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ONLINE ARTICLES

Anatomic safe zones for arthroscopic snapping scapula surgery: quantitative anatomy of the superomedial scapula and associated neurovascular structures and the effects of arm positioning on safety

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Background: Neurovascular anatomy has not been previously quantified for the arthroscopic snapping scapula approach with the patient in the most frequent patient position (''chicken-wing'' position). The purposes of this study were (1) to determine anatomic relationships of the superomedial scapula and neurovascular structures at risk during arthroscopic surgical treatment of snapping scapula syndrome (SSS), (2) to compare these measurements between the arm in the neutral position and the arm in the chicken-wing position, and (3) to establish safe zones for arthroscopic treatment of SSS.

Methods: Eight fresh-frozen cadaveric hemi-torsos (mean age, 55.8 years; range, 52-66 years) were dissected to ascertain relevant anatomic structure locations including the (1) spinal accessory nerve, (2) dorsal scapular nerve, and (3) suprascapular nerve. A coordinate measuring device was used to collect data on the relationships of anatomic landmarks and at-risk structures during the surgical approach.

Results: The dorsal scapular nerve was a mean of 24.4 mm medial to the superomedial scapula in the neutral position and 33.1 mm medial in the chicken-wing position ($P < .001$); the dorsal scapular nerve was 21.7 mm medial to the medial border of the scapular spine in the neutral position and 35.5 mm medial in the chicken-wing position ($P < .001$). The mean distance from the superomedial angle to the spinal accessory nerve intersection at the superior scapular border was 16.5 mm in the neutral position and 15.0 mm in the chicken-wing position ($P = .031$). The average distance from the superomedial angle to the closest point of the spinal accessory nerve was 11.6 mm and 10.4 mm in the neutral position and chicken-wing position, respectively ($P = .039$).

Institutional review board approval was not required for this cadaveric study.

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Conclusion: Neurologic structures around the scapula vary significantly between the neutral arm position and the chicken-wing position commonly used in the arthroscopic treatment of SSS. The chicken-wing position improves safe distances for the dorsal scapular nerve during medial-portal placement and should be considered as a primary position for arthroscopic management of SSS.
Level of evidence: Anatomy Study; Cadaveric Dissection

Keywords: Snapping scapula; anatomy of the superomedial scapula; shoulder anatomy; effects of arm positioning; safe zones for arthroscopic snapping scapula surgery; shoulder surgery; partial scapulectomy

The first description of the pathomorphologic entity of snapping scapula syndrome (SSS) was made by Boinet in 1867.[5,12] Millett et al[15] observed that SSS consists of a variety of symptoms, ranging from intermittent bursitis to debilitating recalcitrant crepitus. The pathomorphology of SSS is multifactorial and results from a combination of various anatomic mismatches of the concave anterior scapula and convex thoracic wall, which can cause inflammatory subscapular bursitis as described by Spiegl et al.[21] Other possible etiologies or contributing factors leading to SSS include post-traumatic changes, the Luschka tubercle, osteochondroma subscapular elastofibroma, and anterior angulation of the medial scapula.[14,15,22]

The first-line treatment for SSS is nonoperative management, which Gaskill and Millett[8] described in 3 categories: anti-inflammatory steroidal injections, physiotherapy to strengthen the periscapular muscles to correct posture and subscapularis deficiencies, and oral nonsteroidal anti-inflammatory drugs. In the case of failed nonoperative treatment, there are various published surgical techniques that may be used. These techniques can be grouped into open and arthroscopic approaches. The benefits of the arthroscopic approach, which was described first by Harper et al[10] and subsequently by Pearse et al,[17] include preservation of the periscapular muscles and the ability to perform additional adhesiolysis, as well as tuberoplasty and scapuloplasty, which lead to improved postoperative management.[15] Both open and arthroscopic techniques facilitate removal of inflamed tissue (supraserratus and/or infraserratus), removal of reactive bursae (trapezoid), and partial scapulectomy, which can alleviate persistent mechanical irritation.[8]

