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Surgical anatomy of the internal branch of the superior laryngeal nerve

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Abstract The internal branch of the superior laryngeal nerve (ibSLN) may be injured during anterior approaches to the cervical spine, resulting in loss of laryngeal cough reflex, and, in turn, the risk of aspiration pneumonia. Such a risk dictates the knowledge regarding anatomical details of this nerve. In this study, 24 ibSLN of 12 formaldehyde fixed adult male cadavers were used. Linear and angular parameters were measured using a Vernier caliper, with a sensitivity of 0.1 mm, and a 1° goniometer. The diameter and the length of the ibSLN were measured as 2.1 ± 0.2 mm and 57.2 ± 7.7 mm, respectively. The ibSLN originates from the vagus nerve at the C1 level in 5 cases (20.83%), at the C2 level in 14 cases (58.34%), and at the C2–3 intervertebral disc level in 5 cases (20.83%) of the specimens. The distance between the origin of ibSLN and the bifurcation of carotid artery was 35.2 ± 12.9 mm. The distance between the ibSLN and midline was

24.2 ± 3.3 mm, 20.2 ± 3.6 mm, and 15.9 ± 4.3 mm at the level of C2–3, C3–4, and at the C4–5 intervertebral disc level, respectively. The angles of ibSLN were mean $19.6 \pm 2.6^\circ$ medially with sagittal plane, and $23.6 \pm 2.6^\circ$ anteriorly with coronal plane. At the area between the thyroid cartilage and the hyoid bone the ibSLN is the only nerve which traverses lateral to medial. It is accompanied by the superior laryngeal artery, a branch of the superior thyroid artery. The ibSLN is under the risk of injury as a result of cutting or compression of the blades of the retractor at this level. The morphometric data regarding the ibSLN, information regarding the distances between the nerve, and the other consistent structures may help us identify this nerve, and to avoid the nerve injury.

Keywords Anatomy · Cervical spine · Complication · Internal branch · Superior laryngeal nerve

Introduction

The superior laryngeal nerve (SLN) originates commonly from the vagus nerve at the level of the C2 vertebra and descends medially toward the thyrohyoid membrane (TM), the membrane between the thyroid cartilage and the hyoid bone [14]. Its position was found to be mostly symmetrical between the right and left sides [15]. The SLN branches into internal and external

branches deep into the internal carotid artery. The internal branch of the superior laryngeal nerve (ibSLN) passes immediately inferior to the greater horn of the hyoid bone, and approaches the TM accompanied by the superior laryngeal artery (SLA), a branch of the superior thyroid artery (STA) [7]. Both the ibSLN and the SLA pierce the external surface of the TM [13, 14]. ibSLN is divided into three branches. The superior branch of the ibSLN innervates the mucosa of the epi-

glottis and a small part of the anterior wall of the vallecule. The middle branch is a sensory branch, which innervates the aryepiglottic folds. The inferior branch sends a few twigs to the interarytenoid muscles [13, 14, 16, 17].

The ibSLN is sensitive to the laryngeal mucosa down to the level of the vocal folds. It also carries afferent fibers from the laryngeal neuromuscular spindles and other stretch receptors.

The SLN may be injured during the anterior or anterolateral cervical spine surgery, thyroid surgery and during carotid endarterectomy [1–3, 6, 10]. Routinely the main trunk and posterior descending branch of the ibSLN was preserved in supraglottic laryngectomy by identification of the main trunk in the viscerovertebral angle medial to the carotid bifurcation [5]. The rate of SLN palsy varies from 9 to 14% in thyroid surgery [10], from 1 to 4.5% in carotid endarterectomy operations [8], and 8% in anterior cervical fusion operations [4]. Injury to the ibSLN results in impairment of the laryngeal cough reflex [12,18]. This reflex protects humans against foreign material aspiration that potentially could result in aspiration pneumonia and other respiratory illnesses [17]. However, the dual innervation of the larynx by SLN decreases the risk of manifest cough reflex loss.

