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Original Article

Comparing safety margin of innervation points of the subscapular nerves from the base and tip of the coracoid process

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ABSTRACT

Introduction: Arthroscopic procedures like repair of subscapularis tendon tears pose a potential risk of injury to subscapular nerves. Damage to these nerves can be minimized by knowledge of relationship of subscapular nerve with nearby bony landmark such as coracoid process.
Methods: Gross anatomic dissection of thirty embalmed human cadaveric shoulder specimens was performed; variations in number and origin of subscapular nerves were noted. Distance of point of entry of upper and lower subscapular nerves into the subscapularis muscle from base and tip of coracoid process was measured in both neutral and external rotation with 30° abduction positions of arm. Length and angulation of coracoid process of 48 dry scapulae were also evaluated.
Results: Variability in terms of origin was more commonly observed in lower than upper subscapular nerve. Minimum safe distance of subscapular nerves was 39 mm medial to the base of a coracoid process with arm kept in neutral position and margin of safety reduced to 33 mm if the arm is in 30° abduction with external rotation position. Range of distance of nerve entry into muscle from tip was very wide as compared to the base of coracoid process. Length of coracoid process ranged from 28 to 45 mm, forward angulation of coracoid process ranged from 53°–86°.
Discussion: Greater margin of safety for upper and lower subscapular nerves was observed with the arm in neutral position in comparison to 30° abduction with external rotation position and base of coracoid could be more dependable landmark than its tip.

1. Introduction

Subscapularis muscle is a triangular, bulky medial rotator of the humerus. Along with the supraspinatus, infraspinatus and teres minor, it assists in stabilizing the head of the humerus in the glenoid fossa during shoulder movements. According to standard text books of anatomy, the subscapularis muscle is classically innervated by the upper and lower subscapular nerves, branches of the posterior cord of the brachial plexus.[1,2] Various studies have documented significant variability in the innervation of this muscle with regard to their origin and number of the subscapular nerves.[1–4]

Knowledge of variations of the subscapular nerve of the posterior cord of the brachial plexus is important during surgical approaches to the axilla and upper arm, during administration of regional anesthetic blocks and interpreting results of nerve compression.[3] Damage to the subscapular nerves may lead to denervation of the subscapularis muscle and inadequate function of the shoulder.[4] Pain, instability, or disability of the shoulder secondary to traumatic, degenerative or inflammatory conditions not responding to conservative management, arthroscopic repair performed by a skilled surgeon is a low-risk option.[5]

During arthroscopic repair of the subscapularis tendon tears as in rotator cuff injuries, the subscapular nerve branches are at risk of getting injured. A few studies have examined the position of the subscapular nerves relative to surgical landmarks like the coracoid process and the glenoid rim.[6–9] However, there is a scarcity of data regarding the location of the subscapular nerves relevant to the arthroscopic approaches. Most arthoscopic procedures on the shoulder joint are done either in neutral or 30° abduction with external rotation of the arm and the coracoid process are used as one of the reference landmarks. The purpose of this study was to

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see the relative margin of safety of the subscapular nerves with the coracoid process as reference landmark in these two positions of the arm and to define the safety margin around the coracoid for safe visualization.

2. Materials and methods

Gross anatomic dissection was performed on the 30 embalmed human cadaveric shoulder specimens (10 males and 5 females; 15 right and 15 left sides) available in the department of anatomy of our institute for this cross-sectional study. The chosen cadavers were free from the history of trauma or surgery of the shoulder region. Body mass index (BMI) of each case was noted. The overlying skin, subcutaneous tissue, deltoid, and pectoralis major were removed. The pectoralis minor, conjoined tendon of coracobrachialis and biceps brachii were cut close to the coracoid and reflected to provide clear access to the axilla. The base of the coracoid, subscapularis muscle and the brachial plexus were exposed.

The brachial plexus was dissected until the upper and lower subscapular nerves were identified (Figs. 1 and 2). The points at which each nerve entered the subscapularis muscle were identified and the nerves were traced back to their origin. The innervation pattern of the subscapularis muscle and variations in number and origin in each specimen were noted. With the arm in the neutral position, the minimum distance of the point of entry of each subscapular nerve into the muscle from the medial side of the base and the anteromedial tip of the coracoid process was measured using a digital vernier caliper (accuracy 0.02 mm, Mitutoya, Japan). In case of two subscapular nerves, the nerve which was closer to the coracoid process was considered for measurement. The position of the arm was changed to 30° abduction with external rotation and the measurements as in step one were repeated.

