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ORIGINAL ARTICLE

Topographical anatomy of the anterior cervical approach for c2-3 level

Soo-An Park · Je-Hun Lee · Yong-Seok Nam · Xiaochun An · Seung-Ho Han · Kee-Yong Ha

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Abstract
Purpose To develop a clinically relevant anterior cervical approach (ACA) to the C2-3 level.
Methods Frequently encountered nerves [hypoglossal (HyN), internal (ISLN) and external superior laryngeal nerves (ESLN)] and vessels [lingual (LiA), superior laryngeal (SLA) and superior thyroid arteries (STA)] in the field of high ACA and the anatomic spatial markers [submandibular gland (SMG); sling for digastrics muscle (SDG); hyoid bone (HyB), and thyroid cartilage (ThC)] were evaluated using 18 fresh cadavers. The vertical distance of each structure at the carotid sheath and larynx and each disc for cervical level were measured from the suprasternal notch.
Results The cervical levels of SDG, SMG and HyB were mostly C3 and that of ThC was C5. The vertical locations of HyN and LiA were not significantly different and the levels corresponded to C2. The levels for ISLN and ESLN were C3 at carotid and C4 and C5 at larynx sides, respectively. The vertical locations of ISLN and HyN were significantly different at carotid ($p = 0.001$) and larynx ($p < 0.001$) sides. The vertical locations and cervical levels of SLA and STA at carotid and larynx sides were not significantly different with those of ISLN and ESLN, respectively. The HyN traversed C2 with accompanying LiA. The ISLN passed C3 and C4 from carotid to larynx sides and accompanied SLA.
Conclusions The C2-3 level can be exposed through the space between the HyN and the ISLN by retracting the LiA superiorly, the SLA inferiorly, the HyB medially, and the carotid sheath laterally.

Keywords High anterior cervical approach · C2-3 · Topographical anatomy

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S.-A. Park (✉)
Department of Orthopedic Surgery, Uijeongbu St. Mary's Hospital, The Catholic University of Korea College of Medicine, 271, Cheonbo-ro, Ujeongbu-si, Gyeonggi-do 480-717, South Korea
e-mail: parksa@catholic.ac.kr

J.-H. Lee
Department of Anatomy, Konyang University College of Medicine, Daejeon, South Korea

Y.-S. Nam · X. An · S.-H. Han
Catholic Institute for Applied Anatomy, The Catholic University of Korea College of Medicine, Seoul, South Korea

K.-Y. Ha
Department of Orthopedic Surgery, Seoul St. Mary's Hospital, The Catholic University of Korea College of Medicine, Seoul, South Korea

Introduction

The Smith–Robinson approach is typically the most common anterior procedure for many cervical spine surgeries. This approach provides an excellent access for anterior cervical spine, but there is a limitation in visualizing the higher levels than C3 [1]. Previous surgical techniques that have been used for the high cervical levels include the transoral, the anterior retropharyngeal retrovascular and prevascular, and the submandibular parapharyngeal approaches [1, 2].

McAfee et al. [3] described the retropharyngeal prevascular approach using the same fascial plane as described by Southwick and Robinson [4] for the lower cervical spine. This anterior cervical approach (ACA) using the submandibular incision is one of the commonly used anterior procedures for the upper cervical levels. However, it has limitations in protecting the hypoglossal and mandibular branch of facial nerves and hypopharynx [3, 5, 6].

Russo et al. [1] reported another submandibular approach to access the C2-3 disc level. This approach takes advantage of a natural corridor proximal to the superior laryngeal nerve and distal to the HyN. However, the neurovascular structures are also in danger during dissection because Russo and colleagues utilized the same wide submandibular incision and did not localize the targeting cervical level and the adjacent structures. Likewise, no previous approaches have been perfect for the highest cervical disc, the C2-3 level.

The objectives of this study are to develop a clinically relevant surgical approach to the C2-3 level by determining the spatial relationships of the anatomic markers [submandibular gland (SMG), sling of digastric muscle (SDG), hyoid bone (HyB) and thyroid cartilage (ThC)], the nerves [hypoglossal (HyN), internal (ISLN) and external superior laryngeal (ESLN) nerves] and the vessels [lingual (LiA), and superior laryngeal (SLA) and superior thyroid (STA) arteries] overlying the C2-3 level using the topographic anatomy and to demonstrate any vulnerable structure.

