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ORIGINAL ARTICLE

Exploiting Suprascapular Nerve Anatomy for Safe Shoulder Surgeries: What do we know? A Cadaveric Study and Review of Literature

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Abstract

Background: Knowledge of the surgical anatomy of the suprascapular nerve (SSN) is imperative in both the prevention of nerve damage during shoulder surgery and release of nerve entrapment, while also sparing damage to surrounding tissues. Our objectives are to provide a review of the surgical anatomy of SSN as well as compare our own acquired data based on six cadaveric SSN dissections with the current literature.

Methods: Six SSNs of three cadavers were dissected using the same stepwise procedure, and 18 predefined measurements were recorded for statistical analysis. Our data were compared with previous reports in the literature, taking particular interest of SSN relationship with infraspinatus, supraspinatus, suprascapular notch, supraglenoid notch and the posterior glenoid.

Results: Our cadaveric studies largely agree with the literature on the 18 parameters of the SSN we measured. There is an approximately 10%-20% variation in each parameter evaluated, which is a good estimate to keep in mind when planning surgical intervention.

Conclusion: Knowledge of the anatomical relationship of SSN to surrounding landmarks is the key to prevention of injury during surgical procedures involving the rotator cuff or the posterior shoulder.

Keywords: Suprascapular nerve, suprascapular notch, transverse scapular ligament, shoulder surgery.

Introduction

The suprascapular nerve (SSN) contributes motor supply to the supraspinatus and infraspinatus muscles and provides neurosensory supply to most (~ 70%) of the shoulder joint, especially the posterior and superior aspects[1-3]. Through the supraspinatus it helps in the arm abduction in the initial 10-15 degrees of its arc and stabilizes the shoulder by pressing the humeral head medially against the glenoid fossa. Through the infraspinatus it helps in transverse extension and lateral rotation of the humerus. The SSN is thus important for normal movements of the arm, and any disruption of its function will render the arm unusable in its full potential.

Injuries of the SSN may be caused by iatrogenic injuries, which amongst others, include those during shoulder operations such as rotator cuff advancements for the management of rotator cuff tears, capsulorrhaphies, and glenoid osteotomies for posterior shoulder instability, the risk being higher when an anterosuperior or posterior approach is used[4-9]. An arthroscopic Bankart repair necessitates blind drilling which may also injure the SSN[10,11]. Rotator cuff repairs (1-2%), arthroplasty procedures (4%) and anterior stabilization procedures (8%) may be associated with neurologic complications and the SSN is at high risk, with the most reported lesion being a transient neurapraxia[4,12-14]. Suprascapular neurotization with spinal accessory nerve as described by Bhandari et al. is also being practiced widely by peripheral nerve surgeons[15,16]. All in all, any surgical procedure on the shoulder may lead to SSN injury[17-21]. It is therefore also important that shoulder surgeons or anesthesiologists

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practicing SSN block thoroughly understand the anatomy of the nerve to prevent any avoidable complications.

The objectives of this article are threefold. First, we present a review of the literature describing the course, surgical anatomy, relationship to bony landmarks, and normal variations of SSN. Most of the current data acquired regarding the SSN anatomy are from males of American or European descent, thus the second objective is to present SSN data acquired from males of Indian descent and suggest variations in anatomy across geographic lines. Such data should prove useful in better estimation of anatomical relationship in males of smaller stature. Third, the authors attempt to illustrate the universal similarities in SSN anatomy that can be exploited to minimize surgical risk.

Methods

Three cadavers of males of Indian descent were dissected to study six SSNs and measure 18 parameters of the nerve along its anatomic course. All dissections were done at SKMCH with the permission of the Institutional Review Board, the procedure being described below. Data gathered were compared to previously reported studies conducted on a multitude of races including North American, European, and Asian, to compare the different anatomical parameters of the nerve along its course.

Cadaver dissection:

We studied the course and relations of the nerve starting from its origin from the upper trunk of the brachial plexus to its termination into branches to the infraspinatus muscle. Magnifying loupes were used to operate under bright light.