The arthroscopic approach uses lateral decubitus positioning or, more frequently, prone positioning with the arm free of drapes to allow full range of motion.[10,11,15,16,19] To enhance visibility and surgical accessibility, some authors suggest positioning the arm of the patient in maximal internal rotation by placing the dorsum of the hand on the small of the back.[11,15,16,19] This position is commonly referred to as the ''chicken-wing'' position. The chicken-wing position functions to increase the subscapular space. In theory, this facilitates safer portal placement and increases space to perform arthroscopy.[11,15,16,19] The general concept of all surgical approaches is to access the subscapular surface, specifically the subscapularis and serratus anterior spaces. Arthroscopically, this is performed by various paravertebral approaches.[11,15,16,19]

One possible operative approach is to start with an initial viewing portal established medially to the inferomedial scapular angle. A second portal—the working portal—is then placed by triangulation medial to the scapula and in line with or inferior to the medial confluence of the scapular spine. This provides access to perform a thorough bursectomy and partial scapulectomy of the superomedial angle (SMA) of the scapula.[14-16,19] Structures at risk during arthroscopic and open approaches are the spinal accessory nerve, dorsal scapular neurovascular structures, and suprascapular neurovascular structures.[13,14,21,22]

Although qualitative anatomy has been described in the literature, detailed quantitative relationships involving the superomedial scapula and adjacent neurovascular structures are lacking. More specifically, the potential quantitative anatomic differences with the arm in the neutral and chicken-wing positions have not been investigated. Quantitative characterization of anatomic relationships is necessary to prevent intraoperative neurovascular complications.[1,2,18] The purposes of this study were (1) to quantify anatomic relationships of the superomedial scapula and neurovascular structures at risk during arthroscopic surgical treatment of SSS, (2) to compare these measurements between the arm in the neutral position and the arm in the chicken-wing position, and (3) to establish safe zones for arthroscopic treatment of SSS. We hypothesized that the chicken-wing position would result in greater distances between scapular landmarks and associated neurovascular structures when compared with the neutral position.

Methods

Specimen preparation

Eight nonpaired, male, fresh-frozen human cadaveric hemi-torsos were tested in this anatomic study. The inclusion criteria consisted of no history of shoulder injury, no metastasis to bone, and no prior shoulder surgery. The mean age of the cadavers was 55.8 years (range, 52-66 years). The specimens were donated to a tissue bank for medical research and then purchased by our institution. All specimens were stored at −20°C and thawed at room temperature for 24 hours prior to preparation. All cadavers were placed in the prone position; skin and subcutaneous tissue were

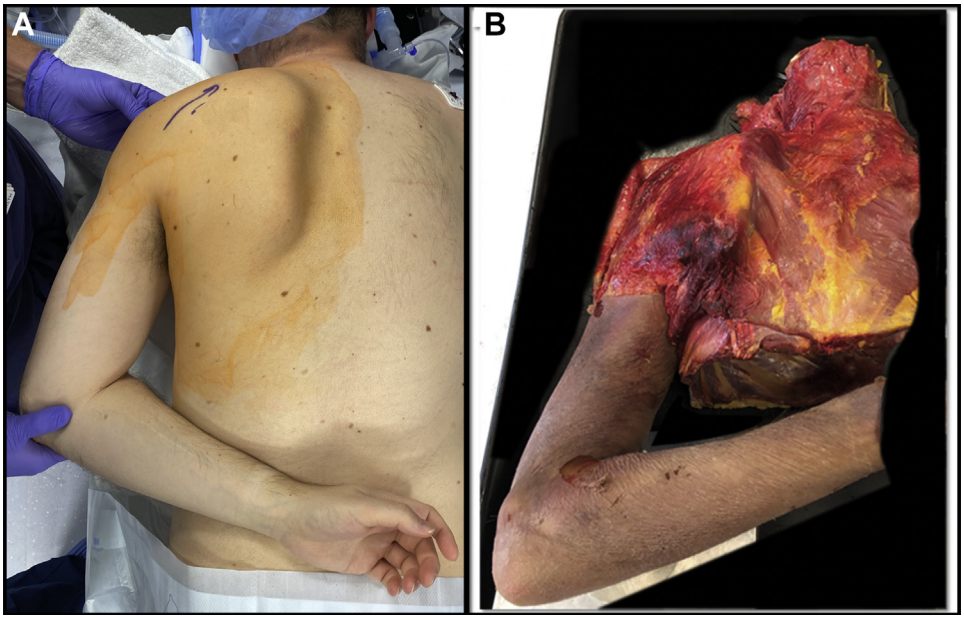

Figure 1 (**A**) Preoperative patient positioning of left upper extremity in chicken-wing position during arthroscopic surgical treatment of snapping scapula syndrome. (**B**) Cadaveric hemi-torso specimen with left upper extremity in chicken-wing position.