Materials and methods

Dissection

Eighteen fresh cadavers (10 males and 8 females; age 79.4 ± 6.9 years, ranging from 64 to 91 years) were included for investigation and another two cadavers were used for illustration in the figures. Cadavers with any gross neck deformity, surgical wound on the neck or severe cervical degeneration were not selected. The dissection was performed in the supine position and the neck was fully extended.

After removing the skin, the anterior neck was exposed by removing the platysma muscle from the suprasternal notch to the mandible vertically within the range of carotid sheath of one side to the other side laterally. The anterior border of the sternocleidomastoid muscle was identified, and a plane between the medial edge of the carotid sheath and the midline structures was developed to expose the cervical spine by incising the prevertebral fascia. All the neurovascular structures encountered in this plane around the high cervical levels were traced and identified with the consensus of the authors and referenced from books of anatomy [7–9]. Finally, the most consistently present nerves (HyN, ISLN and ESLN) and vessels (LiA, SLA and STA) in the ACA and anatomic markers (SMG, SDG, HyB and ThC) for spatial reference were evaluated for this study.

Measurements

The vertical distances of the neurovascular structures (HyN, ISLN, ESLN, LiA, SLA and STA) traversing the space between the carotid sheath and the pharyngolarynx were measured at the points crossing the medial border of the carotid sheath (*c*-point) and the lateral border of the pharyngolarynx (*l*-point) from the suprasternal notch using a digital caliper (Absolute Digimetric; Mitutoyo Corp, Kanagawa, Japan), respectively. The vertical distances of SMG and SDG were measured from the suprasternal notch to the lower-most margin of each structure. For the HyB and the ThC, the vertical distance was measured from the suprasternal notch to the mid-points of HyB and the laryngeal prominence of ThC. For the vertebral level, the vertical distance was measured from the suprasternal notch to the mid-point of each cervical disc (C2–C3 through C5–C6). The vertical distance of each cervical disc ±2 mm was regarded as the range of disc and the intervals between these values were the range of vertebrae.

Statistical analyses

The dependent variables were as follows:

1. For the structures (HyN, LiA, ISLN, ESLN, SLA and STA) traversing the space between the carotid sheath and the larynx, the vertical distance and the corresponding cervical levels at the *c*- and the *l*-points in each side were analyzed.
2. For the structures in both sides not traversing the field of ACA (SMG and SDG), the vertical distance and the corresponding cervical levels in each side were analyzed.
3. For the structures in the midline of the neck (HyB and ThC), the vertical distance and the corresponding cervical levels were analyzed.

The vertical distance of each structure was compared with that of the adjacent structure using a one-way ANOVA. The frequency of the corresponding vertebral level for each structure was compared with that of the adjacent structure using a Chi square test. All statistical tests were performed using SPSS for Windows, version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Anatomic markers

The SMG superficially overlaps the SDG and is partly below the mandible and partly medial to the carotid sheath. The SDG was attached to the HyB and the vertical location of the SDG (133.6 ± 10.5 mm) was not significantly different to the SMG (131.9 ± 11.0 mm) and HyB (128.1 ± 8.2 mm). The vertebral levels for the SDG (62.5 % of cases), SMG (44.4 %) and HyB (85.7 %) were not significantly different and corresponded to C3. The vertical locations for the ThC was 100.1 ± 8.7 mm and the level was C5 in 42.9 %. The vertical location and the level for the ThC were significantly more caudal than the SDG and the SMG (Tables 1, 2; Fig. 1).

Hypoglossal nerve

The HyN was deep to the SMG and the digastric muscle, crossing the pharyngolarynx from the carotid sheath. The HyN appeared consistently thick and strong in all cases and ran transverse in the field of the ACA. The vertical locations of the HyN (139.6 ± 7.5 mm at *c*-point; 138.1 ± 9.8 mm the *l*-point) were significantly higher than those of the SDG, SMG, and HyB, and the levels at *c*- and *l*-points were more cephalad to the C2-3 disc, but more caudal to the anterior tubercle of C1. Therefore, no more dissection to the cephalad direction from the HyN was necessary to access the level of C2-3 in this study (Tables 1, 3, 4; Figs. 2, 3).

