Safety of open suprapectoral and subpectoral biceps tenodesis: an anatomic assessment of risk for neurologic injury

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Background: Surgical techniques for proximal biceps tenodesis that include penetration of the posterior humeral cortex for fixation may pose risk to the surrounding neurovascular structures.

Hypothesis: The risk of neurologic injury with techniques that involve penetration of the posterior humeral cortex for fixation in proximal biceps tenodesis will increase as the tenodesis site moves proximally from the subpectoral to the suprapectoral location.

Methods: Proximal biceps tenodesis was performed on 10 cadaveric upper extremities with 3 separate techniques. The proximity of the hardware to the relevant neurovascular structures was measured. The distances between the tenodesis site and the relevant neurovascular structures were measured.

Results: The guide pin was in direct contact with the axillary nerve in 20% of the suprapectoral tenodeses. The distance between the axillary nerve and the tenodesis site was 10.5 ± 5.5 mm for the suprapectoral location, 36.7 ± 11.2 mm in the subpectoral scenario, and 24.1 ± 11.2 mm in the 30° cephalad scenario (P = .003). The distance between the radial nerve and the anterior tenodesis site was 41.3 ± 9.3 mm for the suprapectoral location and 48.0 ± 10.7 mm for the subpectoral location. The distance of the musculocutaneous nerve from the tenodesis site was 28.4 ± 9.2 mm for the suprapectoral location and 37.4 ± 11.2 mm for the subpectoral location.

Conclusion: In a cadaveric model of open biceps tenodesis, penetration of the posterior humeral cortex at the suprapectoral location results in proximity to the axillary nerve and should be avoided. Subpectoral bicortical button fixation drilled perpendicular to the axis of the humerus was a uniformly safe location with respect to the axillary nerve.

Level of evidence: Basic Science, Anatomy.

Keywords: Biceps; tenodesis; subpectoral; suprapectoral; nerve; cortical button

Open subpectoral biceps tenodesis (OSPBT) is a well-established treatment for disease of the long head of the biceps brachii tendon. Many fixation techniques are available; cortical button fixation is a reliable, biomechanically strong and effective technique. Subpectoral repair with both unicortical and bicortical fixation has been described with success. Mithoefer reported that bicortical button fixation optimizes the strength of initial tendon fixation and minimizes gap formation. It was further proposed that this minimally invasive fixation of the long head of the biceps, with unique tensioning
technique, may help accelerate return to activities. Whereas the bicortical button fixation technique is appealing for these reasons, penetration of the posterior humeral cortex introduces potential new neurologic complications.

Two recent studies have examined the proximity of the axillary nerve to the subpectoral biceps tenodesis site with differing results. In one study, the nerve is directly in line with the tenodesis site; in the other, it lies 33.8 mm away. Resolution of this difference is important in evaluating the safety of any tenodesis technique that involves penetration of the proximal posterior humeral cortex.

The purpose of this study was to use a cadaveric model to define the anatomic relationships of the suprapectoral and subpectoral tenodesis sites with respect to the axillary, radial, and musculocutaneous nerves. These relationships were evaluated in 3 separate scenarios: an open suprapectoral tenodesis location, a perpendicularly drilled subpectoral tenodesis, and a subpectoral tenodesis with the drill aimed 30° cephalad. Our hypothesis was that penetration of the posterior humeral cortex may put neurologic structures at risk, particularly as the tenodesis site moves more proximally from the subpectoral to the suprapectoral location.

Materials and methods

This was a cadaveric anatomic study. Ten frozen, unpaired, human cadaveric upper extremities were studied; the elbow and hand remained on the specimen to maintain neurovascular relationships. All specimens were thawed for 24 hours at room temperature before experimentation. No limbs underwent prior shoulder surgery.

The specimens were placed supine on the operating table, and an open subpectoral biceps approach was performed as previously described. This was performed to imitate the clinical setting. Each step of this study was performed by board-certified fellowship-trained upper extremity surgeons. The key component of the procedure was that the subpectoral tenodesis was started on the anterior humeral cortex, 1 cm proximal to the inferior border of the pectoralis major and centered at the inferior aspect of the bicipital groove. The pectoralis was pulled taught to make this measurement. A guide pin was then drilled perpendicularly into the shaft of the humerus to represent the site of tenodesis, and the intramedullary depth was measured. A 12-mm bicortical button (Arthrex, Naples, FL, USA) was then placed in accordance with the reported technique. A careful dissection was then carried out to identify the relevant neurologic anatomy with careful attention not to disrupt normal anatomic relationships. The axillary, radial, and musculocutaneous nerves were methodically identified.

The distances between the tenodesis site and the axillary (posteriorly), radial, and musculocutaneous (anteriorly) nerves were measured with standard digital calipers. In an effort to accurately measure the more anterior structures, the guide pin was inserted into the drilled hole and used as an anterior reference point for the digital calipers (Figs. 1 and 2). Posteriorly, the
contact the axillary nerve, we chose not to use a button in this scenario as this site was deemed a neurologically unsafe zone for button placement. Nonetheless, the same sequence of measurements was obtained for all 10 specimens in this location.