2.1. Dry osteology

The coracoid process of 48 dry scapulae was evaluated. The length of the coracoid process was measured from its base to the anteromedial tip. For measuring the angle between the longitudinal axis of the coracoid and anteroposterior axis of the scapula, a malleable aluminium strip (0.5 mm thick) was pressed firmly against the coracoid process. The strip was bent at the base of coracoid process (corresponding to point b), bent arm of the strip was fixed in such a manner the it aligned along the anteroposteior axis of scapula. Once the aluminium strip acquired the shape of the angle, it was removed from the bone and placed on a paper and the angle was traced with a pencil, later measured with a protractor. (Fig. 3).

2.2. Statistical analysis

Paired *t*-test was used to compare the distances in neutral versus 30° abduction with the external rotation position of the arm as well as to evaluate bilateral differences in measurements of coracoid process Pearson correlation was done to evaluate correlation of the length with the angulation of the coracoid process. A p value < 0.05 was considered statistically significant.

3. Results

The upper subscapular nerve was single in 26 specimens (86.7%). Typical origin from the posterior cord was present in 18/30 (60%) specimens, and from the axillary nerve in 8/30 (26.7%) of

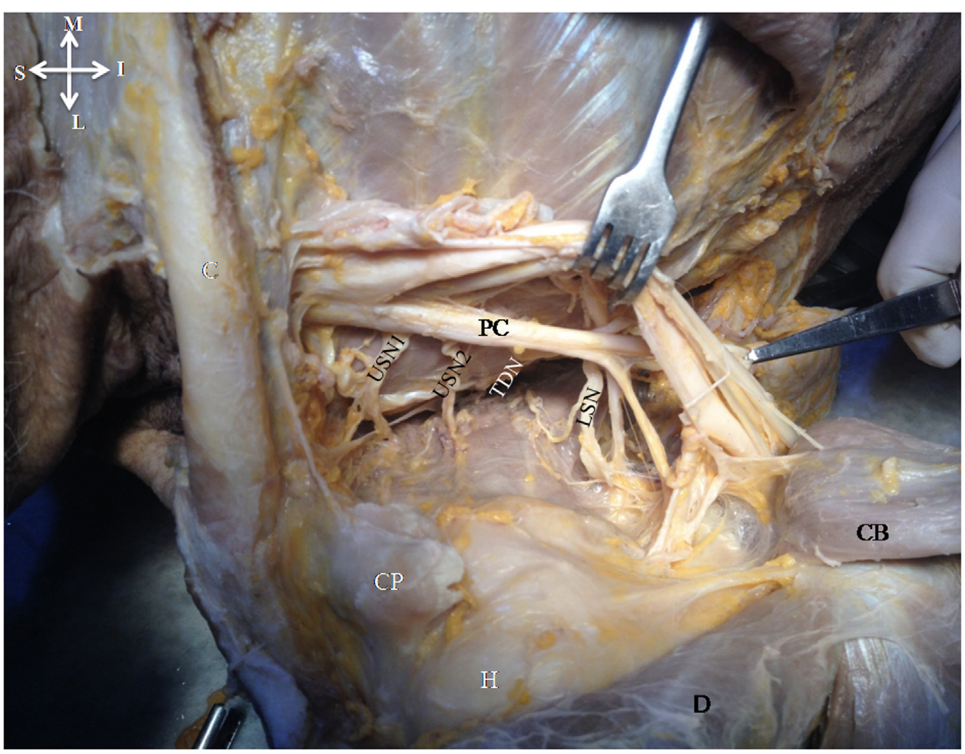

Fig. 1. Dissection of scapular region seen from front of left shoulder after clearing the attachments from coracoid process which shows innervation of subscapularis muscle having two upper subscapular nerves and one lower subscapular nerve, all having origin from posterior cord. (C- Clavicle; CP- Coracoid process, H-Humerus, PC- Posterior cord, USN1- First upper subscapular nerve, USN2- Second upper subscapular nerve, LSN- Lower subscapular nerve, TDN- Thoracodorsal nerve, CB- Coracobrachialis, D- Deltoid; S-Superior, I- Inferior, M- Medial, L- Lateral).

