). For all patients, we used a linear transducer (L12-5). We used a large amount of gel and minimal probe pressure over the scanned area. To minimize anisotropy, the probe was positioned in a perpendicular position to the examined nerve. The focal zone and proper depth were adjusted to improve image quality. Limb movements were needed in some cases to differentiate examined nerve from the adjacent tendon. We performed an examination bilaterally and started from a known anatomic landmark near the nerve. Once the nerve is localized in the short axis, it is traced cranially and caudally to see nerve contour and architecture. The nerve cross-sectional area at each scanned site was measured by circumferential tracing inside the hyperechoic rim of each nerve, showing its peculiar fascicular pattern. The upper limb examined nerves include the following.

The median nerve

It arises from the medial and lateral cord of the brachial plexus and runs along the medial side of the distal arm with the brachial artery and vein. Then it passes deeply into the antecubital fossa and is located at the elbow joint between the biceps brachii and the brachialis muscle[13]. It is located at the wrist superficially to the FDS tendons in the carpal tunnel, just below the flexor retinaculum[14]. The participant is in a supine position with shoulder abduction and external rotation, the median nerve was scanned at

3 predetermined sites within the carpal tunnel (Fig. 1a), then the probe was moved proximally 10cm in the forearm (Fig. 1b), and at the elbow level (Fig. 1c); the probe is placed in the short-axis view on the elbow.

The ulnar nerve

It arises from the medial cord of the brachial plexus; and runs in the medial bicipital groove, posterior and medial to the brachial artery. Midway down the humerus, it lies superficially and lies in the ulnar nerve groove on the posterior aspect of the humerus and after leaving this groove, it moves towards the flexor compartment of the forearm, crossing between the humeral and ulnar heads of the FCU then runs medially to the ulnar artery in the layer between the FCU and FDP muscles[15]. At the wrist joint, the ulnar nerve lies in a fibro-osseous tunnel known as the Guyon's canal that contains the ulnar nerve and artery, located immediately adjacent to the ulnar artery[14]. In our study the ulnar nerve was scanned at 4 sites, The patient is supine with the shoulder in abduction and external rotation, the elbow in a flexed position, and the forearm supinated; first at the Guyon canal (Fig. 2 a), then the probe was moved upwards in the forearm, 10cm above the Guyon canal, the third position was at the level of the medial epicondyle (Fig. 2 b); the fourth position was 1 inch above the medial epicondyle.

The radial nerve

It is the terminal branch of the brachial plexus posterior cord that runs posterior to the axillary artery, then wraps around the humerus and lies in the radial groove between the origin of the lateral and medial heads of the triceps muscle. In the terminal part of the groove, the radial nerve pierces the intermuscular septum and courses on the anterior surface of the humerus towards the cubital fossa[15]. In our study, the radial nerve was scanned at one site only at the level of the mid-arm (Fig. 3). So, in each included female participant, 8 sites were scanned bilaterally. Images of examined upper limb peripheral nerves and results of its cross-section areas were saved electronically and analyzed.

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 21 software (SPSS Inc, Chicago, IL). All data were presented as mean± SD and range. The mean CSA was compared between both sides using Wilcoxon signed rank test. The correlations between the CSA of the scanned nerves, age, weight, and height, were evaluated using Pearson's correlation coefficient (r). *P* value of<.05 was considered significant.

Results

We studied 160 healthy adult volunteers females free from any neuromuscular disease with a mean age of 28.33± 12.13 yrs. (20–49 yrs.). The mean height was 154.48± 7.8 (144–173cm) and weight was 79.11±15.4 (47–125kg). Table 1 showed descriptive statistics, and mean reference values of the scanned nerves together with their reference range. We compared the cross-sectional area values of the 8 scanned sites on the right and left sides and we found no significant differences between the upper limb nerve cross-sectional area on the right and left sides. Also, we found no significant statistical correlation between the nerve CSA and the patient's height. A significant positive correlation of the CSA reference values with age was seen in 5 out of 8 examined sites and it was found for the median nerve at the carpal tunnel in addition to all four scanned sites for the ulnar nerve.