Such a risk necessitates a clear definition of the morphometric and regional anatomy of the ibSLN. This study aims to define the location and trajectory of this nerve, and its vulnerability during anterior cervical spine procedures.

Materials and methods

Twelve adult male cadaver specimens were used for this study. An anterior approach to the cervical spine was performed to dissect the SLN, the ibSLN and its branches. The ibSLN of both sides of the 12 cadavers (24 ibSLN) were dissected under a Carl Zeiss stereoscopic dissection microscope. The vagus nerve was carefully dissected from the jugular foramen to the origin of the trunk of the SLN. Subsequently, the internal and external branches of the SLN were dissected up to their entrance into the larynx. Linear and angular parameters were measured using a Vernier caliper, with a sensitivity of 0.1 mm, and a 1° goniometer. Statistical analysis was performed using Mann Whitney *U* tests. $P < 0.05$ was considered significant. The measured parameters are listed in Table 1.

Results

The SLN arises from the vagus nerve within the carotid sheath at the level of C1–C2 and crosses the internal

carotid artery. The SLN bifurcates into internal and external laryngeal branches which are located beneath the internal carotid artery (Fig. 1). The distance between the origin and bifurcation of the SLN was measured to be 14.1 ± 4.2 mm (mean $\pm$ SD). The ibSLN arises from the SLN at the level of C1 in 5 cases (20.83%), at the level of C2 in 14 cases (58.34%), and at the level of the C2–3 intervertebral disc in 5 cases (20.83%).

The ibSLN was measured to be localized ventral to the superior cervical ganglion in 16 cases (66.67%), and was medial to it in 8 cases (33.33%). The SLN descends in a vertical direction, with an angle of $19.6 \pm 2.6^\circ$ (mean $\pm$ SD) from the superolateral to the inferomedial, relative to the sagittal plane, and with an angle of $23.6 \pm 2.6^\circ$ from the posterosuperior to the anteroinferior, relative to the coronal plane (Fig. 2).

The distance between the ibSLN and midline was measured as 24.2 ± 3.3 mm, 20.7 ± 3.6 mm, and 15.9 ± 4.3 mm at the level of C2–3, C3–4, and at the C4–5 intervertebral disc, respectively. The distances between the ibSLN and the anterior surface of the C2–3, C3–4, and C4–5 intervertebral discs were measured as 9.6 ± 3.2 mm, 15.2 ± 4.6 mm, and 23.0 ± 5.2 mm, respectively. The measurements of the right and left sides are listed in Table 2.

The distance between the origin of the ibSLN and bifurcation of the common carotid artery was 35.2 ± 12.9 mm. The distance between the common carotid artery and the point at which the ibSLN pierces the TM was 7.0 ± 6.3 mm. The distance between laryngeal prominence and the point at which the ibSLN pierces the TM was 13.7 ± 2.8 mm.

The mean diameter of the ibSLN was 2.1 ± 0.2 mm at the level of the C3 vertebra. It was found that the ibSLN was branched more deeply to the piercing point of the TM in 15 cases (62.5%) (Fig. 3) and was branched out proximally to the piercing point of the TM in 9 cases (37.5%, Fig. 4). According to their destination, the branches of the ibSLN could be grouped into superior, middle, and inferior branches. The mean diameters of the superior, middle, and inferior branches of the ibSLN at the point where they pierce the TM were found to be 1.2 ± 0.2 mm, 1.5 ± 0.2 mm, and 1.2 ± 0.3 mm, respectively.

The ibSLN crossed the SLA approximately 31.4 mm superior to the upper pole of the thyroid gland in 18 cases (75%, Fig. 3) and did not in 6 cases (25%, Fig. 4). The ibSLN crossed with the STA approximately 33.0 mm at the upper pole of the thyroid gland in 9 cases (37.5%), and did not in 15 cases (62.5%).

The distance between the origin of the ibSLN and the termination of the middle ramus was 57.2 ± 7.7 mm. The mean distance between the greater cornu of the hyoid bone and the point of termination of the middle branch of the ibSLN was 25.8 ± 5.5 mm.