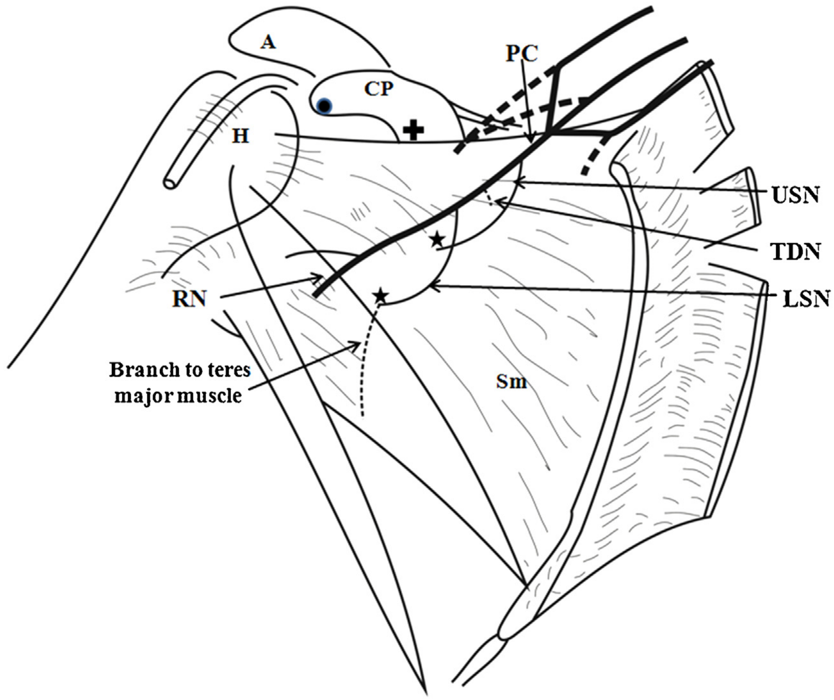

Fig. 2. Diagramatic representation of subscapularis muscle innervation showing upper and lower subscapular nerves originating from posterior cord. Distances were measured from base (✚) and anteromedial tip of coracoid process (●) to upper and lower subscapular nerve entry point (★) into the muscle. (A- Acromion process, CP- Coracoid process, H- Humerus (head), PC- Posterior cord, USN- Upper subscapular nerve, TDN- Thoracodorsal nerve, LSN- Lower subscapular nerve, RN- Radial nerve, Sm- Subscapularis muscle).

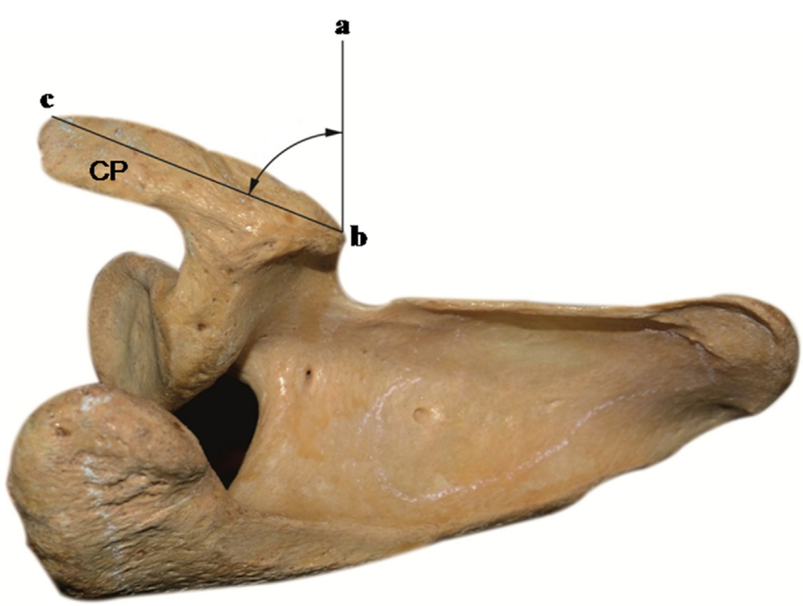

Fig. 3. Superior view of right scapula. Length of coracoid process (CP) was measured from its base to anteromedial tip (b–c in mm) and angle was measured along the longitudinal axis of coracoid with antero-posterior axis of scapula (∠abc).

specimens. Two upper subscapular nerves were seen in 4/30 (13.33%) specimen and both the nerves originated from the posterior cord. The lower subscapular nerve was single in all specimens and originated from the posterior cord in 18/30 (60%) and from the axillary nerve in 12/30 (40%) specimens.