Cadavers: embalmed. Approach: Posterior. Cadaver position: Prone.

Procedure:

We incised the shoulder so as to expose the whole of its back and we went anteriorly up to the clavicle. Starting at the coracoid process we extended the incision anteriorly and superiorly up to the acromion, and medially from the coracoid process over the scapular spine, extending inferiorly further along the medial border of the scapula.

The skin and underlying fascia were removed to expose the trapezius and postero-medial part of the deltoid. We also incised the lateral side of the neck to trace the SSN origin from the upper trunk of the brachial plexus and then up to the cervical roots forming the upper trunk. Once the trapezius was exposed, it was detached from the scapular spine and reflected medially to expose the supraspinatus. The deltoid was also detached at the base of spine of scapula (BSOS). The supraspinatus and infraspinatus muscles were exposed completely.

We dissected further to detach the supraspinatus and reflect it laterally to expose the SSN lying obliquely on the bony floor of the supraspinatus fossa. The SSN was seen to be crossing the suprascapular notch (SuNo) and under the transverse scapular ligament (TSL). The nerve was traced proximally up to its origin. The dissection was extended to see the formation of the upper trunk by the cervical nerve roots. Distally the SSN was delicately traced to reveal all the motor branches to the supraspinatus and infraspinatus muscles. For this the infraspinatus muscle was reflected inferolaterally. The TSL was divided to study the nerve under it.

While traversing from the supraspinatus fossa to the infraspinatus fossa the SSN passes through the spinoglenoid notch (SGNo). We made a note to document the presence of inferior TSL if there was one. The nerve was then dissected to expose and study all the motor branches to the infraspinatus. Blunt instruments were used to inspect and expose the tissue layers.

For every SSN measurement, three readings each were taken down by two examiners (BK & DK) and mean of the six values was used for data analysis. The measurements were taken with the help of a measuring scale and fine vernier calipers with the precision of 0.10 millimeter.

Parameters of Study

Cadaveric dissection measured the anatomical course of SSN and its relationship in innervation of infraspinatus, supraspinatus, and positioning with the SuNo and SGNo. Further, dimensions of the SSN at different points of the anatomical course were measured (described in Table 1 and depicted in Figures 1 and 2).

Results

Infraspinatus and Supraspinatus

Distance (I) from the SSN branch for infraspinatus to posterior glenoid (PG) was averaged to 1.84 ± 0.2 cm. Distance of SSN at the branch for infraspinatus

Table 1: Parameters of the suprascapular nerve and relevant anatomy.
BSOS= base of spine of scapula; SSN=Suprascapular nerve

Sl. / Corresponding labels in figures 1 & 2	Suprascapular and Spinoglenoid Notch	Our Study (Mean ± S.D.)	Other studies
1. A	SSN at the suprascapular notch to the supraglenoid tubercle (cm)	2.81± 0.36	2.3-3.5 [46] 3 (2.5-3.9) [6]
2. B	BSOS to the supraglenoid tubercle (cm)	2.17 ± 0.37	2.5 (1.9-3.2) [6]
3.	SSN from the upper trunk to the suprascapular notch (cm)	5.71± 1.08	-
4. C	Suprascapular notch to the spinoglenoid notch (cm)	1.80± 0.34	3.1 (3.1-5) [15]
5. D	Length of suprascapular notch (mm)	7.87 ± 1.39	9.2 (4-15) [15]
6. E	Height of the suprascapular notch (mm)	10.6 ± 1.35	5.9 (2.5-11) [15]
7. F	Length of the spinoglenoid notch (cm)	1.82 ± 0.19	0.87 (0.8-1) [15]
8. G	Width of the spinoglenoid notch (cm)	1.58 ± 0.23	0.6 (0.5-0.7) [15]
9. H	Posterior glenoid rim to the SSN at base of spinoglenoid notch (cm)	1.81 ± 0.34	1.5 (1.1-1.9) [4] 1.8 (1.4-2.5) [6] 2.01 (1.7-2.4) [44]
10.	Shape of the suprascapular notch	'U' in 80%, Oval in rest	'U' in 63%, rest 'V' [15] 'U' in 77%, rest 'V' [50]
	Infraspinatus and Supraspinatus		
11. I	SSN at branch for infraspinatus to posterior glenoid (cm)	1.84 ± 0.2	1.6-3.2 [46]
12.	SSN at branch for infraspinatus at first insertion into the muscle to the posterior glenoid (cm)	2.46 ± 0.27	2.0 (0.3-2.8) [4] 1.5-4[46]
13. J	SSN last branch to infraspinatus entering the muscle to posterior glenoid (cm)	5.19 ± 0.44	3.9-7.7 [46]
14.	Number of SSN motor branches to infraspinatus (cm)	3 to 5	3 to 4 [53] 4 to 6 [4]
15. K	Suprascapular notch to supraspinatus innervation (cm)	1.43 ± 0.22	-
16.	BSOSto infraspinatus innervation (cm)	3.16 ± 0.32	-
	SSN		
17.	Diameter proximal to entering suprascapular notch (mm)	2.67 ± 0.42	3.8 (1.8-6) [15]
18.	Diameter distal to entering suprascapular notch (mm)	2.25 ± 0.42	3.1-5 [15]

