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ORIGINAL ARTICLE

Localisation of the radial nerve at the spiral groove: A new technique

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KEYWORDS
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Summary *Background:* Localisation of the radial nerve (RN) in the spiral groove by previously reported methods has a wide range and is generalised. The objective of this study was to establish a method unique to a patient to accurately localise the nerve.
Methods: The distance between RN at the midpoint of the spiral groove (D) and the tip of the olecranon (O) was compared with the most distal wrist flexion crease and fingertips on 100 healthy volunteers. The RN was found by ultrasound examination.
Results: The mean distance from O to D was 16.22 cm (12.5–20.5 $\pm$ 1.55), and mean distances from wrist crease (WC) to second, third, fourth and fifth fingertips were 17.79 (14–20 $\pm$ 1.28), 18.66 (15–21 $\pm$ 1.32), 17.71 (14.5–20.5 $\pm$ 1.32) and 15.62 (12.5–20.5 $\pm$ 1.34) cm, respectively. With regards to O–D distance, the strongest relationship was obtained for the distance between the fifth fingertip to the WC ($r = 0.708$, $p < 0.001$). This relationship was stronger among females than males ($p < 0.001$).
Conclusion: The course of the RN can be easily found at the upper arm by this method, which is unique to a patient.
The translational potential of this article: This study presents a new and individualised approach to accurately predict the location of the RN in the spiral groove. This method is clinically relevant and can be used to guide the surgical explorations or expedite interventional methods.

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Introduction

The radial nerve (RN) is the continuation of the posterior cord of the brachial plexus. It takes origin from C5 to T1 spinal nerves. The nerve is located posterior to the brachial artery and descends between the medial and lateral heads of triceps brachii muscle. The nerve trifurcates when comes in contact with the medial border of the humerus [1]. One of these branches is the branch to the medial head of the triceps and anconeus. Remaining two branches, posterior antebrachial cutaneous nerve and RN, travel along the spiral groove along with accompanying vessels. The cutaneous branch diverges from this group of vessels and RN just before entering the lateral intermuscular septum.

The incidence of humerus fractures is increasing due to the increase in high-energy trauma cases. The most common peripheral nerve injury after humeral fractures is RN injuries [2]. Closed reduction attempts, traction or laceration at the time of surgery and impingement between fracture fragments are the most common causes of secondary RN palsy [3]. Overall incidence is reported to be 11.8% in a systematic review and more common in compression plating (0—10%) than intramedullary nailing (0—5%) [4,5]. The posterior approach is also associated with a higher risk than lateral or anterolateral approaches [6].

Until now, numerous studies have been published to predict the location of the RN in the spiral groove. These studies have used anatomic landmarks such as lateral and medial epicondyles, angle of acromion or bifurcation of triceps aponeurosis [2,7—13]. All the previous methods have some degree of success in predicting the location of the nerve but have certain problems such as proposing wide range of measurements in generalised population and broad definition of landmarks.

To date, we are unaware of studies evaluating the associations between landmarks and RN in individualised basis. The aim of this study was therefore to determine a landmark that is unique to any person which will locate the nerve exactly. Our hypothesis was that the distance between fingertips and wrist crease will exactly determine the location of the nerve from the tip of the olecranon.

Materials and methods

Participants

This study was approved by the Institutional Review Board under the case number 2017/64, and informed consent was obtained from all participants. Volunteers with history of elbow, wrist or hand fractures, skin-burn trauma or congenital deformities of the upper extremities were excluded from the study. One hundred healthy volunteers aged between 18 and 55 years gave informed consent to participate in the study. Volunteers were recruited from the outpatient clinics that were referred for radiology department for ultrasound (US) examination.

