Human cadaveric study of subscapularis muscle innervation and guidelines to prevent denervation

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The upper and lower subscapular nerves provide innervation to the subscapularis muscle. However, the axillary nerve may provide a significant innervation to the lower portion of the muscle. The prevalence and patterns of anomalous innervation of the subscapularis muscle were studied to determine if these variations increased the risk of muscle denervation during open shoulder surgery. Twenty human cadaveric shoulders were dissected, and the innervation to the subscapularis was defined. The distance from the nerve insertion to the shoulder joint was measured in neutral and maximal external rotation. In the most common variation, the lower subscapular nerve arose from the axillary nerve (5 specimens; 25%). Although external rotation of the shoulder brought the nerve insertion significantly more lateral (35.2 to 16.9 mm, \(P < .001\)), the origin of the nerve had no significant effect on nerve proximity to the joint. The closeness of the nerve insertions to the shoulder joint warrants care during an anterior approach to the shoulder and dissections on the anterior surface of the muscle. Subscapularis nerve damage or denervation may cause unexplained joint instability and subscapularis dysfunction. (J Shoulder Elbow Surg 2008;17:659-662.)

The subscapularis muscle is the largest muscle in the rotator cuff, and its role in shoulder function and in the passive and dynamic stability of the joint has been well described. This muscle is commonly encountered during open shoulder surgery. Routine approaches involve splitting the muscle in line with its fibers or detaching it at the insertion. Well-known to be at risk during surgery about this muscle are the axillary nerve and posterior circumflex humeral artery at its inferior margin and the infracavicular brachial plexus and axillary artery medially. Various chronic, postsurgical, and traumatic conditions can lead to scarring and retraction of the subscapularis muscle, making surgery in this area even more difficult. Inadvertent damage to the subscapular nerves may lead to denervation of the subscapularis muscle and unexplained instability or loss of function of the shoulder.

The most commonly described innervation to the subscapularis muscle includes the upper subscapular and the lower subscapular nerves, both originating from the posterior cord of the brachial plexus (Figure 1). Numerous studies, however, have documented significant variability in this pattern for both the upper and lower nerves. The upper nerve most commonly originates from the posterior cord, but it frequently arises as more than one branch. Cadaveric studies have shown even greater variability of the lower subscapular nerve. This nerve has been reported to arise as 1 or multiple branches from the posterior cord, axillary nerve, or thoracodorsal nerve (Figures 2 and 3). In particular, this nerve originates from the axillary nerve in 9% to 55% of cases as 1 or more branches.7,8,15

The purpose of the present study was to determine the prevalence and patterns of anomalous innervation of the subscapularis muscle and to determine if these variations would place the nerves at greater risk during open shoulder surgery.

MATERIALS AND METHODS

Dissections were done in 16 shoulders from 8 whole fresh cadavers and 4 shoulders from frozen cadaveric forequarters. The 20 specimens consisted of 10 right and 10 left shoulders from a total of 10 cadavers. The same approach was used in each specimen, which included developing the deltopectoral interval and releasing the pectoralis major muscle from its origin at the clavicle. Next, the conjoined tendon and the pectoralis minor tendon were reflected from the coracoid process to expose the brachial plexus and subscapularis muscle. The axillary nerve was identified at the inferior border of the subscapularis muscle and traced back to the posterior cord of the brachial plexus. The branches innervating the subscapularis muscle were then tagged and traced back to their origin. The innervation pattern of each specimen was recorded, and variations were noted.
The muscular insertion of the upper and lower subscapular nerves, as well as any additional branches, were marked with a pin. When the nerves branched out around the site of insertion, the closest branch to the glenohumeral joint was chosen and marked. The humerus was placed in neutral rotation with no abduction, and the glenohumeral joint was palpated deep to the subscapularis muscle. The center of the joint was marked with a pin on the anterior surface of the subscapularis muscle. Measurements were recorded to determine the distance from the muscular innervation by the lower subscapular nerve to the glenohumeral joint. The humerus was placed in maximal external rotation, and a pin was again placed through the subscapularis in the center of the glenohumeral joint. Measurements were repeated for each specimen in this position.