Lingual artery

The LiA was deep to the HyN and passed C2 at *c*- and *l*-points. The appearance of this artery was bulky and redundant enough when it was retracted. The vertical locations and levels of the LiA for *c*- (138.0 ± 9.2 mm, C2 in 47.2 %) and *l*-points (139.2 ± 8.7 mm, C2 in 69.4 %) were not significantly different to those of the HyN, respectively (Tables 1, 3, 4; Fig. 2).

Table 1 Vertical distances and vertebral levels for the anatomic markers of the cervical discs

Anatomical references	Vertical distance from suprasternal notch (mm)	Vertebral level (Frequency)
Mandible (lower margin)	169.5 ± 12.3	
C2-3 disc	135.8 ± 12.7	
SDG	133.6 ± 10.5	C3 (62.5 %)
		C2 (16.7 %)
		C2-3 (16.7 %)
SMG (lower margin)	131.9 ± 11.0	C3 (44.4 %)
		C2 (30.6 %)
		C2-3 (11.1 %)
HyB	128.1 ± 8.2	C3 (85.7 %)
C3-4 disc	117.4 ± 10.9	
ThC (prominence)	100.1 ± 8.7	C5 (42.9 %)
		C4 (35.7 %)
		C4-5 (21.4 %)
C4-5 disc	99.2 ± 10.9	
C5-6 disc	82.0 ± 10.3	

Table 2 Comparison of the vertical distance and the corresponding vertebral level of each anatomic marker to the adjacent markers

	Vertical distance from suprasternal notch (*P*)	Vertebral levels (*P*)
SMG vs.		
SDG	0.672	0.359
HyB	0.252	0.073
HyB vs. SDG	0.105	0.206
ThC vs.		
SMG	$<$0.001	$<$0.001
SDG	$<$0.001	$<$0.001

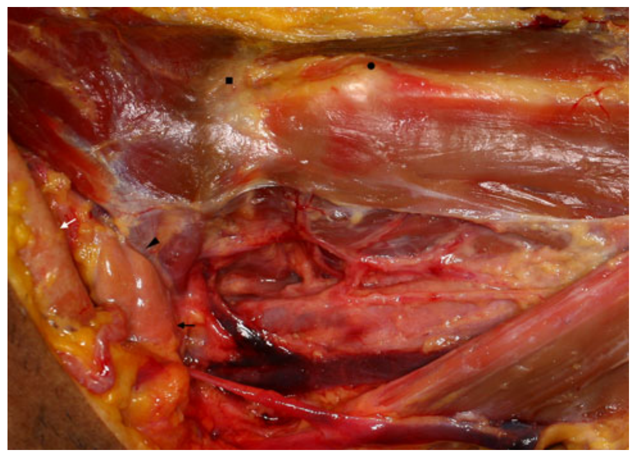

Fig. 1 Right neck of a 53-year-old male. The lower-most margins of SMG (*black arrow*) and SDG (*arrowhead*), the HyB (*black square*), and the laryngeal prominence of the ThC (*black dot*) are in the right neck. The white arrow indicates the mandible (*white arrow*)

Superior laryngeal nerve (SLN)

The SLN descends into the field of the ACA from the vagus nerve, dividing into the external and internal branches. The ISLN appeared to be thick, but was smaller than the HyN in diameter. Topographically, the ISLN was the next nerve caudal to the HyN. The vertical location of the ISLN at *c*-point (127.8 ± 8.3 mm) was not significantly different to those of the SDG, SMG, and HyB, but at *l*-point (116.7 ± 7.2 mm), was significantly more caudal than those of anatomic markers. The levels for the ISLN at *c*- (52.8 %) and *l*-points (41.7 %) were C3 and C4, respectively (Fig. 2). The vertical locations of the ISLN and HyN were significantly different at *c*- and *l*-points and