Table 1: Descriptive statistics of the scanned upper limb nerves					
	No.	Minimum	Maximum	Mean	Std. deviation
Age	160	20	49	28.33	12.13130
Weight	160	47	125	79.11	15.42131
Height	160	144	173	154.48	7.82641
MN at CT	320	4.80	18.00	9.6510	2.76677
MN at FA	320	1.20	15.60	6.5345	2.03460
MN at elbow	320	3.00	22.20	10.3 041	3.72750
UN at Guyon canal	320	1.50	11.00	4.0452	1.45286
UN at FA	320	2.00	13.00	5.1232	1.80762
UN at elbow	320	3.00	14.00	6.4771	2.35550
UN at A	320	3.00	15.00	6.9443	2.50113
RN at A	320	1.20	11.30	5.7055	1.82821

MN= median nerve. UN= ulnar nerve. RN= radial nerve, CT= carpal tunnel, FA= forearm A=arm.

Four out of 8 sites showing a significant positive statistical correlation with patient weight were found for the median nerve at the carpal tunnel in addition to all scanned sites for the ulnar nerve except for the Guyon canal (three out of four scanned sites for the ulnar nerve). However, no significant statistical correlation was noted in relation to the examined upper limb nerve CSA to the patient's height (Table 2). The circumferential tracing of the upper limb nerve at each scanned site was done and the nerve cross-sectional area was measured, the mean median nerve cross-section area was 9.7mm^2 at CT, 6.5mm^2 at the forearm, and at the elbow, it was 10.3 mm^2. Our results revealed that the mean cross-section area of the ulnar nerve was 4mm^2 at Guyon canal; 5.1mm^2 at the forearm; 6.4mm^2 at the elbow, and 6.9mm^2 at the arm. While the mean CSA of the radial nerve was 5.7mm^2 at level of the mid-arm. Table 3, shows a comparison between our results of CSA of upper limb peripheral nerves measured in square millimeters at 8 scanning sites with previous studies[3,5,16,17].

Table 2: Correlations between age, weight, and height reference values of the upper limb nerves.								
	M.N CT	M.N FA	M.N at elbow	U.N at G.C.	U.N forearm	U.N elbow	U.N arm	R.N arm
Age*	.362**	.190	.124	.337**	.325**	.232**	.198*	.144
Sig. (2-tailed)	.000	.022	.140	.000	.000	.006	.017	.090
No.	320	320	320	320	320	320	320	320
Weight*	.293**	.100	.004	.005	.271**	.345**	.316*	.080
Sig. (2-tailed)	.000	.231	.950	.952	.001	.000	.000	.343
No.	320	320	320	320	320	320	320	320
Height*	.035	.037	.102	.060	.013	.041	.000	.060
Sig. (2-tailed)	.661	.663	.224	.473	.880	.611	.994	.462
No.	320	320	320	320	320	320	320	320

**= Pearson correlation, M.N median nerve. U.N ulnar nerve R.N radial nerve G. Guyon Canal,*
** Significant at 0.05, ** Significant at 0.01.*

Discussion

Ultrasound is the most useful imaging tool for musculoskeletal disorders, it is a commonly used method for imaging the upper limb peripheral nerves and it also enables delicate depiction of muscles, tendons, and ligaments[18,19]. Almost all upper

limb peripheral nerves including digital nerves can be imaged by USG and before the scan detailed anatomy should be clear[11]. In our present study, we scanned 8 sites for 3 important upper limb peripheral nerves including median (3 sites), ulnar (4 sites), and radial nerves (one sit). As these nerves generally run along borders of other structures, especially between different muscle groups, we studied each nerve using landmarks and borders, so we follow them every time and in all patients. Bedewi et al.[16] and Kerasnoudis et al.[3] results of their studies showing no significant differences in CSA of examined upper limbs nerves between the right and left sides, and no significant statistical correlation was noted in relation to patient height.