Statistical analysis

Our data consisted of measurements of the distance from the site of the lower subscapular nerve innervation to the glenohumeral joint. These measurements were taken in both neutral and maximal external humeral rotation. The mean distance for all the specimens was compared using a Wilcoxon signed-rank test. We also grouped the data by innervation pattern and compared the distances in each position between groups using a 2-sample t test. Values of $P = .05$ were considered significant.

RESULTS

The 20 specimens revealed significant variability in the innervation pattern of the subscapularis muscle. Ten specimens (50%) had the most commonly described anatomy, consisting of a dominant upper subscapular nerve, 1 thoracodorsal nerve (or middle subscapular nerve), and 1 lower subscapular nerve, all originating from the posterior cord of the brachial plexus. In relation to the upper subscapular nerve, 4 specimens had 2 distinct branches to the subscapularis, which originated from the posterior cord proximal to the thoracodorsal nerve. On the basis of their origin
and entrance into the muscle, we concluded that these represented 2 upper subscapular branches in all 4 cases. Twelve of the 20 specimens had a single lower subscapular nerve arising from the posterior cord distal to the thoracodorsal nerve origin; however, the remaining lower subscapular nerves showed considerable variability. One specimen had 2 lower subscapular nerve branches arising from the posterior cord. Two specimens had a single lower subscapular nerve coming from the thoracodorsal nerve, and in 5 specimens, the lower subscapular nerve arose from the axillary nerve. Two cases, which had the lower subscapular nerve arising from the axillary nerve, had 2 separate lower subscapular nerve branches.

For all specimens, the distance from site of the lower subscapular nerve entrance into the muscle to the glenohumeral joint was 35.2 mm (range, 23-48 mm) with the humerus in neutral rotation and 16.9 mm (range, 0-28 mm) with the humerus in maximal external rotation. This difference was statistically significant (P < .001). In the specimens with a lower subscapular nerve arising from the posterior cord (group 1), these distances were 35.9 mm for neutral rotation and 18.5 mm for external rotation. In the specimens in which the nerve came from the axillary nerve (group 2), these distances were 36.6 mm for neutral rotation and 15.8 mm for external rotation (Tables I and II). When the data from groups 1 and 2 were compared, no statistical difference was found between the groups in neutral or external rotation in the difference between the distance from the site of the nerve entering the muscle to the glenohumeral joint (P = .83 and P = .20). Therefore, regardless of where the lower subscapular nerve began, the innervation site of the muscle is statistically similar.

**DISCUSSION**

The subscapularis is generally regarded as a single muscle innervated by the upper and lower subscapular nerves. However, the differing anatomy and innervation patterns of the superior and inferior portions of this muscle have led many authors to make a distinction between these 2 parts. Klapper et al9 described the teninous bands of the muscle and found that the superior two-thirds coalesced into a tendinous insertion at the lesser tuberosity, whereas the inferior one-third remained muscular at its insertion.1 This interval is also routinely exploited in anterior approaches to the shoulder when the muscle is split in line with its fibers at the junction of the superior two-thirds and inferior one-third.8 McCann et al10 studied the subscapularis muscle using electromyography and found that the upper and lower portions of the muscle exhibit differential activity depending on shoulder position.

Many articles have reported a variable pattern of innervation of this inferior portion of the muscle. Kerr described the innervation of the subscapularis extensively and referred to the lower subscapular as the axillary subscapular nerve due to its innervation of the axillary border of the muscle. Kerr found that the lower subscapular nerve arose from axillary nerve in 55% of his dissections. In a similar anatomic analysis by Kato,7 the origin was from the axillary nerve in 23% of cases. A cadaver study by Yang et al15 found this pattern in 1 of 11 specimens. Our own surgical experience has revealed a similar variable origin of the lower subscapular nerve and prompted the current study. We postulated that a more distal origin of the nerve might bring the nerve supply closer to the surgical field, placing it at greater risk during surgery.