3.1. Upper subscapular nerve (Table 1)

The mean distance of the point of innervation of the upper subscapular nerve from the anteromedial tip of the coracoid process in a neutral position of the arm was 58.55 ± 12.8 mm (range32.89–91.93 mm). This distance varied widely, however 95% Confidence Interval for mean was 53.5–63.4 mm. In 70% of specimens, the nerve was seen entering the muscle within a range of 50–70 mm while in 15% cases the nerve entry point was lying at distance more than 70 mm from the coracoid tip. Coincidently in these 15% cases, the BMI of the cadavers was $>40\ kg/m^2$. In remaining 15% cases the nerve entry point was less than 50 mm. With arm positioned in 30°abduction and external rotation, the mean distance from the tip comes to be

Table 1
Distance of point of innervation of upper subscapular nerve.

Position of arm	From anteromedial tip of coracoid process			From medial side of base of coracoid process		
	Right (n = 15) Mean ± SD (Range) (mm)	Left (n = 15) Mean ± SD (Range) (mm)	Total (n = 30) Mean ± SD (Range) (mm)	Right (n = 15) Mean ± SD (Range) (mm)	Left (n = 15) Mean ± SD (Range) (mm)	Total (n = 30) Mean ± SD (Range) (mm)
Neutral position	58.28 ± 13.82 (32.89–90.80)	58.83 ± 12.15 (33.74–91.93)	58.55 ± 12.80 (32.89–91.93)	51.49 ± 7.90 (39.27–65.11)	55.11 ± 6.12 (43.18–68.04)	
30° abduction with external rotation position	55.99 ± 13.83 (38.22–85.95)	59.17 ± 11.98 (36.97–82.45)		47.07 ± 7.19 (34.86–61.04)		
p-value			0.385			0.000*

* $p < 0.001$.

57.58 ± 12.83 mm.This distance showed a variation of 49 mm (37–86 mm). 95% Confidence Interval for the mean was 52.42–62.25 mm. The mean distance was less in 30° abduction with the external rotation of the arm in comparison to the neutral position of the arm, however, the difference was not statistically significant ($p > 0.05$).

Another landmark used was the base of the coracoid process. With arm kept in the neutral position the mean distance of the point of innervation of the upper subscapular nerve from the medial side of base of the coracoid process was 53.30 ± 7.19 mm and in majority cases (87.5%) the range lies between 40–60 mm and in 9.37% cases the distance was >60 mm and in 3.12% less than 40 mm. In larger distance cases the body mass index of the cadavers was >40 kg/m^{2}. 95% Confidence Interval of the mean was 51.10–56.36 mm. When the arm was kept in the 30° abduction and external rotation the mean distance was 47.91 ± 6.93 mm and number of cases which remains in the range of 40–60 mm comes to be 81.25% while in 12.5% less than 40 mm and in 6.25% more than 60 mm. 95% Confidence Interval for the mean was 46.35–51.05 mm. There was a statistically significant difference in the values in neutral versus 30° abduction and external position ($p < 0.001$).

3.2. Lower subscapular nerve (Table 2)

The mean distance of the point of innervation of the lower subscapular nerve from the anteromedial tip of the coracoid process was 69.92 ± 12.29 mm in a neutral position. 95% Confidence Interval for the mean was 65.33–74.51 mm. In 68% of cases, the nerve entry point was in the range of 60–80 mm. In 14% of the cases, distance was above 80 mm (in these cases the BMI > 40 kg/m^2). With the arm in the 30° abduction with external rotation position, the mean distance was 72.57 ± 12.03 mm and 95% Confidence Interval for the mean was 68.07–77.06 mm. Statistically, a significant difference was present in the values between arm in the neutral and 30° abduction with the external rotation position ($p < 0.05$).