Figure 1a

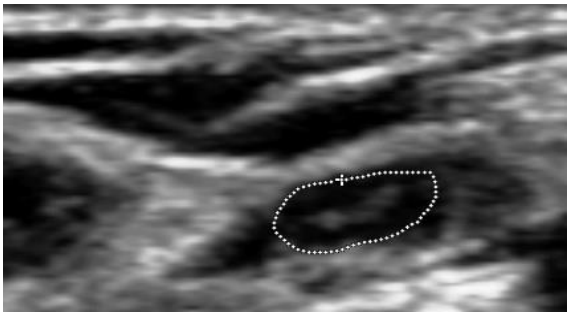

Figure 1.b

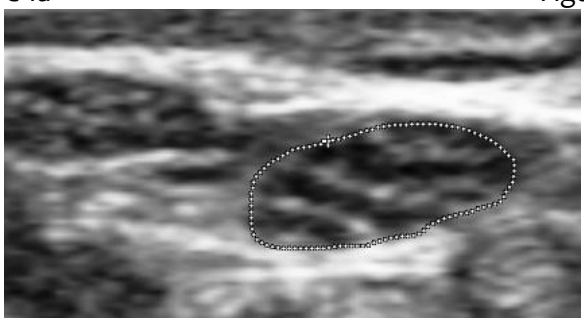

Figure 1c

Figure 1: Axial ultrasound image of the normal median nerve
rounded hypoechoic areas separated by hyperechoic septae, giving a "honeycomb" appearance.
(a) at the carpal tunnel, its CSA measures 10.4 mm^2, (b) at the mid-forearm its CSA measures 4.4mm^2 and (c) at the level of the elbow its CSA measures 10 mm^2

They also revealed a significant positive statistical correlation of the CSA reference values with the age and weight of patients. These results, in general, were comparable to our results, however, our results revealed a significantly positive statistical correlation of the CSA reference values with age in five out of eight sites and four of 8 sites showed a correlation with the weight of patients. The study of Kerasnoudis et al.[3], revealed that the mean median nerve CSA was (8.75 mm2 at the carpal tunnel), (6.7mm2 at the forearm), and in Bedewi et al.[14] study, the median nerve showed the following values (9.8mm2 at the carpal tunnel), and (6.5mm2 at the forearm). While our results show that the mean median nerve CSA was (9.7mm^2 at CT), and (6.5mm^2 at the forearm). The mean median nerve at the elbow in our study was 10.3 mm2 while in Bedewi et al study[16] it was 11.1 mm^2. CSA of the ulnar nerve in our study was (4mm2 at Guyon canal); (5.1 mm^2 at the forearm); (6.4 mm2 at

the elbow), in Kerasnoudis et al.[3] study was (4.8 mm² at Guyon canal); (5.1 mm2 at the forearm); (6.2 mm² at the elbow), whereas in Bedewi et al study was (4 mm² at Guyon canal); (5.5 mm² at the forearm); (7.5 mm² at the elbow).

Table 3: Correlations between our data, with other studies in the literature

	MN CTl	MN FA	MN Elbow	UN GT	UN FA	UN Elbow	UN A	RN
Our study	9.7	6.5	10.3	4	5.1	6.4	6.9	5.7
Bedewi et al.	9.8	6.5	11.1	4	5.5	7.5	7.6	5.7
Qrimli et al	10	7.1	10.3	5	6.2	6.9	6.9	6.5
Won et al	8.3	6.3	7.2	4.9	6.3	7.2	5.8	NA
Kerasnoudis et al	8.75	6.7	NA	4.8	5.1	6.1	NA	NA

MN=median nerve, UN= ulnar nerve, RN= radial nerve, CT=carpal tunnel, FA= forearm, A=arm.
NB: CSA was measured in square millimeters at 8 scanning sites.