Table I Distance measurements between landmarks on medial scapula and dorsal scapular nerve in neutral and chicken-wing positions

Measurement	Average distance, mm	95% CI, mm	
		Low	High
Neutral position			
SMA of scapula to dorsal scapular nerve	24.36	22.16	26.57
Medial border of spine to dorsal scapular nerve	21.72	19.76	23.68
Chicken-wing position			
SMA of scapula to dorsal scapular nerve	33.09	29.59	36.58
Medial border of spine to dorsal scapular nerve	35.48	33.67	37.28

SMA, superomedial angle; *CI*, confidence interval.

Table II Distance measurements between landmarks on medial scapula

Measurement	Average distance, mm	95% CI, mm	
		Low	High
Inferior angle to medial border of spine	125.49	120.66	130.33
Inferior angle to posterior lateral corner of acromion	193.13	184.31	201.96
SMA to medial border of spine	62.14	55.19	69.1
Posterior lateral corner of acromion to SMA	115.4	110.53	120.27
SMA to medial suprascapular notch	50.12	45.62	54.61

SMA, superomedial angle; *CI*, confidence interval.

removed. The superficial musculature was meticulously dissected to expose the transverse cervical artery and the spinal accessory nerve near the cervical spine. The neurovascular structures were then tracked to the scapula. Next, the trapezius was reflected from lateral to medial to expose the dorsal scapular nerves and vessels in their original, anatomic positions. During dissection, specimens were routinely hydrated with normal saline solution.

Quantitative measurements

All pertinent bony and neurovascular landmarks were identified and measured using a digital protractor (20-cm Digital Protractor [product No. 62495]; Shinwa Rules, Niigata, Japan) with an accuracy of 0.3°. All fine dissections were performed by 2 orthopedic surgeons (R-O.D.H. and P.G.), and measurements were performed in agreement by both observers. With the specimen prone, measurements were performed 4 times by each surgeon, twice with the ipsilateral arm in the neutral position and twice in the chicken-wing configuration (Fig. 1). The inter-rater reliability was measured with the intraclass correlation coefficient (ICC). Values for all caliper measurements were calculated at 0.999. The measurements recorded were as follows: (1) distance from the SMA of the scapula to the spinal accessory nerve and the midpoint of the seventh cervical (C7) spinous process, (2) distance between the SMA and the spinal accessory nerve crossing the medial border of the scapula, (3) distance between the SMA and the spinal accessory nerve crossing the superior border of the scapula, and (4) distance to the dorsal scapular nerve from both the medial scapular border and the spinal

Table III *P* values for *t* tests comparing various measurements of medial scapula in neutral and chicken-wing positions

Measurement	*P* value
SMA of scapula to C7	.088
SMA of scapula to spinal accessory nerve intersection at medial scapular border	.400
SMA of scapula to spinal accessory nerve intersection at superior scapular border	.031
SMA of scapula to closest point of spinal accessory nerve	.039
SMA of scapula to dorsal scapular nerve	<.001
Medial border of spine to dorsal scapular nerve	<.001

SMA, superomedial angle.

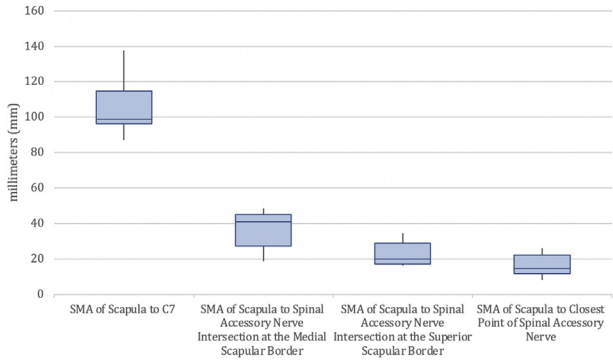

Figure 2 Distance measurements between landmarks on medial scapula in neutral position (*top whisker*, maximum; *bottom whisker*, minimum; *horizontal line*, median). *SMA*, superomedial angle.

column. After resection of the trapezius, measurements were taken (1) from the superomedial border of the scapula to the dorsal scapular nerve and (2) from the medial border of the scapular spine to the dorsal scapular nerve. These measurements were taken in both the neutral and chicken-wing positions. Thereafter, measurements were taken from C7, the first thoracic spinous process (T1), and the second thoracic spinous process (T2) laterally to the dorsal scapular nerve in the neutral position. The arborization level was measured following each of these caliper measurements.

