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Sensory innervation of the subacromial bursa by the distal suprascapular nerve: a new description of its anatomic distribution

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Background: Sensory innervation to the shoulder provided by the distal suprascapular nerve (dSSN) remains the subject of debate. The purpose of this study was to establish consensus with respect to the anatomic features of the sensory branches of the dSSN. The relevant hypothesis was that the dSSN would give off 3 sensory branches providing innervation to the posterior glenohumeral (PGH) capsule, the subacromial bursa, in addition to the coracoclavicular and acromioclavicular ligaments.
Methods: The division, course, and distribution of the sensory branches that originated from the dSSN and innervated structures around the shoulder joint were examined macroscopically by dissecting 37 shoulders of 19 fresh-frozen cadavers aged of 83.0 years (range, 74-98 years).
Results: The 37 dSSN provided 1 medial subacromial branch (MSAb), 1 lateral subacromial branch (LSAb), and 1 PGH branch (PGHb) to the shoulder joint. This arrangement allowed for bipolar—MSAb and LSAb—innervation of the subacromial bursa, acromioclavicular (MSAb and LSAb) and coracoclavicular (MSAb) ligaments, as well as the PGH capsule (PGHb).
Conclusions: The dSSN provided 2 subacromial branches and 1 PGHb to the shoulder joint. This arrangement allowed for bipolar—MSAb and LSAb—innervation of the subacromial bursa, acromioclavicular and coracoclavicular ligaments, as well as the PGH capsule.
Level of evidence: Anatomy Study; Cadaver Dissection

Keywords: Anatomy; sensory innervation; shoulder; subacromial bursa; suprascapular nerve

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Investigational review board approval was not required for this study.

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Most studies suggest that the distal suprascapular nerve (dSSN) provides 70% of the sensory innervation to the shoulder.[9,11] However, this topic continues to be the subject of debate and consensus on the matter has yet to be reached.

Innervation of the posterior glenohumeral (PGH) capsule[2,6,12] and/or the subacromial bursa (SAB)[2] by 1 or 2 sensory branches of the dSSN has recently been described in the literature.[2,6,12] There continues to be a lack of consensus with respect to the arrangement and anatomic location of the sensory branches of the dSSN; furthermore, the course of these branches did not seem to be reproducible.[12] Recently, Ide et al[10] demonstrated a bipolar distribution of the sensory nerve endings in the SAB. We speculated that these nerves include both lateral subacromial branch (LSAb) and medial subacromial branch (MSAb) and a PGH branch (PGHb).

The aim of our study was to establish consensus with respect to the anatomic features of the sensory branches of the dSSN. The relevant hypothesis was that the dSSN would give off 3 sensory branches providing innervation to the PGH capsule, the SAB, in addition to the coracoclavicular and acromioclavicular ligaments.

Materials and methods

Cadaveric dissection

Thirty-seven shoulders (18 left and 19 right) from 19 fresh-frozen cadavers were included. The median age of the specimens (7 men, 12 women) was 83.0 years (range, 74-98 years). A history of radiation to the brachial plexus and/or shoulder, surgery, or trauma in the cervical, supraclavicular, or shoulder girdle area was considered exclusion criteria. None of the specimens were excluded.

To examine the anatomic characteristics of the dSSN and its sensory branches, cadaveric shoulder dissections were performed. The trapezius and deltoid, in addition to the medial two-thirds of the clavicle and scapular spine, were resected to facilitate dissection of the subacromial space and of the rotator cuff muscles. The supraspinatus and infraspinatus muscles were reflected laterally from their origins on the medial scapula. These muscles were sectioned 3 cm from their insertion on the greater tuberosity of the humerus. This superior transverse scapular ligament was systematically preserved, whereas the spino-glenoid ligament was resected. Fine microsurgical instruments and surgical loupes (3.5× magnification) were used for the dissection of the dSSN and its sensory branches. The SAB was preserved to facilitate identification of any potential nerve branches found within its substance. The mesoneurium was not preserved during the dissection. The following anatomical features of the sensory branches were also assessed: number of branches and their origin with respect to the suprascapular (SS) notch, their course, and their terminal extent. Distances were measured in centimeter with a caliper.