The measurements taken at the different tenodesis sites represent 3 operative scenarios: suprapectoral tenodesis, 0° subpectoral tenodesis, and 30° cephalad drilled subpectoral tenodesis (Table I).

The length of the humerus, the intramedullary depth, and the distance from the humeral head to the origin of the tenodesis site were also measured.

Statistical analysis was performed by paired t test, with SPSS version 21.0, setting a P value < .05.

Results

Ten cadaveric upper extremities were studied; 5 right-sided and 5 left-sided extremities were used, 6 female and 4 male. All specimens were from distinct subjects. The mean age at the time of death was 76.8 ± 11.6 years.

The distance between the axillary nerve and the tenodesis site was 36.7 ± 11.2 mm in the 0° subpectoral scenario and 24.1 ± 11.2 mm in the 30° cephalad scenario (P < .001) (Table I and Fig. 2). The distance between the axillary nerve and the tenodesis site in the suprapectoral tenodesis was 10.5 ± 5.5 mm (Fig. 3 and Table II). This was significantly different from both subpectoral tenodesis sites (P < .0001, 0° tenodesis; P = .003, 30° tenodesis). The axillary nerve directly contacted the drill pin in 2 of the 10 specimens in the suprapectoral procedures. The 2 specimens in which the guide pin contacted the nerve were in the median range of humeral length.

All the medial neurologic structures were measured closer to the anterior starting point of the guidewire. For clarification, this was the same starting point for the perpendicular subpectoral and the 30° cephalad tenodesis sites. The distance between the radial nerve and the anterior tenodesis site was 41.3 ± 9.3 mm for the suprapectoral location and 48.0 ± 10.7 mm for the subpectoral location (P = .003) (Table III). The distance of the musculocutaneous nerve from the tenodesis site was 28.4 ± 9.2 mm for the suprapectoral location and 37.4 ± 11.2 mm for the subpectoral location (P = .08) (Fig. 1).

Discussion

Biceps tenodesis procedures that employ penetration of the posterior humeral cortex raise concern about the proximity of the drill and implant to the nearby neurologic structures. Arora et al noted that a bicortical button may put the tenodesis site millimeters away or in contact with the axillary nerve (2.14 ± 2.04 mm), rendering the bicortical button unsafe. However, Dickens et al reported the tenodesis site to be significantly farther away from the axillary nerve (33.8 ± 6.9 mm), thus indicating the safety of OSPBT with the bicortical button. To settle the discrepancy, we performed this anatomic study. We found that during biceps tenodesis, penetration of the posterior humeral cortex in the suprapectoral location was close to or directly contacted the axillary nerve and do not recommend this approach. In contrast, we found that bicortical button fixation drilled perpendicular to the humeral cortex at the subpectoral location was safe and never closer than 2.0 cm from the axillary nerve.

During subpectoral biceps tenodesis, we found the mean distance to the axillary nerve to be 36.7 mm compared with 33.8 mm in Dickens’ study and 2 mm in Arora’s. Careful evaluation of the methods of each of the studies may explain

<table>
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<th>Nerve</th>
<th>Mean ± standard deviation (mm)</th>
<th>Median (mm)</th>
<th>Range (mm)</th>
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<tr>
<td>Radial, suprapectoral</td>
<td>41.3 ± 9.3</td>
<td>42.6</td>
<td>24.8-52.0</td>
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<td>Radial, subpectoral</td>
<td>48.0 ± 10.7</td>
<td>51.0</td>
<td>31.7-60.8</td>
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<td>Musculocutaneous, suprapectoral</td>
<td>28.4 ± 9.2</td>
<td>26.7</td>
<td>14.0-43.1</td>
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<tr>
<td>Musculocutaneous, subpectoral</td>
<td>37.4 ± 11.2</td>
<td>40.4</td>
<td>22.0-49.0</td>
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<td>Axillary, perpendicular subpectoral</td>
<td>36.7 ± 11.2</td>
<td>35.8</td>
<td>20.5-63.5</td>
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<td>Axillary, 30° cephalad subpectoral</td>
<td>24.1 ± 11.2</td>
<td>22.2</td>
<td>9.7-48.1</td>
</tr>
<tr>
<td>Axillary, suprapectoral</td>
<td>10.5 ± 5.5</td>
<td>11.4</td>
<td>0.2-19.23</td>
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Figure 3 Suprapectoral tenodesis approach demonstrating proximity to the axillary nerve.
the discrepancies. In the cadaveric setting, it is easy to retract the inferior border of the pectoralis more proximally than may be possible in the live surgical setting. We were careful to locate the tenodesis site 1 cm proximal to the inferior edge of a tensioned pectoralis, as originally described by Mazzocca et al.7 The accuracy of our selected position of subpectoral tenodesis in this study is further supported by Johannsen et al,7 who identified the radiographic position of subpectoral biceps tenodesis at a mean of 54.8 mm below the proximal aspect of the pectoralis major footprint length and development.