Study process

Before US examination, a standardised physical examination consisting of range of motion of the shoulder, elbow and wrist joints and neurologic examination of the upper extremities were performed on each dominant upper extremity. A blinded sonologist (H.I.) with 10 years of musculoskeletal US experience performed US localisation of the RN (Figs. 1 and 2). A radiology resident with 5 years' practice in medicine performed physical examination and collected anthropometric measurements of the participants including height, the distances between the tip of the Olecranon (O) and RN at the midpoint of the spiral groove (D), the midpoint of the most distal wrist crease (WC) and fingertips (WC to 2nd/3rd/4th/5th fingertips) while the fingers were adjacent (Fig. 3). For measurement of O—D distance, participants were asked to sit onto a chair with slight forward flexion of the trunk. The shoulder was in 60 degrees of abduction and elbow in 90 degrees of flexion and slightly in internal rotation. Wrist—hand measurements were done while participants were sitting with the elbow in 90 degrees of flexion and in full supination.

To scan the RN in the spiral groove, GE Logiq S7 Expert Doppler ultrasound system (GE Healthcare Korea, Seoul, Republic of Korea) with a high-frequency hockey stick probe (L 8—18 MHz) was used. The patient was put in the same position on the chair as in anthropometric measurements. Then, the nerve was evaluated in the spiral groove. The location of entrance (A) and exit (B) and the mid of the spiral groove (D) were marked. Associations between all measurements and the effect of gender were examined.

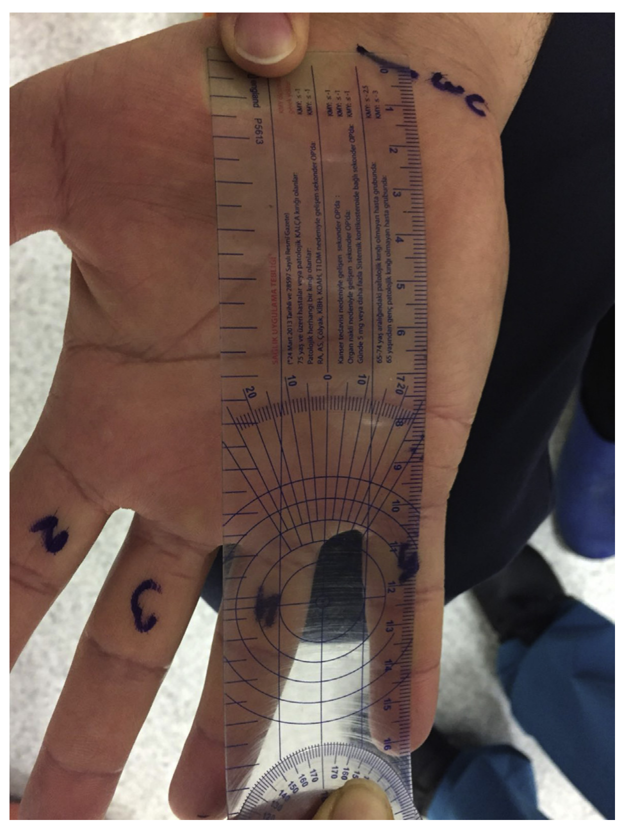

Figure 1 Anthropometric measurement of the distance between the fifth fingertip and wrist flexion groove.