Table 3 Vertical distances and vertebral levels of the neurovascular structures

	At the medial border of carotid sheath (*c*-point)		At the lateral border of larynx (*l*-point)	
	Vertical distance from suprasternal notch (mm)	Vertebral level (Frequency)	Vertical distance from suprasternal notch (mm)	Vertebral level (Frequency)
HyN	139.6 ± 7.5	C2 (50 %)	138.1 ± 9.8	C2 (47.2 %)
		C3 (30.6 %)		C3 (36.1 %)
		C2-3 (19.4 %)		C2-3 (16.7 %)
LiA	138.0 ± 9.2	C2 (47.2 %)	139.2 ± 8.7	C2 (69.4 %)
		C3 (41.7 %)		C2-3 (22.2 %)
		C2-3 (11.1 %)		C3 (8.3 %)
ISLN	127.8 ± 8.3	C3 (52.8 %)	116.7 ± 7.2	C4 (41.7 %)
		C2 (19.4 %)		C3 (27.8 %)
		C3-4 (11.1 %)		C3-4 (22.2 %)
		C4 (11.1 %)		
SLA	123.3 ± 10.4	C3 (41.7 %)	116.7 ± 8.3	C4 (47.2 %)
		C4 (25 %)		C3-4 (27.8 %)
		C3-4 (16.7 %)		C3 (19.4 %)
ESLN	121.6 ± 12.9	C3 (33.3 %)	96.2 ± 9.5	C5 (47.2 %)
		C3-4 (22.2 %)		C4 (25 %)
		C4 (16.7 %)		C4-5 (13.9%)
		C23 (13.9 %)		
STA	120.8 ± 12	C3 (44.4 %)	94 ± 9.6	C5 (69.4 %)
		C3-4 (22.2 %)		C4-5 (8.3 %)
		C4 (16.7 %)		C4 (8.3 %)

there was a space developed between theses nerves corresponded to the C2-3 disc (Fig. 3).

The appearance of the ESLN was much thinner and variable than that of the ISLN and the number of ESLN was more than one in 11 out of 36 sides (30.6 %). The vertical location of the ESLN at *c*-point was not significantly different (121.6 ± 12.9 mm) to that of the ISLN, but that at *l*-point (96.2 ± 9.5 mm) was significantly more caudal than the ISLN. The levels for the ESLN were C3 at *c*-point in 33.3 % and C5 at *l*-point in 47.2 %. The vertical location of the ESLN at *l*-point was not significantly different to that of the ThC (Tables 1, 3, 4) (Fig. 4).

Superior thyroid and superior laryngeal arteries

The vertical locations and vertebral levels of the SLA at *c*- (123.3 ± 10.4 mm, C3 in 41.7 %) and *l*-points (116.7 ± 8.3 mm, C4 in 47.2 %) were significantly different to those of the LiA, respectively. The vertical locations and vertebral levels of SLA at *c*- and *l*-points were not significantly different with those of ISLN, respectively (Fig. 2).

The vertical locations and cervical levels of the STA at *c*- (120.8 ± 12.0 mm, C3 in 44.4 %) and *l*-points (94.0 ± 9.6 mm, C5 in 69.4 %) were not significantly different with those of the ESLN, respectively. The vertical location of the SLA was not significantly different from that of the STA at *c*-point, but was significantly more cephalad at *l*-point. The vertical location of the STA at *l*-point was significantly more caudal to the ThC. However, the levels for the STA at *l*-point and the ThC were not significantly different and mostly corresponded to C5 (Fig. 4).

The SLA is the branch of the STA, but started directly from the external carotid artery (ECA) in six sides. Therefore, the vertical distance of the SLA at *c*-point was measured at the starting point of the STA or the SLA from the ECA when it was an independent branch. Variation in numbers of the STA was also observed in six sides. In these cases, the vertical distance with more cranial level was measured at *c*-point and the one with more caudal level was measured at *l*-point (Tables 1, 3, 4).

Discussion

The anterior approach to the upper cervical spine (more cephalad to the C3 vertebra) is a challenge. In several techniques, the anterior retropharyngeal approach using the submandibular incision (submandibular approach) has been the most appropriate procedure for these levels in terms of less morbidity and feasibility for the instrumentation [2, 3].