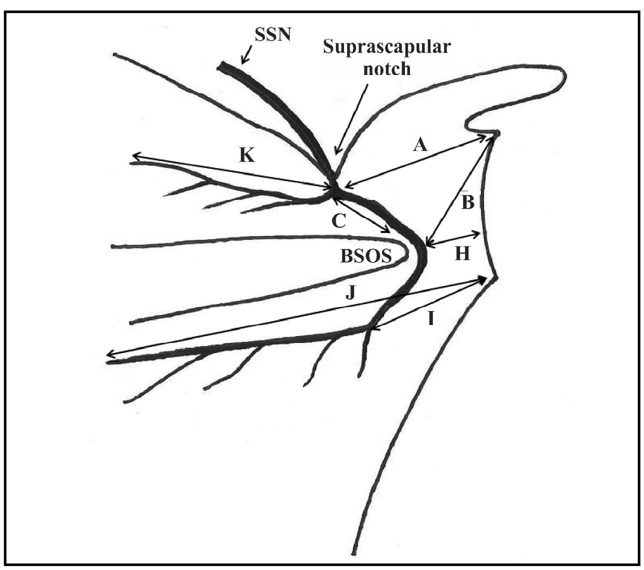
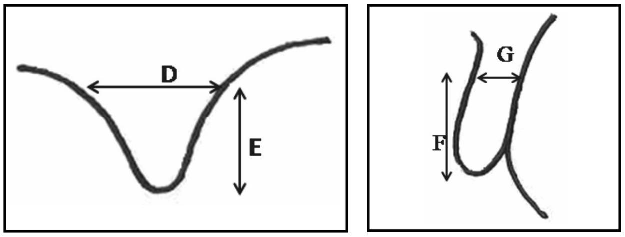


Fig. 1 Schematic representation of the SSN. A= SSN at the suprascapular notch to the supraglenoid tubercle; B= BSOS to the supraglenoid tubercle; C= Suprascapular notch to the SGNo; H= Posterior glenoid rim to the SSN at base of spinoglenoid notch; I= SSN at branch for infraspinatus to posterior glenoid; J= SSN last branch to infraspinatus entering the muscle to posterior glenoid; K= Suprascapular notch to supraspinatus innervation. BSOS= base of spine of scapula; SSN= suprascapular nerve



(a) (b)

Fig. 2 Mean measurements of (a) the Suprascapular notch and (b) *spinoglenoid notch. D= Length of Suprascapular notch; E= Height of the Suprascapular notch; F= Length of the SGNo; G= Width of the SGNo*