Table 1 The measured parameters

Lengths	The length of the SLN The length of the ibSLN
Distances	Distance between the ibSLN and the anterior surface of the corresponding intervertebral discs Distance between the greater horn and the point at which the middle branch of the ibSLN pierces the TM Distance between the ibSLN and midline at the level of the intervertebral disc
Relations	Relations between the ibSLN and superior cervical ganglion Relation between the ibSLN and SLA Relation between the ibSLN and STA Relation between the branches of ibSLN and TM
Diameters	Diameter of the ibSLN Diameters of the superior, middle, and inferior branches of the ibSLN
Angle	Angles of ibSLN with respect to the sagittal and coronal planes
Vertebra levels	The level at which the middle branch of the ibSLN pierces the TM The branching point of the ibSLN from the SLN

SLN, Superior laryngeal nerve; *ibSLN*, Internal branch of the superior laryngeal nerve; *SLA*, Superior laryngeal artery; *STA*, Superior thyroid artery; *TM*, thyrohyoid membrane

Fig. 1 Relations between the ibSLN and SLN and the other anatomic structures. *ibSLN* internal branch of the superior laryngeal nerve, *ECA* external carotid artery, *SLA* superior laryngeal artery

The medial branch of the ibSLN pierces the TM at the level of the C4 vertebra in 12 cases (50%), at the level of the C4–5 intervertebral disc in 6 cases (25%), and at the level of the C5 vertebra in 6 cases (25%).

Discussion

The fact that ibSLN injury causes cough reflex loss requires knowledge regarding the morphology of this nerve. The most important area in which this nerve is under the risk of injury is around the TM, i.e., between the thyroid cartilage and hyoid bone. In this area, the ibSLN is the only nerve traversing lateral to medial, and in most cases is accompanied with the SLA, a branch of the STA [13, 14, 16–18].

The SLN originates from the vagus nerve at the level of the C1 and C2 vertebra, and in most cases bifurcates into the internal and external branches beneath the internal carotid artery at the level of the C2 vertebra [14]. The distance between the origin of the SLN and the bifurcation point was reported to be 15 mm (3–20 mm) by Melamed [12], 21 mm by Lang et al. [11], 16.7 ± 0.9 mm by Furlan et al. [9] and 14.1 ± 4.2 mm in our present work.

The SLN descends in a vertical direction, with an angle of $19.6 \pm 2.6^\circ$ from superolateral to inferomedial, relative to the sagittal plane, and with an angle of $23.6 \pm 2.6^\circ$ from posterosuperior to anteroinferior, relative to the coronal plane.

The ibSLN is located ventral to the superior cervical ganglion in 66.67% of the cases, and is located medial to it in 33.33% of cases.

The length of the ibSLN was reported to be 64 mm by Lang [11], 44.9 ± 1.0 mm by Furlan [9], and was found to be 57.2 ± 7.7 mm in our study. The total length of the SLN and ibSLN was measured to be 71 mm in our studies. The SLN and its branches may be stretched along their relatively long course by medial and rostral

Fig. 2 The angles of ibSLN with respect to SP and CP. *ibSLN* internal branch of the superior laryngeal nerve, *SP* sagittal plane, *CP* coronal plane

blades of retractors during retraction for cervical spine exposure.

The diameter of the ibSLN was found to be 1.8–2.0 mm by Stephens et al. [17], and 2.1 ± 0.2 mm in the present study. This relatively thin nerve may be ligated or cut during surgical approaches. As mentioned before, the external and internal branches of SLN are the only nerves traversing lateral to medial at this level. Although the hypoglossal nerve has a similar direction, this nerve is more superficial and superior than the branches of the SLN, and unlike these nerves directs upward. A close relation between ibSLN and other structures during

exposure along its long course should be taken into consideration.

The ibSLN crosses the greater cornu of the hyoid bone, prior to piercing the TM. The distance between the TM piercing point and the point at which the ibSLN crosses the greater cornu was reported to be 28.52 ± 4.61 mm by Stephens et al. [17]. The same distance was measured as 25.8 ± 5.5 mm here.