With the arm in the neutral position, the mean distance of the point of innervation of the lower subscapular nerve from the medial side of the base of the coracoid process was 67.96 ± 9.12 mm. In 66% of the cases, nerve entry point lies in the range of 60–80 mm and in 23% cases this distance was found to be <60 mm with the arm in the neutral position and in rest of the cases the distance was >80 mm. 95% Confidence Interval for the mean was 64.55–71.36 mm. With the arm in 30° abduction with external rotation position, the mean distance of the point of innervation of the lower subscapular nerve from the medial side of the base of the coracoid process was 62.24 ± 9.02 mm and 95% Confidence Interval for the mean was 58.87–65.60 mm. In 60% cases, the range was from 60 to 80 mm and in approximately 33% of cases, the value was less than 60 mm. The mean distance of the point of innervation of lower subscapular nerve measured in neutral and 30° abduction with external rotation position from the medial side of the base of coracoid process revealed statistically significant difference on both sides of the arm ($p < 0.001$).

3.3. Dry osteology

The length of coracoid from its base to the anteromedial tip ranged from 28.01 mm to 45.04 mm (mean 37.27 ± 7.63 mm) with no statistically significant difference between right and left sides. Mean angle of the longitudinal axis of coracoid with the anteroposterior axis of the scapula was 70.08° ± 13.46 (53°–86°). The angle on the right side was significantly higher (mean 74.14° ± 4.19) than on the left side (mean 66.57° ± 7.24) with $p < 0.05$. No statistically significant correlation was observed between angle and length of coracoid process ($r = 0.2$, $p > 0.05$).

4. Discussion

Old standing subscapularis tear is often associated with its soft tissue adhesions with the inferior surface of the coracoid process. Arthroscopic release of the subscapularis to achieve tension-free repair is a commonly practiced technique. In such cases, exploration near the coracoid process is required. At this time there is a risk of injury to nearby neurovascular structures including nerves to subscapularis. Any injury to the subscapular

Table 2
Distance of point of innervation of lower subscapular nerve.

Position of arm	From anteromedial tip of coracoid process			From medial side of base of coracoid process		
	Right (n = 15) Mean ± SD (Range) (mm)	Left (n = 15) Mean ± SD (Range) (mm)	Total (n = 30) Mean ± SD (Range) (mm)	Right (n = 15) Mean ± SD (Range) (mm)	Left (n = 15) Mean ± SD (Range) (mm)	Total (n = 30) Mean ± SD (Range) (mm)
Neutral position	69.62 ± 14.24 (41.37–102.40)	70.22 ± 10.49 (59.67–100.24)		68.34 ± 9.26 (55.37–88.43)	67.57 ± 9.28 (50.59–84.63)	
30° abduction with external rotation position	71.92 ± 11.58 (55.10–103.10)	73.21 ± 12.84 (53.58–101.78)		62.59 ± 8.74 (50.98–82.06)	61.89 ± 9.58 (47.45–79.66)	(47.45–82.06)
p-value			0.015*			0.000**

* $p < 0.05$.
** $p < 0.001$.

nerve may lead to rotator cuff muscle atrophy. Sometimes steroids with local anesthetics are also injected in and around the injured tendon and muscle.

The upper subscapular nerve innervates the upper and middle portions of the subscapularis and lower subscapular nerves innervate the lower portion of the subscapularis and the teres minor muscle.[10] A study on dissections of 20 specimens by Kasper et al., revealed that in 50% specimens there was single upper subscapular nerve, single thoracodorsal nerve, and one lower subscapular nerve, all originating from posterior cord of the brachial plexus and in four specimens two distinct branches of the upper subscapular nerve, which originated from the posterior cord proximal were observed.[4] Similarly in a cadaveric study by Saleh et al., in all specimens upper subscapular nerves were seen arising from the posterior cord.[11] In the present study, 13.33% shoulder specimens had two upper subscapular nerves and the remaining had a single upper subscapular nerve. Like the above-mentioned studies, most of our specimens showed the typical origin of nerve from posterior cord. However in 26.7% of specimen upper subscapular nerve was seen emanating from an axillary nerve.

Variability in terms of origin is more commonly reported in lower than in upper subscapular nerve. Variant origin of lower subscapular nerve from axillary nerve has been observed in 15–60% cases.[3,4,11,12] Origin from the thoracodorsal nerve is also not uncommon.[3,4,11,12] Our results corroborated with the literature in this regard and origin from axillary nerve was present in 40% of specimens.