After measurements of the distances to neurovascular structures, the remaining soft tissues were removed, exposing the bony landmarks. A coordinate measuring machine (Romer Absolute Arm; Hexagon Metrology, Tucson, AZ, USA) was used to collect the positions of scapular anatomic landmarks. Collected scapular landmarks included the posterolateral acromion, medial border of the scapular spine, inferior angle, medial suprascapular notch, and SMA of the scapula. The key anatomic neurovascular structures for this study are the spinal accessory nerve, dorsal scapular nerve, and suprascapular nerve

Establishment of safe zone model based on arthroscopic surgical techniques

All quantitative measurements collected were calculated as 95% confidence intervals (CIs) with the aim to illustrate an infrascapular anatomic safe zone for the arthroscopic snapping scapula approach.

Data analysis

All measurements taken in this study were reported as means with 95% CIs (Tables I-III, Figs. 2-4). For measurements taken in both the neutral and chicken-wing positions, a paired 1-tailed *t* test was performed to evaluate for significant differences between measurements. The α value for the 1-tailed *t* test was set at $\alpha = 0.05$. The coordinates of the collected points were imported into MATLAB (The MathWorks, Natick, MA, USA) for analysis. Distances between landmarks were calculated as direct linear distances between 2 points. All distances were expressed in millimeters, and all areas were expressed in square millimeters.

Results

Spinal accessory nerve

The average distance from the SMA of the scapula to the C7 spinous process was 94.6 mm with the arm in the neutral position (Fig. 2). The 2 measurements found to have significant differences between the neutral and chicken-wing positions were the distance from the SMA to the spinal accessory nerve intersection at the superior scapular border ($P = .031$) and the distance from the SMA to the closest point of the spinal accessory nerve ($P = .039$) (Table III). In all specimens, the measurement from the SMA of the scapula to the closest point of the spinal accessory nerve was found at approximately the midpoint between the superior crossing and medial crossing of the spinal accessory nerve on the scapula.

Dorsal scapular nerve

The dorsal scapular nerve was found to be an average of 24.4 mm medial to the SMA of the scapula in the neutral position and 33.0 mm medial in the chicken-wing position (Tables I and III) ($P < .001$). The second measurement showed that the dorsal scapular nerve was 21.7 mm medial to the medial border of the scapular spine in the neutral position and 35.5 mm medial in the chicken-wing position (Tables I and III) ($P < .001$). The distances between the dorsal scapular nerve and C7, T1, and T2 are illustrated in Figure 4. The arborization level of the dorsal scapular nerve was found to be at the level of the third or fourth thoracic spine in all specimens measured.

Bony landmarks on scapula: suprascapular nerve

The 95% CI for the measurement from the SMA of the scapula to the medial suprascapular notch was 45.6-

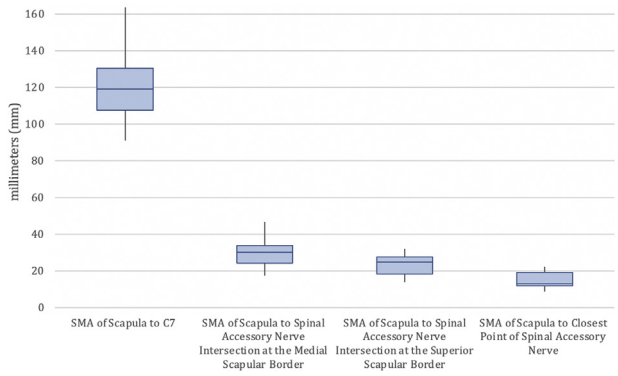

Figure 3 Distance measurements between landmarks on medial scapula in chicken-wing position. *SMA*, superomedial angle.