In this study, we added a 30° cephalad drill angle to see how close the button would get to the nerve if the surgeon errantly drilled proximally. As expected, the distance to the axillary nerve was reduced, in this condition by a mean of 12.6 mm, but still remained at least 10 mm from the axillary nerve in all specimens tested.

Penetration of the posterior humeral cortex with a drill pin in the suprapectoral location had direct contact with the axillary nerve in 2 specimens. The mean distance to the axillary nerve was 10.5 mm from a pin site, which would be reduced to 4.5 mm with use of a 12-mm button. This location puts the nerve at significant risk even when a guide pin penetrates the cortex with use of an intramedullary screw over a bicortical guide pin. Clinically, there is a great deal of variation in surgeons’ exact choice of a suprapectoral tenodesis site—above the groove, high in the groove, or below the groove; we did not study all of these conditions.9 We do not recommend penetration of the posterior humeral cortex in the suprapectoral location when it is drilled at the bottom of the bicipital groove.

We measured the distance to the musculocutaneous nerve. This nerve is inherently at risk during the surgical approach and the most commonly injured nerve. This nerve is at risk during the medial dissection and is not typically injured as a consequence of the hardware employed. Methodical dissection, including careful identification of the interval between the short head of the biceps and the inferior border of the pectoralis, and gentle retraction of the short head of the biceps are the most reliable methods to limit injury to this nerve. The suprapectoral location (37.4 ± 11.2 mm) is farther away from the suprapectoral position (28.4 ± 9.2 mm) of the musculocutaneous nerve.

The posterior cortex of the humerus, where a cortical button may rest, was anatomically distant and unrelated to the musculocutaneous nerve.

We also measured the distance to the radial nerve. The radial nerve is medial to the musculocutaneous nerve and the short head of the biceps and is not typically injured as a consequence of the hardware employed.9 In this study, the radial nerve stayed anterior to the latissimus dorsi tendon
before it wraps around to the posterior cortex of the humerus. In no instances did the subpectoral tenodesis site land distal to the latissimus insertion. Similar to the musculocutaneous nerve, the radial nerve is at risk for injury in an aberrant medial approach, but it is anatomically distinct and safe from the position of a button on the posterior humeral cortex.

This study has limitations. This is a cadaveric study, and neurovascular studies are subject to measurement error. We kept the whole arm intact and were methodical in our dissection, but we acknowledge that OSPBT is often performed after shoulder arthroscopy. Infiltration of the shoulder joint and surrounding structures may alter normal anatomy, and this variable was not controlled for in this study. Furthermore, inherent variation exists in the neuroanatomic course of different nerves as they exit the brachial plexus. We also recognize that the type and placement of instruments will vary on the basis of the surgeon’s preference and experience. The instruments used in this study were selected on the basis of previously described surgical technique for OSPBT.3,7

We did not use hardware in the suprapectoral tenodesis site. It is reasonable to believe that we should have passed a button, akin to the clinical scenario and the methods used to measure the other 2 techniques. We thought that direct contact of the guide pin to the nerve served as satisfactory evidence to suggest that this is a potentially dangerous technique. The value of this study is not predicated on the statistical differences of the mean distance to the axillary nerve; it is an assessment of the safety of this procedure with respect to the nerve. We believe that we have demonstrated this significant risk in an adequate way and that passage of a button would not have helped us deem this technique any more (or less) dangerous.

Finally, this study does not address any clinical debate with respect to tenodesis above or below the bicipital groove, suprapectoral or subpectoral tenodesis location, or unicortical vs bicortical fixation. This is a cadaveric anatomic study. We simply set out to study the safety of bicortical fixation with respect to the nerves mentioned.

Care should be taken in performing the subpectoral approach. The radial and musculocutaneous nerves at greatest risk are medial to the humeral shaft. The surgeon should stay in the interval between the short head of the biceps and the inferior border of the pectoralis. Our recommended safe zone for subpectoral biceps tenodesis with a bicortical button is 1 cm above the inferior margin of the pectoralis, drilled perpendicularly to the axis of the humerus. This will leave a mean of 36.7 mm (and no closer than 20 mm) of distance to the axillary nerve.

**Conclusion**

In performing suprapectoral biceps tenodesis, fixation methods of any type should not penetrate posterior humeral cortex as a pin is close to the axillary nerve.

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### In contrast, at the subpectoral location, bicortical fixation with a button placed perpendicular to the axis of the humerus is a uniformly safe location with respect to the nearby neurologic structures. Button placement with the button inserted 30° cephalad puts the tenodesis site closer to the axillary nerve, and efforts to keep the tenodesis site perpendicular to the humeral cortex should be made.

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