4.1. Subscapular nerves in relation to the base of the coracoid process

In our study, the average distance of upper subscapular nerves from the base of coracoid process in neutral arm position was 53.30 ± 7.19 mm (39.27–68.04 mm). In a similar position of the arm, lower subscapular nerve innervated the muscle 67.9 ± 9.12 mm (33.84–61.34 mm) from the base of the coracoid process. In 20 human cadaveric shoulder specimens dissected by Denard et al.with arm kept in neutral position, the upper subscapular nerve pierced the subscapularis muscle 31.6 ± 6.6 mm (range, 22–45 mm) medial to the base of the coracoid process and the lower subscapular nerve innervated the subscapularis muscle 42.6 ± 7.6 mm (range 25–55 mm) medial to the base of the coracoid.[7] The closest point of innervations of the upper subscapular nerve from the base of coracoid process in neutral position recorded in our study was 39.27 mm whereas Denard et al., recorded 22 mm. When the arm kept in maximal external rotation, the upper subscapular nerve pierced the subscapularis muscle 24.2 ± 7.4 mm (range, 11–35 mm) and lower subscapular nerve 33.9 ± 6.9 mm (range, 24–45 mm) medial to the base of the coracoid and the distance was significantly higher in neutral position ($p < .001$).[7] The authors in the current study kept the arm in 30° abduction with external rotation; hence our results could not be compared with Denard et al. [7] In current study when the arm was positioned in extreme lateral rotation with 30° abduction, the mean distance of upper and lower subscapular nerves from base of coracoid process decreased significantly. In our cases, the body mass index of the subjects varied greatly. It was observed that in bodies with BMI > 40 kg/m^2 the distances recorded were on the higher side and this fact might have influenced the mean values. With the arm kept in a neutral position, the closest point of innervation of superior or inferior subscapular nerve was 39 mm medial to the base of coracoid process and the margin of safety reduced to 33 mm if the arm is in 30° abduction with external rotation position. Our results suggest there is a greater margin of safety for subscapular nerves with the arm in neutral position in comparison to 30° abduction with external rotation position. The potential risk of injury to subscapular nerves can be reduced by knowing the point of innervation of lower subscapular nerve from the coracoid process during any arthroscopic procedures while taking care of other neurovascular structures around the coracoid process.

4.2. Subscapular nerves in relation to the anteromedial tip of the coracoid process

Lo et al.[13] measured the distance of axillary artery, axillary nerve, musculocutaneous nerve and lateral cord of the brachial plexus from the coracoid tip and base with shoulder kept in 30° abduction and slight flexion to simulate its position during shoulder arthroscopy while the location of subscapular nerve was not assessed. We analyzed the nerve entry point in relation to the anteromedial tip of the coracoid process. In the neutral position of the arm, the upper subscapular nerve innervated the muscle 58.55 ± 12.80 mm (range 32.89–91.93 mm) and lower subscapular nerve was at distance of 69.92 ± 12.29 mm (range41.37-102.40 mm) from the anteromedial tip of the coracoid process. In the extreme lateral position, the distance of upper subscapular nerve was 57.58 ± 12.83 mm (36.97–85.95 mm) and lower subscapular nerve was 72.57 ± 12.03 mm (53.58–103.10 mm). Up to 32 mm medial to the tip of coracoid process was safe for subscapular nerve. We found that measurements taken from the anteromedial tip of coracoid process varied remarkably as compared to the base and besides this, the point of innervation of upper subscapular nerve moved closer to tip when measurements were taken in 30° abduction with external rotation position as opposed to the results of lower subscapular nerve. Such inconsistency in results with the tip of coracoid process was obtained compared to base disfavor its applicability as a landmark. To see why results are so much variable from the tip of the coracoid process, authors in the present study measured the length (from its base to anteromedial tip) and angle of the longitudinal axis of the coracoid process with the anteroposterior axis of the scapula. We found the length of coracoid process ranging from 28 to 45 mm and forward angulation of the coracoid process varied greatly (53°–86°). We found length and angulation varied a lot from individual to individual. Variation in length and angulation might influence distance of the neurovascular structure from the tip of coracoid process; this undermines the reliability of well palpable tip as a landmark. Many anatomical and radiological studies on the coracoid process have been reported in the literature [14–18], however, our results could not be compared as in any of the studies, measurements like ours were not taken.

5. Conclusions

The potential risk of injury to the subscapular nerve can be reduced by knowing the point of innervation of subscapular nerve from the coracoid process during any arthroscopic procedures. A Greater margin of safety for upper and lower subscapular nerves was observed with the arm in neutral position in comparison to 30° abduction with external rotation position and base of coracoid can be used as a better landmark than its tip.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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