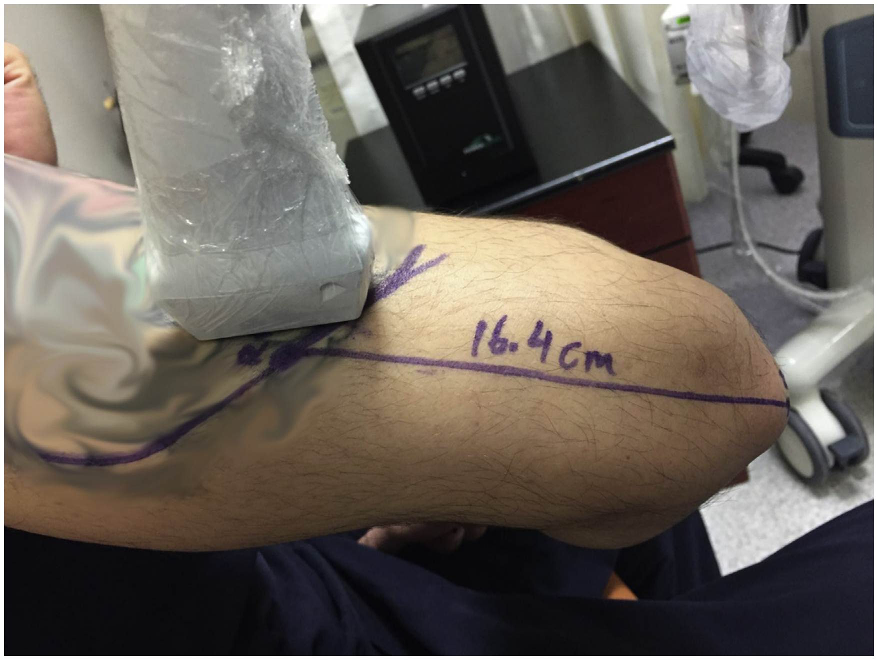

Figure 2 Transfer of the fifth finger—wrist flexion groove distance to posterior arm between the olecranon tip and probable location of the radial nerve.

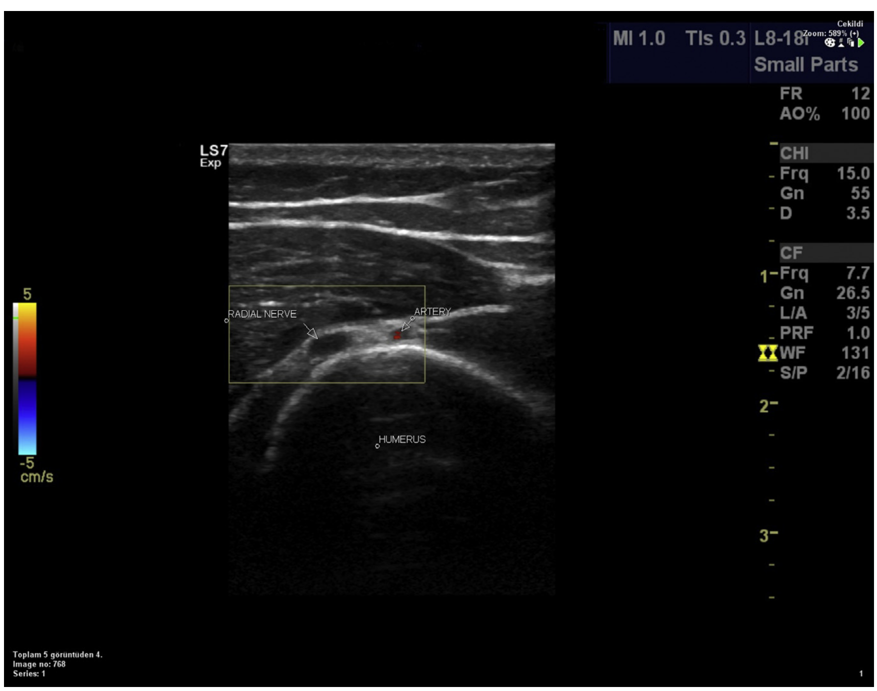

Figure 3 Sonographic appearance of the radial nerve in the spiral groove together with profunda brachii artery.

Statistical analysis

Statistical analysis was performed using Pearson or Spearman correlation test where appropriate. The threshold for significance was $p < 0.05$ in all statistical tests. All statistical test were conducted with SPSS software 19.0 (IBM Corporation, New York, NY).

Results

A total of 100 RNs were scanned. The mean age of the participants was 28.89 $\pm$ 8.14 (range, 18—55) years. Of them, 60 (60%) were female, and 40 (40%) were male. The mean height of the participants was 171.28 $\pm$ 9.12 (range, 148—188) cm.

Considering the distances from D, O, WC and fingertips, there was a strong correlation between the distance from tip of the fifth finger and wrist flexion groove and the distance from O to D. The mean distances were as follows: from the tip of O to D, 16.22 (12.5–20.5 ± 1.55) cm; from the WC to the second fingertip, 17.79 (14–20 ± 1.28) cm; to the third fingertip, 18.66 (15–21 ± 1.32) cm; to the fourth fingertip, 17.71 (14.5–20.5 ± 1.32) cm and to the fifth fingertip, 15.62 (12.5–20.5 ± 1.34) cm (Table 1). The relationship between the distances that were measured was analysed by correlation test, and results are given in Table 2. A positive and strong relationship exists between the distances of O to D and second, third, fourth and fifth fingertips to the WC ($p < 0.001$). The strongest relationship was obtained between the distance of O to D and the distance of the fifth fingertip to the WC ($r = 0.708$, $p < 0.001$).