We found considerable variability in the origin of the lower subscapular nerve. Specifically, the nerve arose from the axillary nerve in 5 of 20 specimens (25%), consistent with the findings of Kerr and Kato. We also found that the nerve came from the thoracodorsal nerve in 2 cases, but we did not believe this was a large enough group to allow statistical comparison. In comparing the distance from the shoulder joint to the innervation site of the lower subscapular nerve, we found no difference between the group with normal anatomy and the group with the nerve arising from the axillary nerve. This held true in both neutral conditions.

<table>
<thead>
<tr>
<th>Table I</th>
<th>Distance from insertion of lower subscapular nerve to glenohumeral joint with the humerus in neutral external rotation and 0° of abduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomy</td>
<td>No.</td>
</tr>
<tr>
<td>Normal (group 1)</td>
<td>13</td>
</tr>
<tr>
<td>Axillary (group 2)</td>
<td>5</td>
</tr>
</tbody>
</table>

*SE, Standard error; SD, standard deviation.

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<thead>
<tr>
<th>Table II</th>
<th>Distance from insertion of lower subscapular nerve to glenohumeral joint with the humerus in maximal external rotation and 0° of abduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomy</td>
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</tr>
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*SE, Standard error; SD, standard deviation.

**P = .83, 2-sample t test.**

**P = .20, 2-sample t test.**
and maximal external humeral rotation. Therefore, although the pattern of innervation of the inferior portion of the subscapularis muscle has a high rate of variability, this does not seem to place the nerve supply at greater risk during surgical dissection.

As expected, we were able to show that the innervation site of the muscle passes significantly closer to the glenohumeral joint when the arm is in maximal external rotation. This was true for all specimens and when the groups were analyzed independently. The mean distance from the point of innervation to the joint decreased from 35.2 mm to 16.9 mm with maximal external rotation (P < .001). This is in line with the findings of Yang et al,15 who showed a similar significant decrease. This led them to recommend caution when dissecting medial to the glenohumeral joint, especially with the humerus in external rotation or while applying traction to a detached subscapularis tendon.15

The current study, as well as the work by Yang et al,15 reveals that the subscapularis muscle innervation is close to the surgical field during a routine anterior approach to the shoulder. Inadvertent damage to these nerves may result in problems with shoulder function and stability. An interesting finding in a study by Flatow et al12 was the documented loss of subscapularis function after total shoulder arthroplasty. They used the lift-off and belly-press tests, as well as the patients' ability to tuck in a shirt, to determine the integrity of the subscapularis muscle after arthroplasty. They reported a 69% rate of subscapularis dysfunction, despite meticulous attention to subscapularis repair. The source of this dysfunction could not be determined because electromyography and advanced imaging studies were not done. In addition, recent work by Gerber et al14 has documented fatty infiltration of the subscapularis muscle in almost half of their patients treated with osteotomy of the lesser tuberosity for total shoulder replacement. This finding occurred despite radiographic evidence of bony healing of the tuberosity. They speculated that inadvertent neurologic injury might have accounted for this phenomenon.

In summary, the subscapularis muscle has a highly variable pattern of innervation. The most common variation of the lower subscapular nerve is as a branch of the axillary nerve, yet this does not seem to place the nerve at greater risk during surgery. Nonetheless, the subscapular nerves innervate the muscle close to the glenohumeral joint, and inadvertent damage may account for unexplained shoulder dysfunction after surgery. Care should be taken when dissecting around or releasing the subscapularis muscle belly, especially with the shoulder in external rotation. In addition, dissection should not be done on the anterior surface of the subscapularis muscle belly medial to the glenohumeral joint. Dissection in this area may lead to inadvertent neurologic damage and subsequent disability. Further research is needed in the field of total shoulder arthroplasty to determine if postoperative subscapularis dysfunction is due to denervation of the muscle at the time of surgery.

REFERENCES