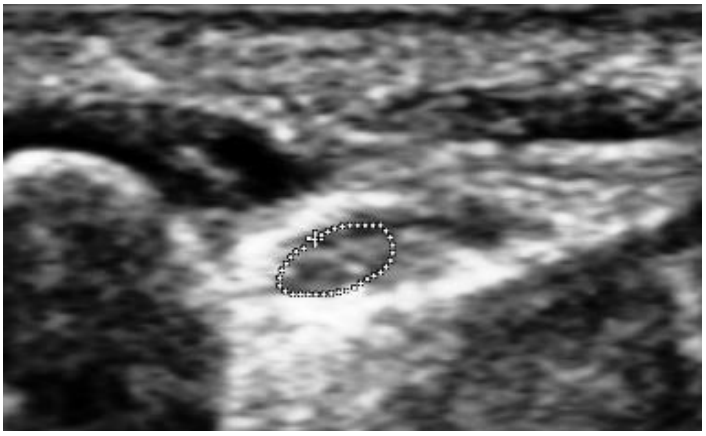

Figure 2a

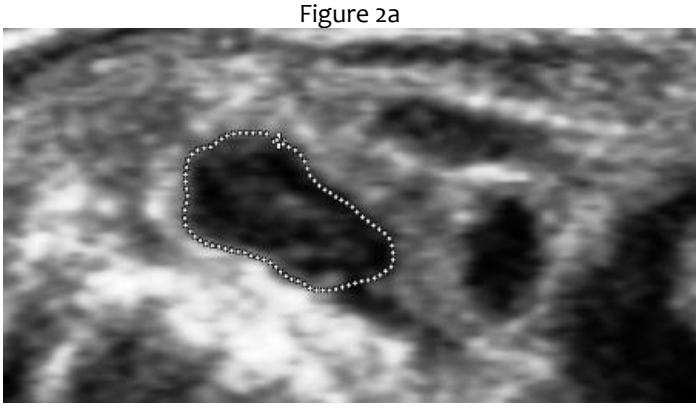

Figure 2b

Figure 2: Ultrasound image short axis depicts the ulnar nerve.
(a) at the Guyon canal, the CSA measures 2.6mm² and
(b) at the level of the elbow, the CSA measures 7 mm²

The ulnar nerve with Won et al showed the following results (4.93mm² at the wrist), (6.3mm² at the forearm), (7.2mm² at the cubital tunnel inlet), (5.8mm² at the mid humerus). Our study result of CSA of the ulnar nerve at mid humerus was similar to the study of Qrimli et al (6.9mm²)[17]. Scanning of the radial nerve might be more difficult than the median and ulnar nerves because it shifts from medial to lateral during

its course on the posterior aspect of the humerus[7], it was measured in only one place, at the level of the mid-arm, the mean CSA in our study, and in Bedewi et al. was 5.7 mm^2 while, it was 6.5 mm2 in Qrimli et al study[17]. The minimal discrepancy in our results compared to the literature may be attributed to that all our patients were adult females and because the probe resolution has improved in the last few years.

Figure 3: Ultrasound image short axis depicts the radial nerve at the level of the mid-arm, the CSA measures 4.2 mm^2

Conclusion

Our work is a trial to build a database for the normal values of upper limbs peripheral nerves of the females in our community using US and in correlation to the demographic data of these subjects. This data can be used as reference values to help in the diagnosis of peripheral nerve abnormalities in our community. Further work on more subjects with different demographic data is recommended to increase the efficiency of our database.

Study limitations

The present study has some limitations including that all our patients were females, so we did not study the reference values for males, Also the study did not include side-to-side difference ratio CSA variability and other nerves, like musculocutaneous and axillary nerves.

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Abbreviation

USG; ultrasonography. CSA; cross-sectional area. MN; Median nerve. UN; ulnar nerve. RN; radial nerve. FDS; flexor digitorum superficialis. FCU; flexor carpi ulnaris. FDP; flexor digitorumprofundus