Anatomical Relationship of the Axillary Nerve to the Pectoralis Major Tendon Insertion

BRIAN SHIU, MD; EHSAN JAZINI, MD; ASTOR ROBERTSON, MD; R. FRANK HENN, MD; S. ASHFAQ HASAN, MD

Abstract

Axillary nerve injury is a risk of the deltopectoral approach to the proximal humerus. The anterior motor branch is potentially vulnerable during subdeltoid dissection. Insertion of the pectoralis major tendon is an easily identifiable landmark on the humerus. This anatomical study explored whether the superior aspect of the pectoralis major tendon is a useful landmark for localizing the anterior motor branch of the axillary nerve as it travels under the lateral and anterior deltoid muscle. A total of 30 fresh-frozen human bilateral cadaveric upper extremities were examined. A deltopectoral approach was used to expose the pectoralis major tendon insertion and the anterior motor branch of the nerve under the deltoid muscle. The distance between the nerve as it crossed the posterolateral humerus and superior border of the pectoralis major tendon was measured. The axillary nerve was a mean 3.2 mm (range, 0-8 mm) distal to the superior border of the pectoralis major tendon insertion. No significant differences were observed in this anatomical relationship with the shoulder in abduction or external rotation. The nerve was not proximal to the superior border of the pectoralis major tendon in any specimen. The superior border of the pectoralis major tendon insertion represents a reliable landmark for the anterior motor branch of the axillary nerve as it travels under the deltoid muscle. The nerve is located at the level of the proximal centimeter of the pectoralis major tendon. Appreciation of this relationship may decrease risk of injury to the nerve when using a deltopectoral approach. [Orthopedics. 2017; 40(3):e460-e464.]

The axillary nerve is vulnerable to injury during a deltopectoral approach to the shoulder, and iatrogenic injury has been described.1-4 The vulnerability of the nerve as it crosses the inferior aspect of the subscapularis muscle belly and then dives under the inferior glenohumeral capsule is well appreciated and widely thought of as the most common location of iatrogenic injury. However, the anterior motor branch of the nerve is also vulnerable as it travels under the deltoid muscle, and it is possible that the nerve could be injured at that location, either directly during subdeltoid dissection or indirectly from a stretch injury during deltoid retraction.

Improved understanding of the subdeltoid position of the axillary nerve in relation to the deltopectoral approach might contribute to the safety of the approach and potentially limit iatrogenic nerve injury. Clinically, the senior author (S.A.H.) noted a fairly consistent relationship between the superior aspect of the pectoralis major tendon insertion on the humerus and the position of the axillary nerve under the deltoid muscle. This study examined whether a consistent relationship exists between the pectoralis major tendon humeral insertion and the anterior motor branch of the axillary nerve and whether...
the tendon can be used as a visual reference for location of the nerve as it travels under the deltoid muscle.

**Materials and Methods**

Thirty fresh-frozen human bilateral cadaveric adult shoulders (15 matched pairs) with the entire upper extremity were obtained. The shoulders were thawed at room temperature, and dissection was performed after the specimens were fully thawed. None of the specimens had any evidence of previous surgical procedures to the extremity, and no gross deformities were evident.

An incision was made over the deltopectoral interval. After skin flaps were raised, the deltopectoral interval was developed, exposing the insertions of the pectoralis major tendon and the deltoid muscle. The subdeltoid space was developed from the acromion down to the deltoid insertion, and the axillary nerve was identified. The superior aspect of the pectoralis major tendon humeral insertion was identified, and a tangent to this was marked on the lateral humeral shaft. The upper thickened portion of the tendon, not the thinner more membranous falciform ligament, was used as the reference point for all measurements. The falciform ligament has a distinctive upward curve to it, as opposed to the sternal head, which inserts perpendicular to the humerus.

The distance between the superior aspect of the pectoralis major tendon and the level at which the anterior branch of the axillary nerve crossed the lateral humerus was measured with the arm in 3 different positions: (1) adduction and neutral rotation (Figure 1), (2) adduction and 45° of external rotation (Figure 2), and (3) 45° of abduction and neutral rotation (Figure 3). The arm was placed first in adduction and neutral rotation (“arm by the side”) with the deltoid muscle gently retracted laterally to afford exposure and visualization of the axillary nerve; this measurement was obtained in all 30 specimens. In a subset of 8 shoulder specimens, measurements were obtained in the 2 additional positions to account for arm position manipulation during surgical procedures. The deltoid muscle was not released either proximally or distally to ensure that normal length ratios were not altered.

The distance between the axillary nerve and the superior border of the pectoralis major tendon insertion was measured using a digital measurement caliper (Mitutoyo America Corporation, Aurora, Illinois). Each measurement was obtained twice and then averaged. All measurements were performed by 1 investigator (B.S.) and dictated to another investigator (E.J.). The second investigator input all measures into an Excel spreadsheet (Microsoft, Redmond, Washington) and confirmed that the measures were accurate, obtaining perfect intraobserver agreement (Cohen kappa value of 1.00).