Literature review

The aim of this study was to collect and review the international literature about the dSSN anatomy published between 1900 and 2018. A literature search was performed using 5 different databases: Ovid Medline, Ovid Embase, Scopus, Web of Science, and Cochrane using the Medical Subject Headings and keywords. The search was limited to English language literature; terms used were combined with "AND" and "OR": suprascapular nerve, articular branch, and anatomy were used in various combinations to assist in review. The references in each study were reviewed to identify additional articles corresponding to the research criteria. After using these search criteria, 25 articles were found and evaluated. Seven articles for each nerve were deemed to be relevant to the purpose of this study. The figures of dissections and descriptions of the course of each branch were reviewed and are summarized in Table I.

Results

The 37 dSSN passed through the SS notch, inferior to the superior transverse scapular ligament. Three proprioceptive branches were described for the 37 (100%) dSSN dissected (Fig. 1): the MSAb, the LSAb, and the PGHb. Two LSAb were identified in 3 of the cadaveric shoulders (8.1%) (Fig. 2, *A*).

The MSAb branched at 1.3 cm (range, 0-3.5 cm) from the SS notch. The majority of MSAb (n = 27; 73%) originated proximal to the SS notch. Only the MSAb originated proximal to the SS notch, and all branches passed through it along the lateral aspect of the parent nerve. In all shoulder dissections, the MSAb turned superolaterally around the base of the coracoid process, giving off branches to the coracoclavicular ligaments (ie, conoid and trapezoid), and then ran superolaterally toward the medial pole of the SAB until it reached the medial edge of the deep face of clavicular insertion of the acromioclavicular ligament (Fig. 2, *B*).

The LSAb diverged at a mean of 0 cm (range, 0-2.6 cm) from the SS notch. Most LSAb originated (n = 19; 51.4%) at the level of the notch itself. Distal to the SS notch, the LSAb coursed obliquely and laterally along the inferior surface of the supraspinatus muscle until it reached the deep interval between the supra- and infraspinatus muscles. It then coursed over the superior face of the supraspinatus tendon and giving off 1 or 2 sensory branches to the lateral subacromial pole and acromial insertion of the acromioclavicular ligament (Fig. 2, *C*). No sensory branches to the supraspinatus tendon were identified. Among all the 37 (100%) cadaveric shoulders, there were 2 subacromial branches that provided bipolar—medial and lateral— sensory innervation to the SAB (Fig. 2).

The origin of the PGHb was at a median distance of 3 cm from the SS notch; no PGHb origin was reported proximal to the SS notch. Distal to the spinoglenoid notch, the PGHb ran inferomedially toward the posterior shoulder capsule.

Table I Summary of literature review for sensory branches of the suprascapular nerve