The effect of gender on this relationship was also examined. The relationship between the distance of O to D and fingertips to WC was stronger among females than males ($p < 0.001$) (Table 3).

Discussion

The RN can be injured by trauma, during closed reduction of a humerus fracture or exploration and operative fixation of the humerus shaft fractures especially at the location between the spiral groove and the lateral intermuscular septum [1]. A meta-analysis found the incidence of RN palsy as 11.8% after such fractures. Besides meticulous exposure during operative fixation or gentle closed reduction attempt, an RN palsy can be seen due to traction and

Table 1 Distances from the olecranon tip to the midpoint of the spiral groove (D) and fingertips to wrist crease.

Measurements	n	Minimum	Maximum	Mean	SD
Olecranon to D	100	12.50	20.50	16.22	1.55
2nd fingertip–wrist crease	100	14.00	20.00	17.79	1.28
3rd fingertip–wrist crease	100	15.00	21.00	18.66	1.32
4th fingertip–wrist crease	100	14.50	21.00	17.71	1.32
5th fingertip–wrist crease	100	12.50	20.50	15.62	1.34

SD = standard deviation.

Table 2 Relationship between the distances of olecranon tip to the midpoint of the spiral groove (D) and fingertips to wrist crease.

Measurements		Olecranon to D
2nd fingertip–wrist crease	*r*	.627**
	p	<0.001
	N	100
3rd fingertip–wrist crease	*r*	.632**
	p	<0.001
	n	100
4th fingertip–wrist crease	*r*	.708**
	p	<0.001
	n	100
5th fingertip–wrist crease	*r*	.690**
	p	<0.001
	n	100

r = correlation coefficient; n = number of volunteers. **, $p < 0.001$

Table 3 Relationship between the distances of olecranon to the midpoint of the spiral groove (D) and fingertips to wrist crease according to sex.

Measurements		Olecranon to D	
		Male	Female
2nd fingertip–wrist crease	r	.523**	.679**
	p	<0.001	<0.001
	n	60	40
3rd fingertip–wrist crease	r	.531**	.690**
	p	<0.001	<0.001
	n	60	40
4th fingertip–wrist crease	r	.593**	.777**
	p	<0.001	<0.001
	n	60	40
5th fingertip–wrist crease	r	.623**	.748**
	p	<0.001	<0.001
	n	60	40

r = correlation coefficient; n = number of volunteers. **, $p < 0.001$

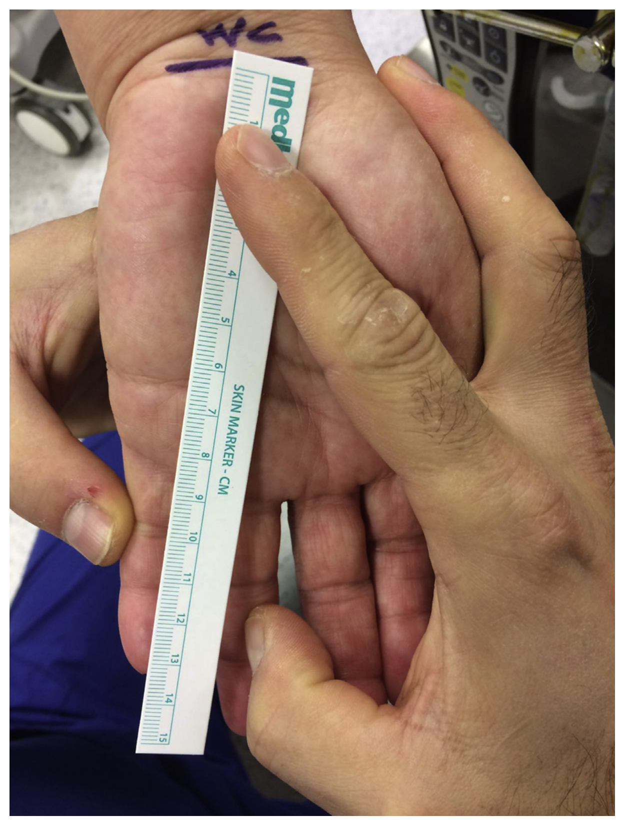

Figure 4 Preoperative measurement of the fifth fingertip–wrist flexion groove distance of a 43-year-old woman with a left-sided humerus shaft pseudoarthrosis.