**Statistical Analysis**

Statistical significance was set at \( P < .05 \). Independent samples \( t \) tests were conducted to compare the measured mean distances. Interobserver correlation coefficient was calculated between the dictated measurements by rater 1 and the reconfirmed and observed measurements by rater 2. Post hoc analyses were conducted, evaluating all different comparisons. A maximum type II error of 20% was used to determine whether the findings were sufficiently powered. Analysis was conducted using Excel Analysis ToolPak statistical software (Microsoft) and SPSS 2013 IBM SPSS Statistics for Windows.
RESULTS
The axillary nerve passed distal to or at the level of the superior border of the pectoralis major tendon insertion in all specimens in all positions. The nerve was not found to be proximal to the superior aspect of the tendon insertion in any specimen.

For the entire group of 30 shoulders, the mean distance between the main trunk of the axillary nerve and the superior border of the pectoralis major tendon insertion in adduction and neutral rotation was 3.2 mm (range, 0-8 mm). For the subset of 8 shoulders in which nerve position was measured with the arm in 2 different positions, the results were similar. The mean distance between the axillary nerve and the tendon with the arm in 45° of abduction and neutral rotation was 3.6 mm (range, 0-8 mm) (SD, 2.7 mm). The maximum observed distance of the axillary nerve distal to the insertion was 8 mm. The axillary nerve was not observed to be proximal to the insertion in any specimen. It was at the level of the superior aspect of the tendon in 4 specimens. No statistically significant differences were found with the shoulder tested in 3 different positions: adduction and 45° of external rotation, adduction and 45° of external rotation vs abduction and neutral rotation (P=.36). For all described differences, post hoc analyses showed the findings for all measures were not sufficiently powered because of the small sample size (power<.80) (Table).

DISCUSSION
The deltopectoral approach is routinely used for multiple indications, including anterior stabilization of the glenohumeral joint, shoulder arthroplasty, and proximal humeral fracture fixation. Axillary nerve injury is a recognized potential complication associated with this approach, and identification and protection of the nerve during surgery are important.1–4

The anatomy of the axillary nerve after it branches from the posterior cord of the brachial plexus has been well described. The nerve first courses over the anteroinferior subscapularis muscle, just medial to the musculotendinous junction, before diving under the inferior shoulder capsule and then exiting posteriorly through the quadrangular space. It typically divides into an anterior and posterior branch as it traverses the quadrangular space. Although varying branching patterns are seen, the posterior branch typically gives off a branch to the posterior deltoid, the teres minor, a cutaneous branch, and the anterior motor branch that travels on the undersurface of and innervates the middle and anterior heads of the deltoid muscle.5–7

During a deltopectoral approach, the axillary nerve is vulnerable to injury anteroinferiorly as it travels across the subscapularis muscle and under the glenohumeral capsule. The anterior motor branch of the axillary nerve is also vulnerable laterally as it runs under the deltoid muscle. It is usually easily palpable as it courses over the inferior subscapularis muscle belly; awareness of the importance of identifying and protecting the nerve at that location is high. In contrast, the anterior branch of the axillary nerve is not as easily palpable as it travels on the undersurface of the deltoid muscle. During deltotoid mobilization, aggressive subdeltoid dissection could injure the nerve, as could retractor placement.

The current study demonstrates that regardless of shoulder position, the superior aspect of the pectoralis major tendon insertion can serve as a reliable landmark for localization of the anterior branch of the axillary nerve as it travels on the undersurface of the deltoid muscle, with an average location of approximately 3 mm distal to the insertion and only a small standard deviation. The maximum observed distance of the axillary nerve distal to the insertion was 8 mm. The axillary nerve was not observed to be proximal to the insertion in any specimen. It was at the level of the superior aspect of the tendon in 4 specimens. No statistically significant differences were found with the shoulder tested in 3 different positions: adduction and neutral rotation, adduction and external rotation, or abduction and neutral rotation. These findings further support the consistency of the relationship of the axillary nerve to the pectoralis major tendon insertion.

The superior aspect of the pectoralis major tendon insertion onto the humerus can be visualized easily during a deltopectoral approach. This is also true for cases of comminuted proximal humeral fractures in which the pectoralis major tendon insertion typically is preserved. The data from the current study provide guidance.