Author and year	Specimens	No. of shoulders	Excerpt describing the articular branch sensory innervation	Reinterpretation
Gardner, 1948[8]	N/A	7	✔ *"As this nerve enters the supraspinous fossa it gives off a branch, which runs laterally, deep to the tendon of the supraspinatus muscle. During its course it gives a branch to the periosteum of the coracoid process and frequently one to the coracoacromial ligament. It ends as fine rami in the superior region of the capsule."*	⇒ Medial subacromial branch
			✔ *"In the fetal joints, these fibers, together with the blood vessels which they accompany, ramify in the capsule adjacent to the glenoid lip."*	⇒ Posterior glenohumeral branch
Horiguchi, 1979[9]	N/A	6	✔ *"The cutaneous nerve either arose from the upper branch to the supraspinatus muscle or from the stem of the suprascapular nerve under the superior transverse scapular ligament. The branch turned superolaterally along the anterior aspect of the supraspinatus muscle to the postero-inferior aspect of the coracoclavicular ligament, where it gave a filament to the acromio clavicular joint."*	⇒ Medial subacromial branch
Ajmani, 1994[1]	N/A	34	✔ *"The cutaneous branch arose from the upper branch to the supraspinatus muscle, or from the stem of the suprascapular nerve 3mm above the transverse scapular ligament, or arose deep to the transverse scapular ligament. Whatever the source of origin, the cutaneous branch turned upwards and laterally along the upper part of the supraspinatus muscle. It then passed deep to the acromio-clavicular ligament where it gave a filament to the acromio-clavicular joint."*	⇒ Medial subacromial branch
Aszmann et al, 1996[2]	Fresh-frozen adult cadavers	25	✔ *"After entering the suprascapular notch, the suprascapular nerve sends lateral articular branches to the coraco-clavicular ligaments."*	⇒ Medial subacromial branch
			✔ *"After giving off lateral articular branches to the coracoclavicular ligaments, the nerve then gives articular branches to the coracohumeral ligament, subacromial bursa, and posterior ACJ capsule."*	⇒ Medial subacromial branch
			✔ *"After giving a muscular branch to the suprascapular m., the suprascapular nerve gives lateral articular branches to the posterior joint capsule."*	⇒ Glenohumeral posterior branch
Vorster et al, 2008[13]	Embalmed adult cadavers	31	✔ *"After passing the suprascapular notch, the suprascapular nerve gives an articular branch which travels superolaterally around the base of the coracoid process then turns to run inferomedially toward the posterior shoulder capsule."*	⇒ Medial subacromial branch
			✔ *"A second branch of the suprascapular nerve split off from the main stem just proximal to the scapular neck and ran on the scapula under the supraspinatus muscle before entering the infraspinatus muscle near its tendon. In the other 2 shoulders, it branched off proximal to the transverse scapular ligament to run across and anterior to the base of the coracoid process*	⇒ Lateral subacromial branch

(*continued on next page*)

Table I Summary of literature review for sensory branches of the suprascapular nerve (*continued*)

Author and year	Specimens	No. of shoulders	Excerpt describing the articular branch sensory innervation	Reinterpretation
			and superior to the glenoid to the infraspinatus muscle."	
Ebraheim et al, 2011[5]	Embalmed adult cadavers	12	✓*"Immediately after passing the suprascapular notch, the direct sensory branch turned laterally along the base of the coracoid process and ran superiorly to the supraspinatus muscle towards the acromioclavicular joint."*	⇒Medial subacromial branch
			✓*"Just before entering the infraspinous fossa, a branch of the suprascapular nerve ran laterally and entered the posterior inferior aspect of the capsule deep to the tendons of the infraspinatus muscle."*	⇒Posterior glenohumeral branch
Eckmann et al, 2017[6]	Embalmed and fresh-frozen adult cadavers	16 embalmed, 1 fresh frozen	✓*"Superiorly to the spinoglenoid notch the articular branches were seen along the supraspinous fossa of the spine of the scapula, coursing laterally toward the posterior GH joint and head of the humerus in all specimens. The nerves were then seen piercing the fascia overlying the head of the humerus."*	⇒Lateral subacromial branch
			✓*"As the SN passed inferiorly through the spinoglenoid notch, the main trunk proceeded medially to innervate the infraspinatus muscle, whereas the articular branches coursed laterally in the infraspinous fossa of the spine of the scapula toward the posterior inferior GHJ and head of the humerus."*	⇒Posterior glenohumeral branch

N/A, not available.
There is limited literature describing the sensory articular branches of the suprascapular nerve in cadaveric models. The nerve's path has been described previously by the authors above.