Table 4 Comparison of the vertical distance and the corresponding vertebral level of each neurovascular structure to the adjacent structures

	At the medial border of carotid sheath (*c*-point)		At the lateral border of larynx (*l*-point)	
	Vertical distance from suprasternal notch (*P*)	Vertebral levels (*P*)	Vertical distance from suprasternal notch (*P*)	Vertebral levels (*P*)
HyN vs.				
SMG	0.002	0.077	0.013	0.136
SDG	0.001	0.024	0.004	0.046
HyB	<0.001	0.001	0.001	0.002
LiA	0.125	0.162	0.326	0.498
ISLN	0.001	0.001	<0.001	<0.001
SLA	<0.001	<0.001	<0.001	<0.001
LiA vs.				
SMG	0.023	0.052	0.002	0.023
SDG	0.028	0.039	0.001	0.005
HyB	0.002	0.001	<0.001	<0.001
ISLN	0.001	<0.001	<0.001	<0.001
SLA	<0.001	<0.001	<0.001	<0.001
ISLN vs.				
SMG	0.039	0.623	<0.001	<0.001
SDG	0.1	0.189	<0.001	<0.001
HyB	0.901	0.267	<0.001	0.007
ThC	<0.001	<0.001	<0.001	<0.001
SLA	0.107	0.181	0.302	0.669
STA	0.005	0.343	<0.001	<0.001
ESLN	0.018	0.11	<0.001	<0.001
SLA vs.				
SMG	0.018	0.032	<0.001	<0.001
SDG	0.001	0.042	<0.001	<0.001
HyB	0.191	0.124	<0.001	0.002
ThyC	<0.001	<0.001	<0.001	<0.001
STA	0.859	0.895	<0.001	<0.001
ESLN vs.				
ThC	<0.001	<0.001	0.187	0.737
STA	0.788	0.901	0.325	0.176
SLA	0.7	0.552	<0.001	<0.001
STA vs.				
ThC	<0.001	<0.001	0.043	0.099

In McAfee's submandibular approach [3], the SMG was resected with dividing the digastric and stylohyoid muscles. However, Hsu and Kutler [10] mentioned the complications following a SMG resection. The most common complication is a weakness of the depressor muscles of the lower lip from an injury to the marginal mandibular nerve. The lingual and HyN can also be injured. Likewise, the morbidity of the SMG resection must not be underestimated.

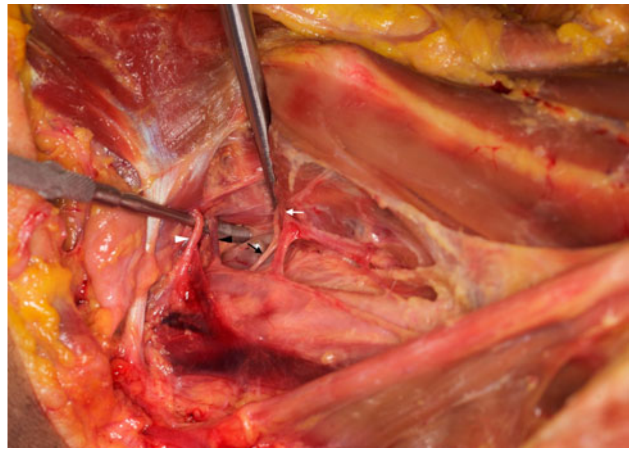

Fig. 2 Right neck. Identification of the HyN (*white arrowhead*), the LiA (*black arrow head*), the internal branch of the superior laryngeal nerve (*black arrow*) and the superior laryngeal artery (*white arrow*) in the right neck. The C2-C3 disc is marked by a ball-tipped pin

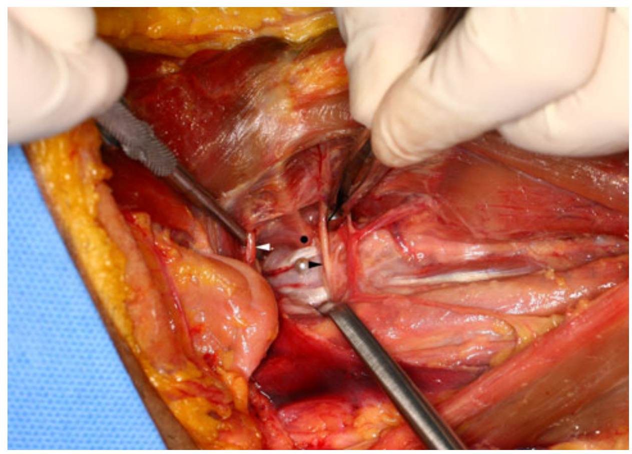

Fig. 3 Right neck. The space for the C2-3 disc (*ball-tip pin*) is developed by the retraction of the HyN (*white arrowhead*) and the LiA superiorly, the internal superior laryngeal nerve (*black arrowhead*) and the superior laryngeal artery inferiorly, the HyB (*black dot*) medially, and the carotid sheath laterally