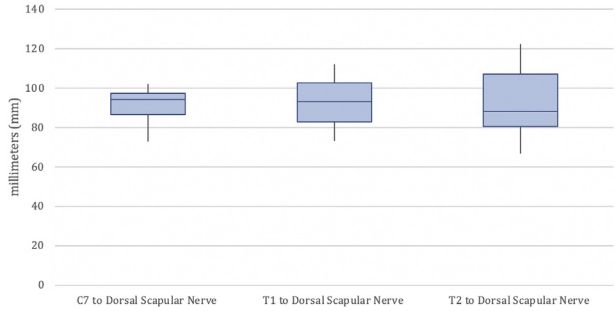

Figure 4 Distance measurements between dorsal scapular nerve and cervical and thoracic spinal landmarks.

54.6 mm. This is the space between the SMA and where the suprascapular nerve overlies the scapula. The approximate distance between the superior crossing of the spinal accessory nerve on the medial scapula and the suprascapular nerve was 32.7-37.6 mm (Fig. 2, Table II). The 95% CI for the distance from the inferior angle of the scapula to the medial scapular spine was 120.7-130.3 mm, and the distance from the medial scapular spine to the SMA was 55.2-69.1 mm (Table II).

Discussion

The principal finding of this study was that the dorsal scapular nerve is the nearest at-risk neurovascular structure to the SMA of the scapula. The nerve is closest during medial-portal placement with the arm in the neutral position. Another important finding was the significantly different quantitative anatomic measurements for various landmarks when comparing the neutral and chicken-wing positions. In addition, the distances between neurovascular structures and bony landmarks were demonstrated to be consistent between specimens. An understanding of these data and their consistency will help to establish arthroscopic safe zones for the arthroscopic snapping scapula approach.

Past studies have investigated the anatomic variability of neurovascular structures in different patient positions. Chuaychoosakoon et al[6] illustrated several relationships of neurovascular structures to the coracoid tip while comparing the supine, lateral decubitus, and beach-chair positions. Gelber et al[9] compared structures at risk between the beach-chair and lateral decubitus positions when establishing the anteroinferior shoulder portal. Cuéllar et al[7] observed different distances of the axillary nerve between the beach-chair position and the lateral decubitus position while performing an inferior glenohumeral ligament plication. However, to address SSS in an arthroscopic fashion, the patient is placed in either the prone position or the lateral decubitus position.[4,10,11,15,16,19] The ipsilateral arm is free of drapes, which allows for full range of motion.

Early technical descriptions by Harper et al[10] and Pearse et al[17] did not specify arm positioning. Although the qualitative neurovascular anatomy is generally well known, most available quantitative data are not specific for the more frequently used arm position (ie, the chicken-wing position).[1,18] Ruland et al[18] first described the anatomy specifically for this arthroscopic procedure by analyzing 8 specimens via anatomic dissection and 8 shoulders by dissection after arthroscopy. A key difference in this study was that all scapulae were detached from the cadavers at the costotransverse and clavicular articulations.[18] The findings of our study showed significant differences in the anatomic relationships between neutral arm positioning and chicken-wing positioning.

The arthroscopic technique to address SSS can be divided into the following 4 major steps: (1) portal placement, (2) superomedial bursectomy, (3) subspinous bursectomy, and (4) resection of the superomedial border.[3,21]

Portal placement

The structure that is most at risk during portal placement is the dorsal scapular nerve as the medial portal is established. Ruland et al[18] recommended medial-portal placement inferior to the scapular spine based on their reported findings. They also described the dorsal scapular neurovascular structures as 1 cm from the vertebral border of the scapula. Bhatia[3] recommended placing this medial portal 4 mm below the scapular spine and 2-3 cm medial to the scapular spine. Millett et al,[15] Saper et al,[19] Nascimento and Claudio,[16] and Islam et al[11] all placed this medial portal 3 cm medial to the medial scapular spine. In all of the aforementioned studies, the patients were positioned prone. Pearse et al[17] and Blønd and Rechter[4] performed their approaches with patients in the lateral decubitus position with the medial portal placed 3-4 cm and 2 cm medial to the vertebral border, respectively.