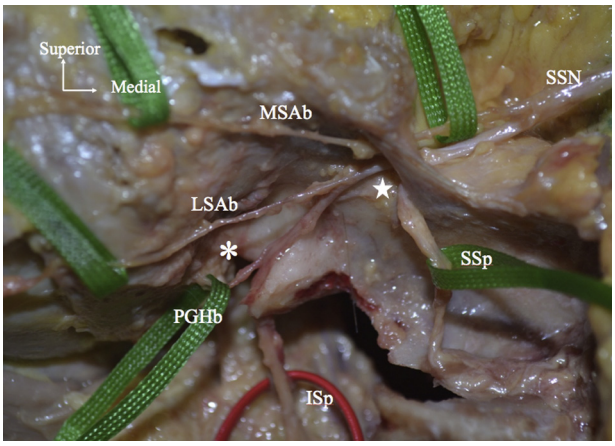

Figure 1 Origins of the 3 sensory branches of the suprascapular nerve (SSN). The SSN gives off the medial subacromial branch (MSAb) proximal to the SS notch (*white star*). The lateral subacromial (LSAb) and posterior glenohumeral (PGHb) branches arise from the SSN distal to the SS notch (*white star*) and at the spinoglenoid notch (*white asterisk*), respectively. ISp and SSp, Branches to infraspinatus and supraspinatus muscles.

Based on the measurements of the 37 cadaver dSSN, the anatomic features of the dSSN and its sensory branches are illustrated in Figure 3.

Discussion

The dSSN contributed 3 distinct sensory branches to the SAB (medial and lateral poles), coracoclavicular and acromioclavicular ligaments and PGH capsule (Fig. 3). This study has elucidated previously undescribed anatomy of the dSSN and its 3 distinct articular branch courses: an MSAb, an LSAb (or 2 in 8.1% cases [Fig. 2]), and a PGHb, the course of which had already been described in the literature (Table I). The description of a bipolar innervation of the SAB was consistent with the bipolar distribution of the nocireceptors in the medial and lateral part of the SAB described by Ide et al.[10]

Prior studies of the dSSN identified terminal sensory branches to the SAB,[2,12] PGH capsule,[2,6] acromioclavicular joint,[1,5] and ligaments (coracoclavicular and coracohumeral ligaments).[2,5] There has been significant confusion in the

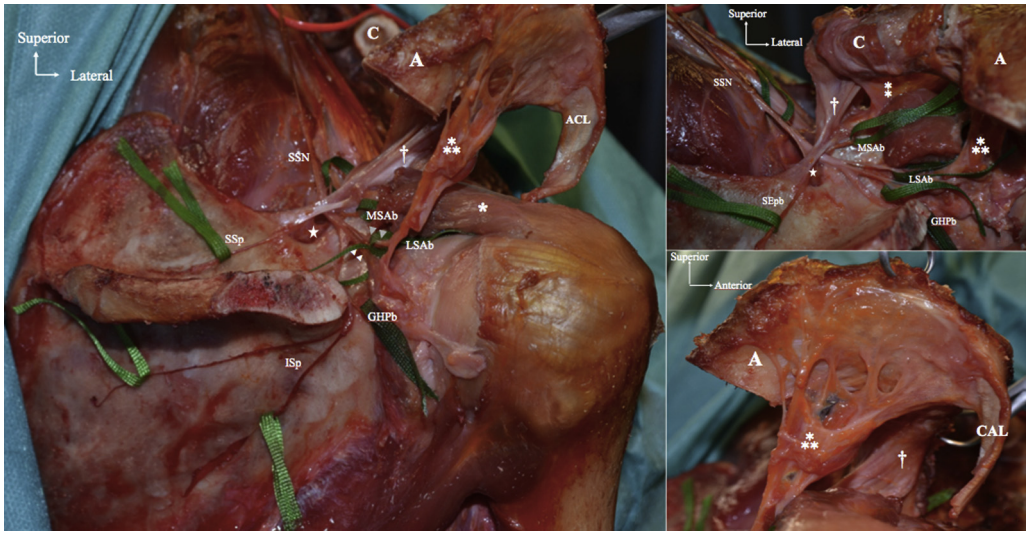

Figure 2 Three sensory branches of the suprascapular nerve (SSN). The SSN gives off the medial subacromial branch, which courses lateral to the SSN in the SS notch (*white star*) and courses laterally around the coracoid process to innervate the coracoclavicular ligaments (†) and the medial portion of the SA bursa (* *). Two lateral subacromial branches (LSAb) (*white and grey head arrows*) arise from the SSN distal to the SS notch and terminate over the supraspinatus muscle (*) in the medial portion (* * *) of the SA bursa and the acromial insertion of the acromioclavicular ligament (ACL). Distal to the spinoglenoid notch, the posterior glenohumeral branch (PGHb) arises from the SSN to innervate the posterior glenohumeral capsule. *A*, acromion; *C*, clavicle; *ISp*, branch to infraspinatus muscle; *SSp*, branch to supraspinatus muscle.