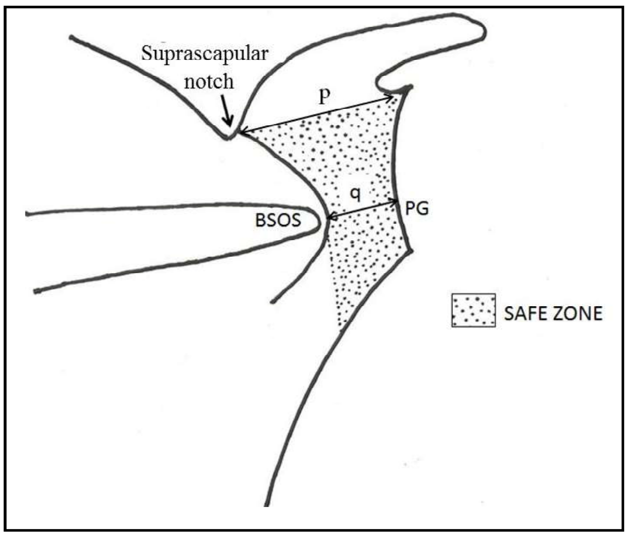


Fig. 3 Schematic representation of the 'safe zone'. p- distance from the SSN at the Suprascapular notch; q-distance from the posterior glenoid rim to the SSN at the base of the spinoglenoid notch. BSOS= base of spine of scapula; PG= posterior glenoid

at its first insertion into the muscle to the PG was averaged to 2.46 ± 0.27 cm. The mean length (J) of the last branch of SSN to infraspinatus entering the muscle to the PG was 5.19 ± 0.44 cm. SSN motor branches to infraspinatus in our cadavers were averaged at 4 ± 1 branches. The average distance (K) from the SuNo to the supraspinatus innervation point was 1.43 ± 0.22 cm. Lastly, the mean length from the BSOS to infraspinatus innervation point was 3.16 ± 0.32 cm.

Suprascapular and Spinoglenoid Notch

The average length (A) of the SSN at the SuNo to the supraglenoid tubercle was measured to be 2.81 ± 0.36 cm. The BSOS to the supraglenoid tubercle average distance (B) was 2.17 ± 0.37 cm. The average length of SSN from the upper trunk to SuNo was 5.71 ± 1.08 cm. Average distance (C) of SuNo to SGNo was 1.80 ± 0.34 cm. The average length (D) and height (E) of SuNo were 7.87 ± 1.39 mm and 10.6 ± 1.35 mm, respectively. The average length (F) and width (G) of SGNo were 1.82 ± 0.19 cm and 1.58 ± 0.23 cm, respectively. The distance (H) of the SSN at the base of the SGNo to the PG rim was measured to be 1.81 ± 0.34 cm. The shape of SuNo was U-shaped in five of the dissected shoulders, and oval in one.

SSN

Diameter of the SSN taken just proximal and distal to its course through SuNo averaged to 2.67 ± 0.42 mm and 2.25 ± 0.42 mm respectively.

It is noteworthy that the studies used in comparison incorporate different races and thus direct comparison on the parameters listed above is not possible, rather the trend is of importance. That is to say, larger frames of cadavers of North American descent as presented in the studies of Bigliani[17], Ticker[22], Shaffer[23], and Bailie[24] accordingly have an expected difference in the size of the SSN along its course as compared to the smaller Indian frames of our cadavers. Similarly, we would expect our data to most closely resemble the findings of the similarly sized Japanese cadavers presented by Shishido[6]. The values presented in European based studies by Warner[8] and Duparc[25] reflect cadavers of Swiss and French descent respectively, and thus are expected to reflect a size-adjusted set of parameters as compared to our data.

Discussion

Anatomical course and relations

The SSN takes its origin from the upper trunk of the brachial plexus, near the confluence of the C5 and C6 ventral rami, courses deep into the trapezius and omohyoid muscles, crosses the SuNo and passes under the TSL where it is closely accompanied by the scapular vein. The SSN is relatively fixed when it passes under the TSL and then runs obliquely across the supraspinatus fossa giving motor branches to the supraspinatus. Next, it descends through the SGNo, lying under the cover of a loose fascial band which stretches over it, and curves around the lateral border of the scapular spine. It then enters the infraspinatus fossa along with the suprascapular artery and innervates the infraspinatus muscle. The vessels run lateral to the nerve . The motor branches supplying the infraspinatus are all of the same length and diameter, but are slightly longer and thicker than those supplying the supraspinatus[26]. In the supraspinatus fossa it also gives filaments to the capsule of acromioclavicular and shoulder joints[8,17,27-29]. The sensory component supplies the glenohumeral joint, the acromioclavicular joints, subacromial bursa, coracohumeral and coracoacromial ligaments as well as the cutaneous region of the upper lateral shoulder in about 15% population[27].

