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ORIGINAL ARTICLE

Which parameters are more reliable in proximal humerus surgery in terms of the axillary nerve?

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ABSTRACT

Objectives: This study aims to examine the reliability of the old and new parameters in determining the axillary nerve safe area for surgical interventions in the proximal humerus by measuring the distances between the top of the humeral head, the top of the greater tuberosity, the base of the greater tuberosity, and the acromion and axillary nerve.

Materials and methods: Between 2020 and 2022, a total of 52 shoulders of 26 fresh frozen male human cadavers (mean age: 46±25.5 years; range, 28 to 64 years), 26 right and 26 left were included. The deltopectoral approach was used. The intersection distances of the anterolateral end of the acromion, the top of the humeral head, the top of the tuberculum majus, and the base of the tuberculum majus with the N. axillaries were determined. All measurements were performed using the Microscribe® G2X.

Results: The mean distance from the top of the tuberculum majus to the axillary nerve (shown as "A") was measured as 4.36±0.17 cm and 4±0.21 cm on the right and left, respectively. The mean distance from the center of the base of the tuberculum majus to the axillary nerve (shown as "B") was measured as 1.27±0.18 cm and 1.24±0.11 cm on the right and left, respectively. The mean distance from the apex of the humeral head to the axillary nerve (shown as "C") was measured as 6.15±0.39 cm and 5.89±0.34 cm on the right and left, respectively. The mean distance between the anterolateral end of the acromion (shown as "D") was measured as 6.15±0.39 cm and 5.89±0.34 cm on the right and left, respectively. There was a moderate positive correlation between distances A and B measured on the right and left side, respectively (r=0.484; p=0.012) (r=0.454; p=0.020).

Conclusion: A strong positive correlation was found between the distances A and B. The A, B, and C parameters had a weak correlation with parameter D. The anatomical parameters A and B was found to be less variable and more reliable than parameter D.

Keywords: Axillary nerve, morphometric evaluation, proximal humeral surgery, safe surgical area.

Proximal humerus fractures are the most common upper extremity fractures and account for approximately 4 to 5% of all fractures.[1] Proximal humerus fractures can be treated conservatively, particularly in the elderly.[2,3] Surgical options come to the forefront in comminuted and unstable fractures. Transosseous suture fixation, closed reduction and percutaneous fixation, open reduction with conventional or locking plate fixation, locking intramedullary nail, hemi, and total shoulder arthroplasty is among the different surgical options for surgically planned proximal humerus fractures.[4] The use of plating systems in the treatment of proximal humerus fractures has become more common owing to the effectiveness of locked plate applications.[5,6]

The axillary nerve arises from the posterior cord of the brachial plexus. The nerve passes the quadrilateral space posterolaterally at the lower border of the subscapularis muscle. It is divided into two major anatomical trunks.[7,8] Before terminating as the superior lateral brachial cutaneous nerve, the posterior trunk supplies a branch to the teres minor

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muscle as well as the posterior aspect of the deltoid muscle. The anterior trunk loops around the surgical neck of the humerus and give off branches that supply the medial and anterior aspects of the deltoid muscle.[8] The deltoid muscle is innervated by the axillary nerve.

The axillary nerve must be protected during the placement of plates used in fracture fixation and locking screws in locking nails. The deltopectoral approach for proximal humerus osteosynthesis is the most commonly used.[9,10] Both shoulder arthroscopy and open shoulder surgery can injure the axillary nerve.[7,10]

Neurological injury is more common in open shoulder surgery. Studies examining ongoing neurological injury in open surgical procedures have shown rates ranging from 3.1 to 10%, while clinical neurological injury after shoulder arthroplasty ranges from 0.4 to 4.3%.[11]

Several studies have shown that implant placement in the proximal humerus carries a risk of iatrogenic axillary nerve injury.[12] Determining the relationship between the axillary nerve and proximal humeral anatomy is of utmost importance in minimizing the risk of injury to the axillary nerve during the surgical procedure.[13-15]

In the present study, we aimed to examine the distance from the anterolateral end of the acromion to the axillary nerve, the distance from the base of the greater tuberosity to the axillary nerve, the distance from the peak of the humeral head to the axillary nerve, and the distance from the type of greater tuberosity to the axillary nerve to minimize the risk of injury to the axillary nerve during placement of plates and other implants and to determine the safe surgical site and to identify the correlation between the parameters and the changes in each parameter.