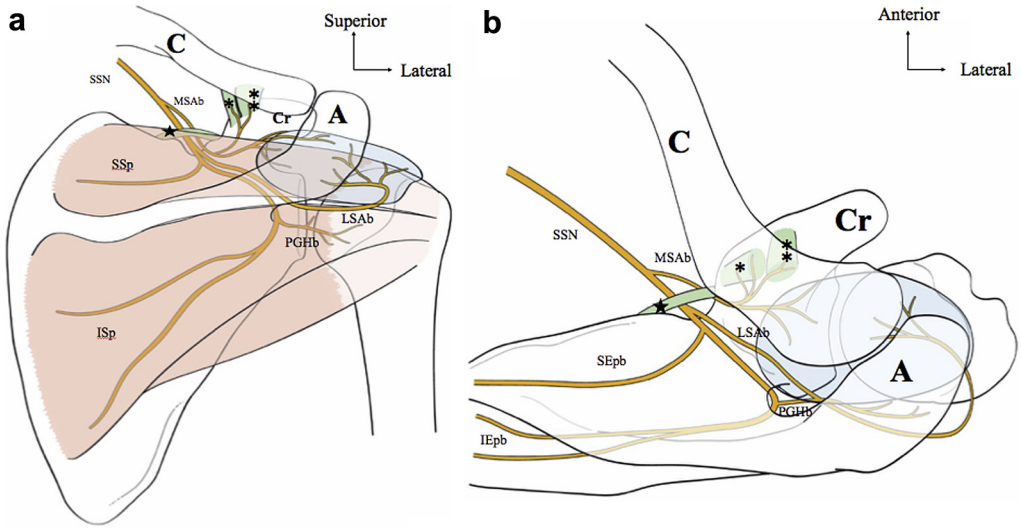

Figure 3 Schematic diagram of the distal suprascapular nerve (dSSN) and its sensory branches (**a**, *posterior view*; **b**, *superior view*). The SSN has 3 sensory branches: a medial subacromial branch proximal to the suprascapular notch, a lateral subacromial branch (LSAb) at the level of the suprascapular notch, and a posterior glenohumeral branch (PGHb) distal to the spinal glenoid notch. The subacromial branches provide bipolar innovation to the subacromial bursa (*in blue*); the medial subacromial branch (MSAb) also innervates the coracoclavicular ligaments (conoid (*) and trapezoid (**) ligament). The PGHb provide sensory innervation to the posterior glenohumeral capsule. *A*, acromion; *C*, clavicle; *Cr*, coracoid process; *ISp*, branch to infraspinatus muscle; *SSp*, branch to supraspinatus muscle.

literature with regard to the anatomic features of the sensory divisions of the dSSN, and the structures it innervated (Table I). Gardner[8] described a lateral articular branch of the dSSN in 1948, which provided innervation to the coracoclavicular ligaments, and terminated its course in the superior aspect of the glenohumeral capsule. Aszmann et al[2] described this branch as a medial articular branch—innervating coracoclavicular and coracohumeral ligaments and SAB. They also identified distal and lateral articular branches terminating within the posterior joint capsule. Vorster et al[13] provided data to support this medial articular branch course and therefore recommended that it be named "nervus suprascapularis ramus articularis." The authors also described the course of a new branch, splitting

off from the parent nerve just proximal to the scapular neck and running on the scapula deep to the supraspinatus before entering the infraspinatus near its tendon. Ebraheim et al[5] confirmed that the medial articular branch turns laterally along the base of the coracoid process and terminates in the acromioclavicular joint and SAB. They also described a second branch running laterally before the infraspinous fossa and entering the posterior aspect of the capsule deep to the infraspinatus. Eckmann et al[6] classified articular branches with respect to the spinoglenoid notch (superior and inferior). These articular branches were reported to course laterally in the supraspinous (superior branch) and infraspinous (inferior branch) fossae of the scapula to innervate the PGH capsule, SBA, and posterior fascia of the head and neck of the humerus. The authors did not report a finite anatomic area of innervation in their paper.