Early Course

The SSN branches off from the upper trunk about three cm above the clavicle and arises from the upper trunk of the brachial plexus. The composition of the SSN can vary by level of contributing cervical nerves. Ajmani's study[27] showed that in 5 cadavers out of the 34 dissected, the SSN had contributions from C4 as well. Horiguchi's study[30] also showed that in 4 cases the SSN took contributions from the C4, C5 and C6 nerves. It also described one case where the SSN branched off from the lateral aspect of combined rami of C4 and C5 even before the confluence could be joined by the ventral ramus of the C5 nerve.

More distal to its origin, the SSN courses towards the upper trunk of the brachial plexus, where the nerve is surrounded by the fascia of the scalene muscles. Even more distally the nerve lies in the fascia covering the subclavius and omohyoid muscles[29]. These fascia surrounding the SSN may predispose the nerve to potential stretch damage. Twenty nine out of the 30 cadavers dissected by Duparc *et al*[25] showed the presence of well delineated fascia which was found to be continuous with the fascia of the supraspinatus muscle. While describing ultrasound (USG) - guided SSN block, Siegenthaler *et al*[31] reported that the SSN could be identified under the omohyoid in 81% cases where it was found to be located at a median depth of 8 mm.

Suprascapular Notch

The size and shape of SuNo is varied. In up to 15% of the population, the SuNo may not even be a defined structure[32]. Ofusori *et al*[33] proposed that SuNo absence could be one of the possible causes of SSN entrapment. When defined, the notch may be 'U', 'V' or 'O' shaped. The literature suggests the most prevalent shape to be the U-shape, estimated between 63%-77% of notches while the V-shape represents 23%-37% of notches[22,25]. Our cadaveric dissections correlate to these findings in which we report five of the six shoulders having U-shaped notch, with a single incidence of an oval foramen due to ossification of the superior TSL.

Rengachary[34] categorized scapulas into different groups depending up on the shape of the SuNo. The shape is defined as 'U' when it has parallel sides and a rounded base; whereas 'V' shape is defined as the non-parallel sides converging on a narrow base. The shape of the notch may not be the same bilaterally although most of the times it is[22]. The shape of the notch, whether 'V' or 'U' does not predispose to nerve entrapment[25]. Imaging techniques such as fluoroscopy and CT have been used to precisely locate the SuNo, which is seen superior to the scapular spine, with coracoid process lying lateral to it and rib margins medial to it. The C-arm may be needed to be obliquely angled away from the side of interest and oriented caphalo-caudally to get adequate visualization of the SuNo[35].

Duparc *et al*[25] noted a decrease in nerve diameter from 3.8 mm to 3.1 mm as SSN progresses through the SuNo; similarly, our findings indicate a decrease from 2.67 mm to 2.25 mm. These findings suggest that SSN decreases in diameter by up to 15-20% as it exits the SuNo.

Transverse Scapular Ligament (TSL)

Also known as the suprascapular ligament, the TSL turns SuNo into a foramen. It varies from being hard to soft. Ticker *et al*[22] found it to be hard in 23% shoulders and comparatively soft in the rest. Calcification of the TSL or its rigidity does not imply SSN entrapment, although suprascapular foramen stenosis from TSL ossification may result into SSN compression[36]. Traction has been described to be a major cause of injury of the SSN[28,29]. There is a sling effect as it crosses the notch under the TSL[34,37]. This implies that as the shoulder droops, the nerve will be under increased tension kinking under the TSL, clinically shown after trapezius palsy and shoulder arthrodesis and spine surgery[38,39]. Yang *et al*[40]. reported that the TSL was wider in males than in females.