MATERIALS AND METHODS

This human cadaveric study was conducted at Akdeniz University Faculty of Medicine, Department of Anatomy between 2020 and 2022. A total of 52 shoulders of 26 fresh frozen male human cadavers (mean age: 46±25.5 years; range, 28 to 64 years), 26 right and 26 left were included. Those with a history of trauma, tumor, infection, or surgery were excluded. Before preparation, all subjects were frozen at -20°C and thawed at room temperature for 24 h. The subjects were prepared with the elbow in 90° flexion and the arm next to the body in neutral rotation with the shoulder. The anatomical parameters of the coracoid process, the anterolateral end of the acromion, scapula, and acromioclavicular joint were determined before the skin incision. The coracoid process was palpated and a deltopectoral incision was made from the clavicula to the interosseous of the deltoid muscle, while the cadaver was in the supine position and the elbow was flexed 90°. The humeral head and tubercules were exposed after the skin, subcutaneous fascia, and deltoid muscle were dissected. The axillary nerve was dissected with care (Figure 1). The MicroScribe®-G2X (MicroScribe, USA), which can measure to the thousandth of a millimeter, was used to determine the distances between the acromion, the peak of the humeral head, the top of the greater tuberosity, and the base of the greater tuberosity to the axillary nerve (Figure 2). Two different researchers recorded the measurements independently. For each measured variable, the mean and standard deviation (SD) values were calculated.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation, median (min-max) or number and frequency, where applicable. The Pearson and Spearman correlation analyses were performed between the determined anatomical points and axillary nerve distance. A p value of <0.05 was considered statistically significant.

RESULTS

The anterior branch of the axillary nerve in the quadrilateral space was accompanied by the posterior circumflex humeral vessels in all subjects, and the nerve was located above the vessels. The axillary nerve was easily palpable as a cord-like structure a few centimeters away in the loose alveolar tissue between the deltoid and humerus and was visible in all subjects for both observers.

The distance from the greater tuberosity type to the axillary nerve is shown as "A" (Figure 2) and the mean measurements were 4.4±0.2 cm and 4±0.2 cm on the right and left, respectively.

The distance from the base of the greater tuberosity to the axillary nerve is shown as "B" (Figure 2) and the mean measurements were 1.3±0.2 cm and 1.2±0.1 cm on the right and left, respectively.

The distance from the peak of the humeral head to the axillary nerve is shown as "C" (Figure 2) and the mean measurements were 6.2±0.4 cm and 5.9±0.3 cm on the right and left, respectively.

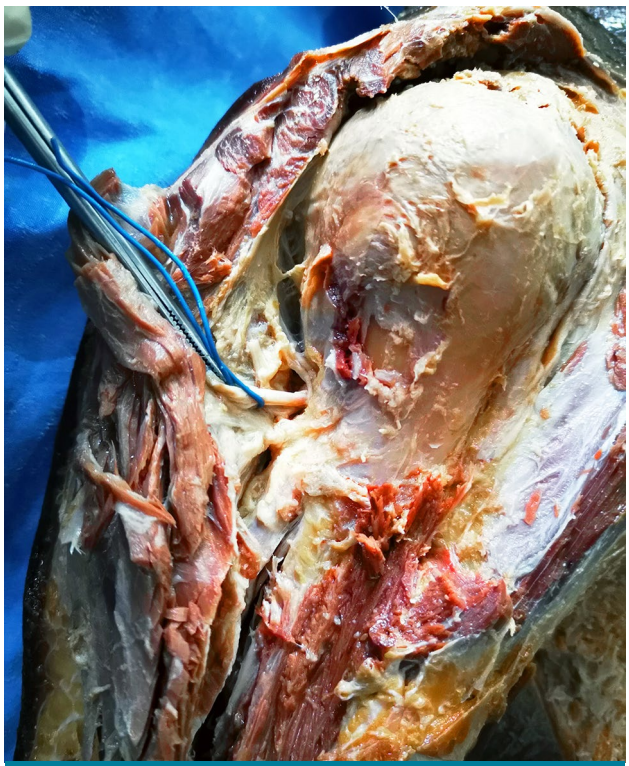

FIGURE 1. Axillary nerve.