Russo et al. [1] reported a strategy to expose the C2–3 level while preserving the SMG, when the approach is through the parapharyngeal quadrilateral space. The anatomical borders of their quadrilateral space were the HyN superiorly, the ISLN and the HyB inferiorly, the stylopharyngeus muscle medially, and the carotid sheath laterally. However, they did not localize the anatomic structures around this level.

In the current study, the HyN was consistently located on the C2 vertebra and the ISLN passed C3 and C4 at *c*- and *l*-points, respectively. The vertical locations of these nerves were significantly different and the mean differences were about 12 and 22 mm at *c*- and *l*-points, respectively, when no retractions were applied. The

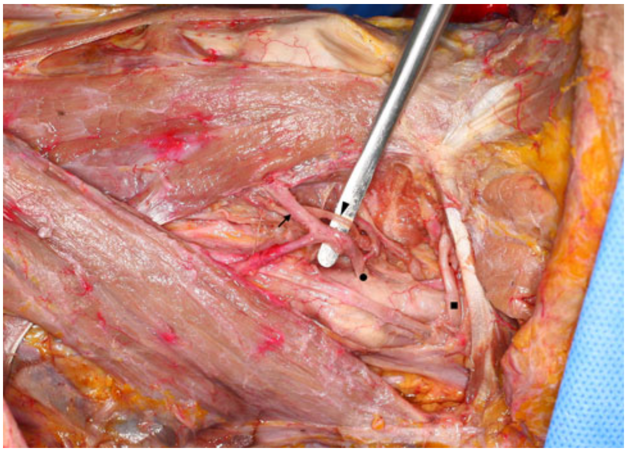

Fig. 4 Left neck of a 74-year-old male. The superior thyroid artery (*black dot*) starts from the external carotid artery. Its main branch (*black arrow*) goes distal to the thyroid gland and accompanies the external superior laryngeal nerve (*black arrowhead*) lies deep to it. The black square indicates the HyN

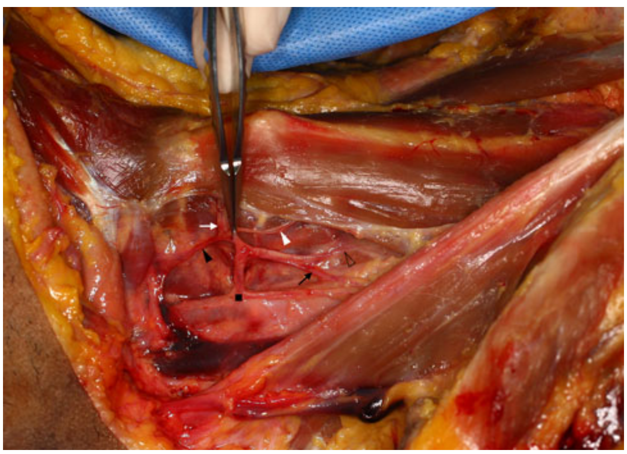

Fig. 5 Right neck. The superior thyroid artery starts from the external carotid artery (*black square*) and gives off four branches: infrahyoid (*black arrowhead*), superior laryngeal (*white arrow*), sternocleidomastoid (*black arrow*) and cricothyroid arteries (*white arrowhead*). The main branch descends to the thyroid gland (*lined arrowhead*)

vertical locations of the HyN were more cephalad to the anatomic markers (SDG, SMG, HyB). The vertical location of the ISLN at *c*-point was not significantly different, but that at *l*-point was significantly more caudal to those of these markers. Therefore, the vertical locations of these markers at the lateral margin of the larynx may be a good starting point to develop the space between the HyN and the ISLN for the C2-3 level.