The depth of suprascapular ligament from the skin surface has been variedly reported from 3.9 ± 0.7 cm[41] to 9 ± 1 cm[36]. Tubbs *et al*[42] reported that the mean distance from the skin to the SSN deep to the suprascapular ligament was 4 cm (3.5-6 cm). While performing USG guided blocks in about 36% cases Siegenthaler *et al* identified the SSN to be located in the supraspinatus fossa at a median depth of 35mm[31].

Ticker *et al*[22] dissected 79 shoulders and found that in one case there were two superior TSL bands (bifid) and the motor branches to supraspinatus muscle passed between the two bands while the rest of the nerve passed from under the lower band. In another shoulder they noticed that there were 3 bands (trifid) and the whole nerve passed from under the lower most band.

The TSL is sometimes referred to as the superior TSL to differentiate it from an inferior TSL, the incidence of which is varied[43,44]. Ticker *et al*[22] reported it to be found in only 14% (11/79) of the cadaver shoulders and only one of them showed its bilateral presence. Kaspi *et al*[44] dissected 25 shoulders to study the presence of inferior TSL and its relation to the notch and the nerve. They found that the ligament was absent in 50% females and rudimentary in one, but absent in only 13% males. The variation in the distance between the nerve and the ligament and ligament and bone was similar in males and females. The variations in size and shape of SuNo and the "sling effect" together predispose the nerve to injury at this point[44,45].

Motor Branches

In a study on 90 cadavers, Bigliani *et al*[17] reported that the SSN passed inferior to the TSL in all the cases and the motor branches to the supraspinatus took origin from the SSN within 10 mm of the SuNo. In 89% (80/90) cases the SSN innervated the infraspinatus within 1 cm from the base of the scapular spine. In 65.5%of the 30 cadavers dissected by Duparc *et al*[25] to study the SSN, the motor branch to the supraspinatus originated immediately after the SSN exited out of the SuNo in ~65% of the cases.

Shishido and Kikuchi[6] report of distance intervals regarding SSN along its anatomical course, many of which match the data obtained from our cadaveric dissections. In particular, the distance of SSN from the BSOS to the PG, distance from the branching point of SSN to infraspinatus to the PG, and distance of the last branch to infraspinatus to the PG are agreeable between the two studies (Table 1).

Warner *et al*[8] in their report of dissection results on 31 cadavers pointed out that the first motor branch was always larger of the two supplying the supraspinatus muscle. They found that in 86% cases (26/31) the first motor branch to supraspinatus took origin either under the TSL or within one millimeter distal to it. They proposed that the first motor branch is at risk for injury due to kinking under the TSL while the second motor branch is at risk owing to its small size and short course. According to them the mean distance from the origin of the long tendon of the biceps to the motor branches of the supraspinatus was 3 cm and they suggested that this could permit a safe mobilization of only one cm because of the presence of neurovascular bundles. Also, they reported that there was no difference in measurements when comparing cadavers of men and women, right and left sides, fresh or embalmed.

Acromial Branch

Vorster *et al*[1] noted in their study that in 23/31 (~75%) of the dissected shoulders the branch terminated in the infraspinatus close to the tendon, in 21 out of which it split off proximal to the neck of the scapula while in two it did so proximal to the TSL. They referred to this branch as the "acromial branch." A similar acromial branch was described by Aszmann *et al*[3] who described that the branch separated from the main stem at the level of the spine of the scapula, and traveled towards the posterior joint capsule and finally terminated at the junction of infraspinatus tendon, rotator cuff and posterior joint capsule. Vorster *et al*[1] suggest that this could be the proprioceptive branch which could have resulted in the immunohistochemical evidence of nociceptive nerve endings in the study by Ide *et al*[46].