Figure 5 The distance (13.4 cm) was transferred to the posterior arm to locate the radial nerve.

consequently development of fibrosis [5] (Shao et al., 2005). Therefore, accurate location of the nerve at the upper arm is utmost important during operative fixation of the humerus shaft fractures with or without palsy. In this study, the O was marked, the distance between the wrist crease and fingertips was noted and the RN was defined at the midpoint of the spiral groove (D). We found that the distance between O and D was strongly related to the distance between the fifth fingertip and the wrist crease especially in female volunteers where all were within 2 mm of variation or less (Figs. 4—6).

A plethora of landmark-oriented studies exist, none of which has been proven superior for accurate location of the nerve, but the key remains for the prediction of the exact location of the nerve for technical purposes (Table 4). Studies to ascertain the location of the nerve are almost all cadaver studies, with wide range of distances reported. In these studies, the distance from the lateral epicondyle to the entrance of the RN into the spiral groove was reported to be 6—16 cm. Introducing these findings into the operating theatre least likely delineates recommendations for optimal surgical exposures [1,9—14]. All these cadaver studies used similar methods for predicting the location of the nerve, but all with confusing landmarks such as entrance or emergence of the nerve into or from the spiral groove and osseous areas which were described as anatomical landmark definitions. As Van Sint Jan et al stated that these relatively broad bony areas may lead to imperfect localisation of the nerve, strict definitions for these landmarks should be proposed [13]. Apart from these cadaver studies, Arora and Goyal published an excellent study in which the distance of the RN was measured along the shaft of the humerus beneath the two heads of triceps muscle in trauma patients during surgical exposure [7]. They stated that the distance between the emergence of the RN from the spiral groove and medial and lateral epicondyles has been reported to have a wide range, and therefore, these measurements cannot predict the location of the nerve preoperatively. Their findings greatly help us to find the nerve while posterior to the humerus; however, this study also does not predict the location of the nerve preoperatively.

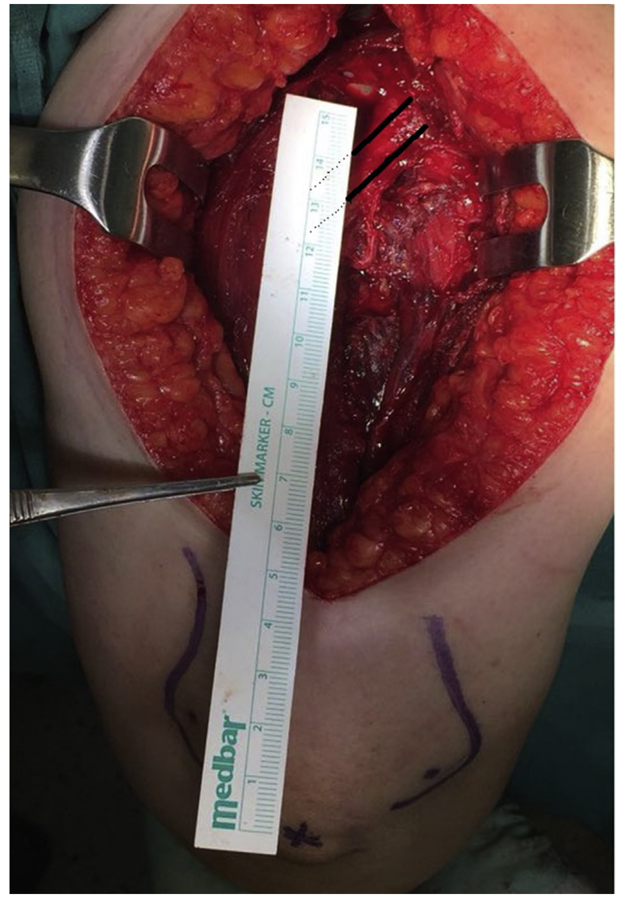

Figure 6 Intraoperative view of the radial nerve passing exactly at the preoperatively determined location.