The 95% CIs in our study showed that the dorsal scapular neurovascular structures were 19.76-23.68 mm medial to the medial scapular spine in the neutral position and 33.67-37.28 mm medial in the chicken-wing position ($P < .001$). Our findings indicate that placing the medial

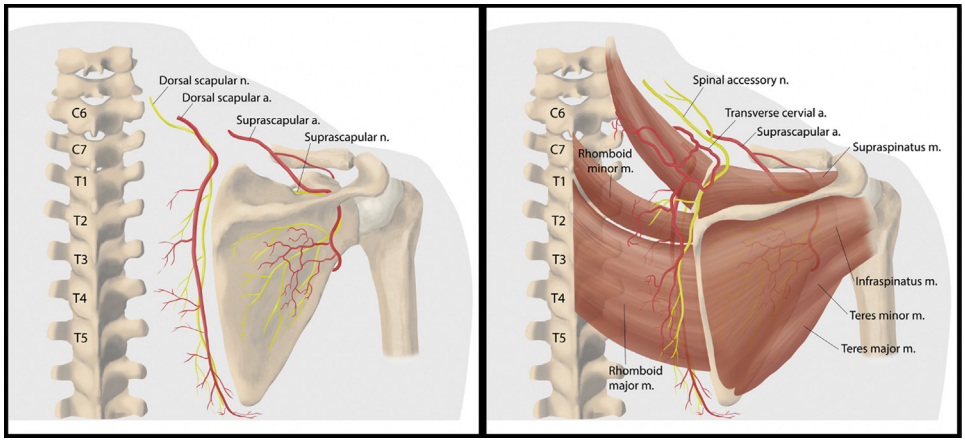

Figure 5 Posterior view of shoulder depicting various landmarks integral to arthroscopic approach for treating snapping scapula syndrome. *n*, nerve; *a*, artery; *m*, muscle.

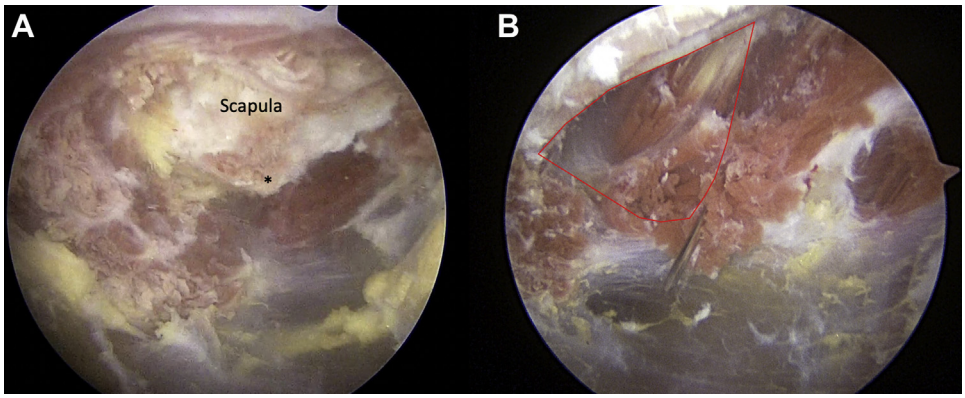

Figure 6 (**A**) Arthroscopic view of left scapulothoracic space via inferomedial portal 1.5 cm medial to medial border of scapula and 3.5 cm proximal to inferomedial border of scapula prior to superomedial partial scapulectomy. The superomedial angle of the scapula is marked (*). (**B**) Arthroscopic view of scapula after final resection of superomedial scapula. The red outline indicates the area of the resected scapula.

portal with the patient in the chicken-wing position can decrease the risk of neurovascular injury. A decision can also be made to place this portal only 2.5 cm medial to the scapular spine to further decrease this risk, but doing so can potentially hinder triangulation with the arthroscope or instruments.

Bursectomy of superomedial border

Ruland et al[18] described 2 subscapular spaces: the subscapularis and serratus anterior spaces. The structures at risk in this area include the spinal accessory nerve and the suprascapular neurovascular structures (Fig. 5). Spiegl et al[21] described a technical pearl that uses a spinal needle at the SMA to yield improved orientation in the convoluted subscapular spaces. Ruland et al described a similar technique for the inferior angle along with placement of the medial portal slightly inferior to the medial spine. The distance between the intersection of the spinal accessory nerve at the superior border of the scapula and the SMA had a 95% CI of 18.7-14.3 mm in the neutral position and 12.9-17.0 mm in the chicken-wing position ($P = .031$). The 95% CI for the measurement of the closest distance from the SMA to the spinal accessory nerve was 9.5-13.6 mm in the neutral position and 8.9-11.9 mm in the chicken-wing position ($P = .039$). These findings demonstrate that the resection of the superomedial border is typically safe for 2 burr widths (8 mm) (Figs. 6 and 7). They also show that the bursectomy can be performed 1.5-2 cm from the spinal needle positioned at the SMA in the chicken-wing position. This distance is slightly decreased from the distances used in the techniques described by various authors in the literature.[3,15,16] Millett et al[15] suggested removing a triangular section of 2 cm superiorly to inferiorly and 2-3 cm medially to laterally. Similarly, both Bhatia[3] and Nascimento and Claudio[16] recommended removing 5-10 mm of bone. To achieve this, Bhatia reported a demarcation of 0.5 cm of the SMA along with co-planing the SMA with a motorized 4-mm rasp and a 4-mm burr to remove bone. Other authors did not specify the resection width.[11,20]