Albritton *et al*[47] measured that the mean angle between the SSN main branch and its first motor branch was 140.7 degree. On medial rotation of the rotator cuff this angle was found to be decreasing significantly, and there was increased tension on the nerve. Shaffer *et al*[23] reported that from the glenoid rim to the SSN at the BSOS, the distance was 20.1 mm (range from 17-24 mm). They also noted that the distance of the glenoid rim to the first branch of the SSN in the infraspinatus-splitting interval was 22.5 mm (range from 17-30 mm).

Number of motor branches to infraspinatus has been poorly described in the literature. Warner *et al*[8] found the average number of branches to be between three to four, which is in line with the findings of our study. However, Bailie *et al*[24] reported of an average of four to six motor branches to infraspinatus. The true average is likely to fall in between, as each study is limited by small sample size.

Articular/Cutaneous Branch

In a study performed by Vorster *et al*[1] in 87.1% (27/31) of the 31 dissected shoulders a branch took origin at the level of the TSL, in 13 of which the branch split off proximal to the ligament, in 11, inferior to it, while in the rest the branch took origin distal to the ligament.

They referred to this nerve as the "articular branch." They described this branch as a sensory, articular branch supplying the capsular tissue of the shoulder. This branch has been described by others as a cutaneous branch and not articular[3,27,30]. The incidence of this nerve was recorded to be different by different observers- 3.3%[48], 9.8%[30], 14.7%[27] and 87.1%[1]. Vorster *et al*[1] suggest that this difference could be because of the variation in the method of dissection or the difference in the origin point of the branch itself. Ajmani[27] suggests that the nerve probably gets damaged in routine dissections when dividing the deltoid near its origin. This nerve lies in close relation to the undersurface of the deltoid and is adherent to it. Ajmani's study[27] demonstrated that the cutaneous branch in question was seen only in the male cadavers. Also, in some it arose from the upper branch, in others it arose from the stem of the SSN three mm above the TSL. He noted that in either condition, the cutaneous branch turned upwards and laterally along the upper part of the supraspinatus muscle only to run deep to the acromioclavicular joint. Then it pierced the deltoid near the muscle's acromial origin.

Spinoglenoid Ligament

The spinoglenoid ligament originates at the BSOS and inserts at the site of the posterior capsule near the PG rim where it shares a common border with the capsule. The thickened supraspinatus fascia reinforces it to form a narrow pathway, which protects the SSN from the muscular contractions but this canal may be a site of an entrapment or a compression[25]. The spinoglenoid ligament has been mostly described to be present constantly and there is no difference in the length of the spinoglenoid ligament in males and females. However in the 23 cadavers dissected by Demirhan *et al*[43] the spinoglenoid ligament was found in 14 (60.8%) and in one of them it was seen in two distinct parts.

SSN Injury

The SSN may be compressed at one of the three levels- in the SuNo, SGNo, or along the course between the bone and deep to the fascia[25]. The entrapment of SSN at the SuNo is much more common than at the SGNo[43,49]. Further, dimensions of the SGNo are not well defined in current literature. Duparc *et al*[25] reported an average length and width of 0.87 cm and 0.6 cm, respectively. This was notably different from the average measurements calculated during our dissections, with an average length and width of 1.82 cm and 1.58 cm, respectively. Reports of the dimensions of SuNo are more consistent. Duparc *et al*[25] found the average length and height to be 9.2 mm and 5.9 mm, similar to average length and height of 9.8 mm and 5.8 mm as reported by Yang *et al*[40]. Depth and width were measured by USG in cadavers by Yucesoy *et al*[50], who found the respective averages to be 8.22 mm in right and 8.06 on left (depth) and 12.85 mm on right and 12.39 mm on the left (width). These are more similar to our findings, suggesting an average length and height of 7.87 mm and 10.6 mm. However, discrepancies are most likely due to small sample size in our study. Distance from the SuNo to the SGNo as reported by Duparc *et al*[25] averaged to be 2.43 cm but ranged between 1.7 cm to 2.9 cm; these findings are similar to those in our study, finding an average length of 1.80 cm ± 0.34 cm.