Both technical simplicity of our strategy to localise the nerve and finer and strict landmarks we used differentiate our study from previously published reports. First, unless coexistence of a distal humerus fracture or a malunited olecranon fracture does not exist, it is pretty easy to find the tip of the olecranon. Similarly, if the patient is not exposed to a finger amputation or burn to his/her hand, locating the wrist crease and fingertips is quite easy. In the clinical setting, basic tools are enough to predict the nerve on posterior humerus by our technique. This concept also has the advantage of using individualised approach within 5 mm of range rather than defining a wide and generalised range.

Limitations of this investigation are similar to those inherent to all observational studies. First, nonobese, healthy and relatively young adults participated in the study. But, it is obvious that to find both fingertips and olecranon tip is easy even in obese patients. Second, the nerve was located while the volunteer was sitting on the chair with the shoulders in 60 degrees of abduction and

Table 4 Published reports on defining the location of the radial nerve with the aid of different landmarks.

Author	Study type	Methods and findings
Van Sint Jan S [13]	Cadaver	RN entry-emergence to LC and MC: 97.9 vs. 108.5 Using MC—LC ratio, REM should occur at 78%, and REN should occur at 140.4%
Guse TR [12]	Cadaver	RN entry-emergence to LC, MC, acromion REM-LC: 126, REM-MC: 131, REN-MC: 181 REN-acromion: 124, REM-acromion: 176 REM: 42% of humeral shaft proximal to LC, 43% of humeral shaft proximal to MC REN: 41% of humeral shaft distal to acromion, 43% of humeral shaft proximal to MC
Arora S [7]	Trauma px	RN to apex of triceps aponeurosis: If body height >180: 2.7, 166—180: 2.57 and 151—165: 2.48
Bono CM [14]	Cadaver	RN to identifiable bony landmarks: RN traversed the lateral intermuscular septum 17 cm from the proximal humerus, 12 cm from the olecranon fossa and 16 cm from the distal humerus
Carlan D [1]	Cadaver	RN to LC and DDT: REN to LC: 17.1, REM to LC: 10.9, RN at spiral groove to DDT: 0.1
Chaudhry T [8]	Cadaver	RN to triceps aponeurosis, LC to REN, LC to REM, 2.4 cm, 15.6 cm, 11.1 cm, respectively
Cox CL [9]	Cadaver	RN to greater tuberosity, RN at lateral intermuscular septum to LC: 14.7 cm and 11.8 cm
Fleming P [10]	Cadaver	RN at LIS to junction of proximal 2/3 and distal 1/3 of a line between lateral acromion and LC: 2.6 mm
Gerwin M [11]	Cadaver	RN to MC and LC: 20.7 and 14.2 cm

DDT = distal deltoid tuberosity; LC = lateral condyle; LIS = lateral intermuscular septum; MC = medial condyle; REM = radial nerve emergence; REN = radial nerve entrance; RN = radial nerve.

slight internal rotation. In clinical setting, for posterior approach to the humerus, surgeons prefer to set the patient in prone position while the shoulders are in 90 degrees of abduction and internal rotation. Although reference points do not change, the nerve can be exposed to traction. Again, the lengthening of the nerve does not affect the location in the spiral groove. Finally, the contribution of the soft tissue injury in severely displaced humerus shaft fractures may affect the distance between the nerve and olecranon tip, but gentle traction and position of the upper arm will generally be adequate for taking the humerus in its nearly anatomic position.

In summary, unlike previous reports on localisation of the RN at the upper arm, our technique has the advantage by using an individualised approach. The measurements from the tip of the fifth finger and wrist crease have enough reliability to predict the exact location of the nerve in the spiral groove. We think that this observational study is reproducible by using strict landmarks. Further studies on trauma patients may reveal the importance of this technique.

Conflict of interest

The authors report no conflicts of interest in this work.

Ethical approval

This study was approved by the Ethics Committee of Erciyes University under the case number 2017/64.

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