The LiA is the second proximal branch to the STA from the ECA [8]. The LiA was observed deep and mostly parallel to the HyN and occasionally in between the HyN and the ISLN. The superior laryngeal artery is the second proximal branch of the STA and accompanies the ISLN. However, in

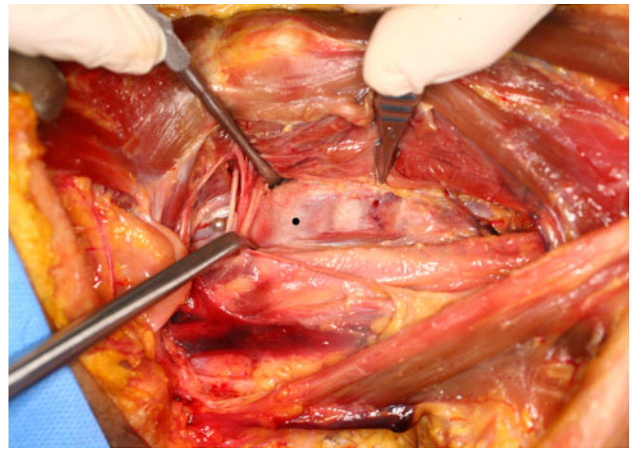

Fig. 6 Right neck. The C3-4 disc (*black dot*) was exposed with full retraction of superior laryngeal nerve and accompanying vessels with a wide dissection from more caudal levels. Approach to C2-3 disc (*ball-tipped pin*) from more caudal level may not be available without injuring these nerves and vessels

this study, the SLA was not branched from the STA but directly from the ECA in six sides. Moreover, in reality, the beginning of the STA from the ECA was more caudal to the ISLN at the *c*-point. For comparison between the LiA and the SLA, the LiA appeared bulky and redundant and was bigger than the SLA in diameter (Fig. 2).

The STA gives off four branches: infrahyoid, superior laryngeal, sternocleidomastoid and cricothyroid arteries (Fig. 5) [7, 8]. Only the superior laryngeal and the main branch of superior thyroid arteries were investigated in this study.

When developing the space between the HyN and the ISLN, the LiA should be retracted cranially and the SLA caudally. Thus, the borders of the quadrilateral space for the approach at C2-3 level should be the HyN and the LiA superiorly, the ISLN and the SLA inferiorly, the HyB medially (helpful to displace the midline structures), and the carotid sheath laterally.

This quadrilateral space was good to expose the bodies of C2 and C3 and the C2-3 disc (Fig. 3). However, the higher than C2-3 level was not exposed through this approach without injuring the HyN and/or the LiA. Approach to the C2-3 disc with a wide dissection from a more distal level was also not available without injuring the SLN and its accompanying vessels (Fig. 6).

The appearances of the HyN and the ISLN were thick and consistently present in the field of the ACA. The HyN appeared thicker than the ISLN but both nerves were strong enough to endure the manual retraction. The HyN is a somatic motor to the tongue muscles [8]. Injury to the HyN paralyzes the ipsilateral half of the tongue and iatrogenic injury is very rare to our knowledge [11].

The SLN divides within the carotid bifurcation and results in the internal and external branches. The ISLN descends to the thyrohyoid membrane, passing above the SLA (Figs. 2, 3). It ends by piercing the inferior pharyngeal constrictor. The ISLN is sensory to the laryngeal mucosa down to the level of the vocal folds. Injury to the ISLN causes a loss in cough reflex [8, 12, 13]. Hill et al. [14] recommended the superior to the superior horn of the ThC as the landmark of the ISLN at the larynx and it corresponded to C4 in this study.

Conclusion

The C2-3 level can be approached through the space between the hypoglossal and the internal superior laryngeal nerves by a little retraction of the LiA superiorly, the superior laryngeal artery inferiorly, the HyB medially and the carotid sheath laterally. This approach provides a working space enough for the C2-3 level while preserving the SMG and even without needing to access the previously noted marginal mandibular nerve. When considering the vertical locations of the anatomic markers, such as the SMG and the HyB, this approach can be minimized from the old techniques using wider submandibular incision [1, 3].

Conflict of interest None.

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