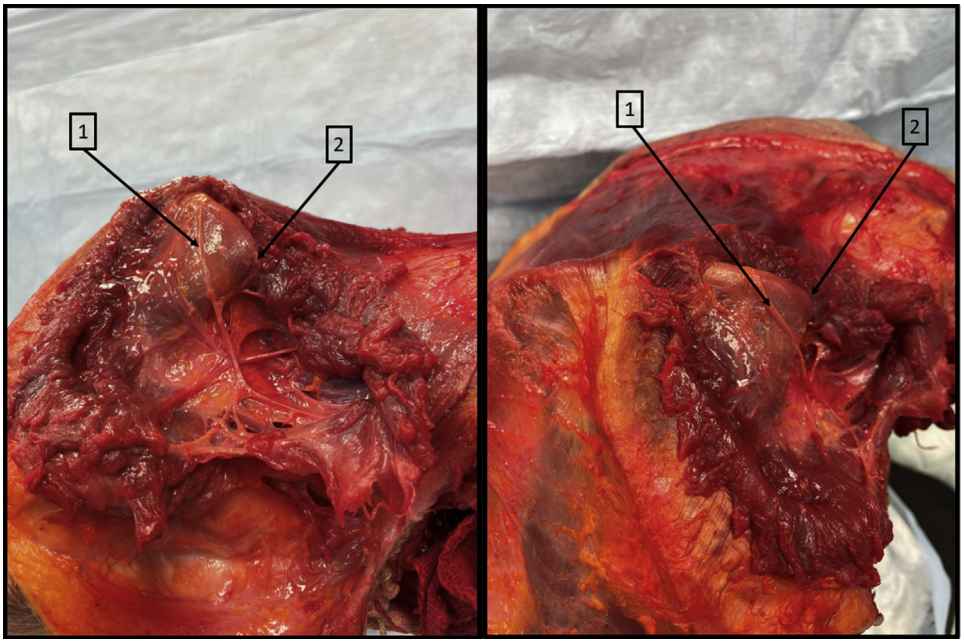

Figure 7 Superior (*left*) and lateral (*right*) views of dissected left shoulder demonstrating spinal accessory nerve (1) and superomedial border of scapula (2).

The location of the suprascapular neurovascular structures is described as within the suprascapular notch beneath the suprascapular ligament. Aggarwal et al[1] analyzed 92 intact dry scapulae in the Indian population and concluded that the average distance between the SMA and the medial edge of the scapular notch was 43.7 ± 7.0 mm. These values are similar to our findings, which show a 95% CI of 45.6-54.6 mm, and suggest that 4 cm of lateral extension of the bursectomy from the SMA without major complications is safe. Additionally, we were able to demonstrate that the arborization level of the dorsal scapular nerves in all 8 specimens was between T3 and T4, characterizing a further zone at risk.

Limitations

This study has several limitations owing to its cadaveric design. Our study used fresh-frozen male specimens as opposed to formalin- and alcohol-fixed specimens, which allows for more detailed preparation of neurovascular structures. As in previous studies, all specimens were male; thus, sex-related differences could not be evaluated. Finally, this study evaluated the quantitative anatomy in the prone position, the most frequently used position, with a focus on arm positioning. Possible variations in anatomic relationships exist in other patient positions and were not evaluated in this study.

Conclusion

Neurologic structures around the scapula vary significantly between the neutral arm position and the chicken-wing position commonly used in the arthroscopic treatment of SSS. The chicken-wing position improves safe distances for the dorsal scapular nerve during medial-portal placement and should be considered as a primary position for arthroscopic management of SSS.

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