FIGURE 2. Parameters with distance from axillary nerve.

The distance between the anterolateral end of the acromion and the axillary nerve is shown as "D" (Figure 2) and the mean measurements were 7.0±1 cm and 6.8±1.0 cm on the right and left, respectively. The above measurements are shown in Table I.

There was a moderate positive correlation between distances A and B measured on the right and left side, respectively (r=0,484; p=0,012) (r=0,454; p=0,020). There was no significant correlation between distance D and other measurements right and left side (p>0.05) (Table II and Table III).

DISCUSSION

Some studies refer to the type of acromion in determining the location of the axillary nerve on the proximal end of the humerus. Most authors calculated the average distance of the axillary nerve from different parts of the acromion, such as lateral, anterolateral, posterior, and posterolateral, and reported different length distance definitions.[16] Ferreira et al.[17] found that the average distance from the axillary nerve to the lateral edge of the acromion in the right shoulder was 7.18 cm and 7.32 cm in the left. In our study, we took measurements from

TABLE I
Descriptive data of the measurements (n=26)

	Right			Left		
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max
A	4.4±0.2	4.3	4.1-4.7	4±0.2	4.1	3.6-4.3
B	1.3±0.2	1.2	1.1-1.8	1.2±0.1	1.2	1.1-1.5
C	6.2±0.4	6.3	5.6-6.7	5.9±0.3	5.9	5.4-6.5
D	7.0±1	7.5	5-7.8	6.8±1.0	7.2	4.8-7.7

A: The mean distance from the top of the tuberculum majus to the axillary nerve; B: The mean distance from the center of the base of the tuberculum majus to the axillary nerve; C: The mean distance from the apex of the humeral head to the axillary nerve; D: The mean distance between the anterolateral end of the acromion.

TABLE II
Correlation between the measurements on the right side

	A	B	C	D
A				
r	1			
p	-			
B				
r	0.484	1		
p	**0.012**[1]	-		
C				
r	-0.054	0.136	1	
p	0.794	0.508	-	
D				
r	-0.151	0.173	0.045	1
p	0.461[2]	0.399[2]	0.826[2]	-

A: The mean distance from the top of the tuberculum majus to the axillary nerve; B: The mean distance from the center of the base of the tuberculum majus to the axillary nerve; C: The mean distance from the apex of the humeral head to the axillary nerve; D: The mean distance between the anterolateral end of the acromion; [1] Pearson correlation test; [2] Spearman correlation test.

TABLE III
Correlation between the measurements on the left side

	A	B	C	D
A				
r	1			
p	-			
B				
r	0.454	1		
p	**0.020**[1]	-		
C				
r	0.243	0.052	1	
p	0.231[1]	0.799[1]	-	
D				
r	0.123	0.167	-0.040	1
p	0.549[2]	0.414[2]	0.846[2]	-

A: The mean distance from the top of the tuberculum majus to the axillary nerve; B: The mean distance from the center of the base of the tuberculum majus to the axillary nerve; C: The mean distance from the apex of the humeral head to the axillary nerve; D: The mean distance between the anterolateral end of the acromion; [1] Pearson correlation test; [2] Spearman correlation test.

the anterolateral edge. The mean distance from the anterolateral edge of the acromion to the axillary nerve in our study was 7.0±1 cm on the right shoulder and 6.8±1.0 cm on the left.

Burkhead et al.[18] examined the axillary nerve in 51 mummified and five fresh cadaver subjects. They found that, in roughly one-fifth of the cadavers, the nerve was less than 5.00 cm and a minimum distance of 3.10 cm from the edge of the acromion at some point in its course around the humerus in the deltoid muscle. The materials used in this study differ (fresh cadavers) in some ways. We believe that distances measured using fresh-frozen cadavers that were not formalin-fixed or embalmed were more reliable in our study. The study by Burkhead et al.[18] did not identify a defining point as to where on the edge of the acromion.