Regional SSN anesthetic blocks and a number of procedures on the shoulder predispose the SSN to iatrogenic injury. SSN blocks are commonly applied during shoulder operations for their numerous benefits over general anesthesia[2,5]. Other than eliminating the adverse effects of general anesthesia, an added benefit is that leaving an indwelling catheter in place can help patients start early physiotherapy, by reducing the post-operative pain[51]. SSN blocks are used in the management of acute and chronic pain and for diagnosing suprascapular neuropathy. In the posterior approach to block the SSN, the nerve is numbed at the level of the SSN while in the superior approach the SSN is blocked by injecting in the vicinity of the nerve on the floor of the supraspinatus fossa. Warner *et al*[8] suggest that techniques for repairs of severe and massive tears of the rotator cuff as described by different authors[52-54] are practically impossible to conduct without damaging the suprascapular neurovascular bundle. Zanotti *et al*[9] reported that of the 104 massive rotator cuff repairs performed, 10 required cuff mobilization and acromioplasty and when these patients were followed up after 2-3 years post-surgery, only one of them suffered iatrogenic SSN injury. They, thus, proposed that iatrogenic injury to SSN during operative procedure can occur but a poor functional outcome is more dependent on other factors such as inadequate cuff muscle function.

Prevention of Injury

Anatomic relationships regarding the course of the SSN can be exploited during shoulder surgery to minimize risk potential, especially when taking a posterior approach. Shishido and Kikuchi[6] report various measurements to define the anatomical relationship of the SSN to the surrounding bony structures. They thus defined a 'safe zone' to avoid SSN injury while performing shoulder joint dissection with the posterior approach. The range of the 'safe zone' was reported to be within 2.3 cm from glenoid rim at the level of superior rim of the glenoid and within 1.4 cm from the posterior rim of the glenoid at the level of the BSOS. Of importance, these values are similar to the findings of our cadaveric dissections, showing the 'safe zone' (Figure 3) indicated by distance from the PG rim to the SSN at the base of the SGNo to be 1.81± 0.34 cm (q) and from the SSN at the SuNo to the supraglenoid tubercle to be 2.81± 0.36 cm (p); (>2.3 cm as described by Shishido and Kikuchi). The values of Shishido and Kikuchi's study were obtained from Japanese heritage while our values are of Indian descent, thus we would expect our data to be similar. In the case of larger frames in individuals of European or North American descent, parameters of the safe-zone will most likely differ; for such anatomical discrepancies, imaging studies can prove useful to mark the course of the SSN. Surgeons operating on the SSN can employ X-ray, C-arm, or USG to mark the safe zone by understanding its relationship to surface landmarks and bony landmarks. In this sense, marking the safe zone before arthroscopic procedures or other minimally invasive procedures on the shoulder can reduce risk of damage to the SSN.

Further, Bigliani *et al*[17] suggest of a safe zone for nail placement in arthroscopic Bankart repair surgeries, on PG neck, one cm at the level of the spine of the scapula and two cm at supraglenoid level. Karas *et al*[55] propose that if dissection is done more than two cm medial to the superior aspect of the glenoid rim, the SSN may be injured during the procedure.

Limitations

Findings of our study are limited by a small sample size. We also recognize that our cadavers are of Indian heritage and thus expectedly are of smaller frame and stature than the cadaver bases of many of the available literature reports. Further, studies including a larger sample size are warranted to better characterize anatomical dimensions and expand the current literature.

Conclusion

An appreciation of the anatomical knowledge is important in the prevention of SSN damage during surgical interventions including treatment of posterior instability[7,56], rotator cuff tears[57,58], SSN entrapment decompression[37,49] through TSL sectioning[28] or SuNo resection, and in new surgical techniques to repair anterior glenohumeral instability[59]. Further, it has been shown that arthroscopic release of the superior transverse ligament is more effective in freeing the SSN as compared to the traditional open surgical approach[49,60].

The data acquired during our cadaveric dissections are broadly consistent with the parameters of the SSN spelled out by other reports. It appears that the course of the SSN, although varying in some aspects, is largely similar as seen by the comparison of our cadavers of Indian descent versus the North American cadaveric measurements in the literature, the differences noted are pointed out.

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