<table>
<thead>
<tr>
<th>Anatomical Position</th>
<th>Mean Measurement (Range), mm</th>
<th>P</th>
<th>Post Hoc Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Adduction and neutral rotation</td>
<td>3.2 (0-8)</td>
<td>.37</td>
<td>0.47</td>
</tr>
<tr>
<td>B. Adduction and 45° of external rotation</td>
<td>2.4 (0-7)</td>
<td>.70</td>
<td>0.71</td>
</tr>
<tr>
<td>C. 45° of abduction and neutral rotation</td>
<td>3.6 (0-8)</td>
<td>.36</td>
<td>0.53</td>
</tr>
</tbody>
</table>

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to surgeons regarding the location of the anterior motor branch of the axillary nerve and might help surgeons protect the nerve by avoiding sharp dissection in that area.

Surgeons also should avoid placing retractors, especially self-retaining retractor, under the deltoid muscle at or immediately distal to the superior aspect of the pectoralis major tendon insertion as prolonged static retraction potentially could increase the risk of traction injury to the axillary nerve. This might be particularly relevant in patients with a proximal humeral fracture or dislocation, in which axillary nerve injury is not uncommon; reported rates range from 14% to 82%.

Using electromyography (EMG), Visser et al\(^6\) reported an axillary nerve injury rate of 82% for low-energy displaced proximal humeral fractures. Warrender et al\(^4\) performed intraoperative monitoring of the brachial plexus during open operative treatment of proximal humeral fractures and found axillary nerve EMG changes in 46% of patients. During surgery for proximal humeral fractures, it might be beneficial to limit additional intraoperative traction on the nerve from retractors to avoid a “second crush” nerve injury. Although no attempt was made in the current study to measure nerve tension from retraction, based on the anatomic findings, it might be advisable to place deltoid retractors distally at the level of the deltoid muscle insertion and proximally in the subacromial space and to avoid placing retractors, especially self-retaining retractors, at the proximal aspect of the pectoralis major tendon insertion.

Most of the literature on axillary nerve anatomy has focused on establishing a safe zone to avoid injury to the anterior branch of the axillary nerve when working through a limited deltoid-splitting approach. The nerve location generally is accepted as being an average of 5 cm (range, 3.5-7.1 cm) distal to the acromion.\(^5,9,11\) Burkhedt et al\(^6\) reported the nerve was an average distance of 5.7 cm from the anterolateral corner of the acromion and 5.8 cm from the midportion of the acromion laterally. In female specimens, the nerve was an average 1 cm closer to the acromion than in male specimens.

Cetik et al\(^6\) attempted to define a safe zone for deltoid-splitting operations. They reported average distances of 60.8 and 48.7 mm from the nerve to the anterior acromion and posterior acromion, respectively. Stecco et al\(^11\) investigated axillary nerve position in relation to the humeral head and acromion and reported the nerve to be a mean of 5.6 and 6.9 cm distal, respectively.

However, these findings might have limited applicability in deltopectoral approaches because deltoid length can be difficult to measure. This might be especially true with proximal humeral fractures in which normal deltoid tension is lost and the humeral head-nerve distance is not reliable. In contrast, the pectoralis major tendon insertion usually is easily identifiable with primary deltopectoral approaches and usually is preserved in cases of proximal humeral fractures.

Although abundant data are available regarding axillary nerve position with deltoid-splitting approaches, limited data are available on the position and potential vulnerability of the axillary nerve with more distal exposures. No previous studies have addressed the relation of axillary nerve position to the superior aspect of the pectoralis major tendon. Dickens et al\(^12\) investigated the relation of neurovascular structures to bone tunnel placement in subpectoral biceps tenodesis. The distance from the tenodesis site (described as 1 cm proximal to the inferior border of the pectoralis muscle) to the axillary nerve was 33.8 mm. Although providing insight into a subpectoral approach, this information is less useful during a deltopectoral approach because the area is not universally exposed during proximal humeral exposures.

A potential limitation of the current study is that no attempt was made to dissect the individual small branches of the nerve because the arborization anatomy of the nerve has been well described previously.\(^7,11\) Instead, measurements were made in relation to the main trunk of the axillary nerve as it ran under the deltoid muscle. Injury to individual small branches is possible but likely to be of varying clinical significance depending on the location and extent of injury.

In contrast, injury to the main trunk of the nerve would likely have serious clinical ramifications. The deltoid muscle was retracted laterally to visualize the nerve. Intraoperative retraction of the deltoid muscle could arguably change the relative nerve position. However, the current data show that the nerve can be well localized during the initial deep approach using the pectoralis major tendon as a reference and that once the nerve has been localized, the surgeon should be better able to protect it.

In addition, it is important to recognize that the landmarks and measurements described in this study are limited to the primary setting. In a revision setting with potentially disrupted anatomy, these landmarks are no longer reliable or accurate.

**Conclusion**

The superior border of the pectoralis major tendon insertion represents a reliable landmark for the anterior motor branch of the axillary nerve as it travels around the lateral humerus. Appreciation of this relationship might decrease the risk of injury to the axillary nerve during a deltopectoral approach.

**References**

5. Ball CM, Steger T, Galatz LM, Yamaguchi K.