According to Melamed et al. [12], the ibSLN pierces the TM at the level of the C3–4 intervertebral disc. Our studies, however, revealed that the ibSLN pierces the TM at the level of C4 in 12 cases (50%), at the level of

Table 2 Measurements of the right and left sides

SLN–ibSLN	Right	Left	Mean
Lengths			
The length of the SLN	14.8 ± 4.4	13.5 ± 4.0	14.1 ± 4.2
The length of the ibSLN	58.0 ± 8.2	56.3 ± 7.4	57.2 ± 7.7
Distances			
ibSLN–anterior surface of the C2–3 IVD	10.7 ± 3.5	8.0 ± 2.0	9.6 ± 3.2
ibSLN–anterior surface of the C3–4 IVD	16.3 ± 5.7	14.0 ± 3.0	15.2 ± 4.6
ibSLN–anterior surface of the C4–5 IVD	22.3 ± 5.6	23.5 ± 5.3	23.0 ± 5.2
greater horn –middle branch pierces the TM	25.9 ± 6.2	25.6 ± 5.0	25.8 ± 5.5
ibSLN –idline at the C2– IVD	24.0 ± 3.6	24.5 ± 3.1	24.2 ± 3.3
ibSLN –idline at the C3– IVD	20.1 ± 3.6	21.3 ± 3.6	20.7 ± 3.6
ibSLN –idline at the C4– IVD	15.5 ± 5.0	16.3 ± 4.2	15.9 ± 4.3
Diameters			
IbSLN	2.2 ± 0.1	2.0 ± 0.3	2.1 ± 0.2
Superior branch of ibSLN	1.2 ± 0.2	1.3 ± 0.2	1.2 ± 0.2
Middle branch of ibSLN	1.6 ± 0.3	1.5 ± 0.2	1.5 ± 0.2
Inferior branch of ibSLN	1.2 ± 0.2	1.2 ± 0.3	1.2 ± 0.3
Angles			
ibSLN–agittal plane	18.9 ± 2.1	20.3 ± 2.9	19.6 ± 2.6
ibSLN–oronal plane	23.0 ± 4.1	24.3 ± 5.2	23.6 ± 4.6

Fig. 3 A case of the ibSLN branching out deep to the TM and ibSLN crossing the SLA. *ibSLN* internal branch of the superior laryngeal nerve, *SLA* superior laryngeal artery, *TM* thyrohyoid membrane, *BC* bifurcatio carotidea

Fig. 4 A case of the ibSLN uncrossing the SLA and ibSLN branching out proximally to the TM. *ibSLN* internal branch of the superior laryngeal nerve; *ECA* external carotid artery; *a* superior branch, *b* middle branch, *c* inferior branch; *SLA* superior laryngeal artery; *TM* thyrohyoid membrane

the C4–5 intervertebral disc in 6 cases (25%), and at the level of C5 vertebra in 6 cases (25%). This localization should be taken into consideration during the placement of blades of retractors, both cranially and medially.

The ibSLN is divided into three branches either before or after piercing the TM. Stephens et al. [17] reported that the ibSLN branched distal to the TM in 21 of 25 cases, and proximal to it in four cases. This is in part parallel to the results of our study, in which the ibSLN branched distal to the TM in 15 cases (62.5%), and proximal to it in 9 cases (37.5%).

Stephens et al. [17] measured the distance between the TM and ibSLN trifurcation as 6.95 ± 3.71 mm. The

same distance was measured as 11.7 ± 3.8 mm in our study.

Conclusion

In summary, anterior and anterolateral approaches to the upper cervical spine may result in ibSLN injury. This requires knowledge regarding the course of this nerve. This study revealed that the ibSLN descends anteromedially, and reaches the TM. The described course of this nerve may lead to an injury due to a stretch by retraction, ligation or cutting, particularly in the middle area of the cervical spine.

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