Duparc et al.[15] reported a 3.40-cm mean distance between the axillary nerve and the deltoid muscle insertion on the acromion. However, Hoppenfeld and deBoer[14] found that this distance was 7.00 cm. The large margin of these data creates many uncertainty. The axillary nerve is not at a constant distance from the end of the acromion at every point along its course, according to Çetik et al.,[9] and the mean distance between the axillary nerve and the anterolateral end of the acromion was 6.1±0.5 cm. In our study, it was 7.0±1 cm on the right and 6.8±1.0 cm on the left.

According to Theeuwes et al.[13] and Schippinger et al.,[19] the reason for not using the acromion as a reference point in their study is that the natural anatomical shape of the acromion varies from person to person. The anatomical difference in the acromion ends in our cadavers was observed macroscopically. Vathana et al.[20] previously described the natural variation in the relative positions of the acromion and the axillary nerve and suggested that this was a good reason not to use the acromion as a reference point and concluded that it was not a favorable surgical landmark.

Theeuwes et al.[13] were the first to take individual variability in the subacromial space into account and correlate the position of the anterior branch of the axillary nerve with the deltoid muscle. They also revealed that while performing lateral approaches, the danger zone for potential nerve damage was much larger than previously thought and that in dynamic clinical situations where the subacromial space varied, using the peak of the humeral head rather than the acromion might provide a more accurate representation of the axillary nerve position.

In 10 mummified subjects, Theeuwes et al.[13] performed anatomical dissection of the axillary nerve and its branches. In the lateral view, the anterior (main) axillary branch measured 6.3 (range, 4.7 to 7.9) cm

from the peak of the humeral head. Stecco et al.[21] found that the average distance between the point where the axillary nerve entered the deltoid muscle and the humeral head was 5.0 cm and 6.8 cm from the acromion process in a study of 16 non-mummified cadavers. The mean distances between the peak of the humeral head and the midpoint of the bone in the proximal humerus in our subjects were 6.2±0.4 cm on the right and 5.9±0.3 cm on the left. Although we consider that mummification is a factor for this discrepancy, we believe that the data we obtained are more reliable due to the larger number of cases.

The distance from the superior aspect of the greater tuberosity to the axillary nerve was measured by Moatshe et al.[22] as 50.3 mm, while the distance from the lateral acromion to the axillary nerve was reported to be 69.3 mm on average. Although several studies refer to the greater tuberosity in the literature, it is not specified where the greater tuberosity is referenced.

The axillary nerve was measured from the acromion edge, the peak of the other humeral head, the greater tuberosity type, and the greater tuberosity base respectively right and left. The importance of the distances of these parameters to the axillary nerve is the thought that the distance between the humerus and the acromion may be variable due to soft tissue or bone structure deterioration from trauma, contracture development, or deltoid muscle atrophy is one of the reasons for making these choices. In our study, we attempted to examine whether the distances to the axillary nerve measured using different other parameters correlated with each other, in addition to our new parameter from the base of the greater tuberosity.

The lack of data on different age groups and different sexes is the main limitation to the present study.

In conclusion, our study results showed a positive correlation between the distances A and B measured from the right and left sides. The anatomical parameters A, B, and C were found to be less variable and more reliable than parameter D. Further studies are warranted to confirm these findings.

Ethics Committee Approval: The study protocol was approved by the Clinical Research Ethics Committee of the University of Health Sciences Türkiye, (date: 08.09.2022, no: 2022-274). The study was conducted by the principles of the Declaration of Helsinki.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Provided input into the concept and design of the study, and provided the materials: M.Ö., İ.E., C.A.; Collected and assembled the data: M.Ö., İ.E.; Analyzed the data: M.Ö., İ.E., C.A.; Carried out literature review: M.Ö.., C.A.; Wrote the article: M.Ö., İ.E., C.A.; All authors have critically revised the article, read and approved the final version at the time of submission.

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