Although innervation of the coracohumeral ligament has already been described, the present study did not report it.[2] This could be explained by the posterior approach used for the cadaveric shoulder dissection, which did not provide us good access to the anterior structures of the shoulder. Bipolar innervation of the acromioclavicular ligament at the clavicular and acromial insertion has been reported,[1,2] but we were unable to reliably describe innervation of the acromioclavicular ligament or acromioclavicular joint in the present study. According to Aszmann et al,[2] these 2 ligaments were innervated by small branches from a medial articular branch. We therefore speculate that the branch they described is equivalent to our MSAb; however, contribution from the LSAb should also be considered.

The present study reports that 23.6% (n = 27) of proprioceptive branches originated proximal to the SS notch and subsequently coursed along the lateral aspect of the SSN beneath the transverse scapular ligament. These branches consisted exclusively of MSAb, the most proximal of which originated 3.5 cm from the SS notch (Fig. 1). Aszmann et al[2] described an articular branch of the dSSN originating at an average of 4.5 cm proximal to the transverse scapular ligament and running with the parent nerve to enter the SS notch beneath at its most lateral aspect. The origins of the sensory branches were proximal to the SS notch in 48.2% of cases according to Vorster et al.[13] Eckmann et al[6] described the sensory branches according to their position with respect to the spinal glenoid notch. This led to a categorization of the dSSN branches into 2 groups: subacromial branches (MSAb and LSAb) and PGHb. In this way, the spino-glenoid notch was a reliable anatomic landmark used to discriminate between sensory branches of the dSSN, destined for anatomic zones and differential functions about the shoulder.

This new description of the dSSN is especially important for both surgical and regional anesthesia applications. The suprascapular nerve is potentially at risk during shoulder surgery, especially when a posterior approach is used or during arthroscopic procedures.[3,4,14] To decrease the risk of iatrogenic nerve injury and optimize selective nerve blocks, a thorough understanding of the anatomy of the dSSN branches is important. The typical landmark used to perform posterior blocks of the SSN is the SS notch.[13] Despite the fact that the MSAb originated proximal to the SS notch, its course remained tied to that of the dSSN until both traverse the notch. However, given the high level of anatomic variation of the SS notch,[7] in addition to the small sample sizes across studies of the dSSN and its branches, it has been recommended that optimal blockade of the dSSN be performed proximal to its most proximal branch origin (3.5 cm according to the present study or 4.5 cm according to Aszmann et al[2]).

This study is subject to the inherent biases associated with cadaveric studies. Furthermore, the limited number of specimens limited the reliability of descriptive parameters and our ability to identify variations from normal anatomy. The cadaver dissection step could have modified the normal anatomy, which may have distorted the study's findings. The posterior approach did not allow us to describe the fine network of branches of the medial and lateral subacromial nerves within the SAB and limited the access to the anterior subacromial elements such as the coracohumeral ligament. A complementary superior approach to the shoulder with the removal of the acromion and the three-quarter medial clavicle would have been necessary for meticulous description of the SAB and anterior anatomical structures of the shoulder.

Conclusion

The dSSN provided 2 subacromial branches and 1 PGHb to the shoulder joint. This arrangement allowed for bipolar—medial and lateral—innervation of the SAB, acromioclavicular and coracoclavicular ligaments, as well as the PGH capsule. Further studies are needed to detail the course of the subacromial branches and describe their role in innervation of ligamentous structures (coracoacromial and acromioclavicular ligaments).

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