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RESEARCH

RELATIONSHIP BETWEEN VARIATIONS OF THE EXTERNAL BRANCH OF THE SUPERIOR LARYNGEAL NERVE AND THE RECURRENT LARYNGEAL NERVE AND NECK CIRCUMFERENCE: A CADAVERIC STUDY

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SUMMARY

Objectives/Hypothesis: The aim of this study was to investigate whether a relationship was evident between variations of the external branch of the superior laryngeal nerve (EBSLN) and the recurrent laryngeal nerve (RLN) and neck circumference in adult cadavers.

Methods: Bilateral neck dissections were performed on 42 cadavers (84 sides); 31 males and 11 females with a of mean age 56.48 ± 10.10 years. EBSLNs were classified using the system proposed by Cernea et al. and RLNs were classified in terms of their relationship to the inferior thyroid artery.

Results: We found statistically significant associations between EBSLN and RLN Types. EBSLN Type 2b was significantly more common in patients with type B RLNs compared with type A RLNs (p=0.015) and type C RLNs (p=0.037). Also, EBSLN Type 2a was significantly more common in patients with type A RLNs compared with type C RLNs (p=0.018). We found no significant association between EBSLN or RLN Type and neck circumference, except for Type 2a and 2b EBSNs. The neck circumference of cases with Type 2a EBSLNs was less than that of those with Type 2b EBSLNs (p=0.005).

Conclusions: The relationships that we have identified may aid surgeons to identify the EBSLN.

Keywords: Superior laryngeal nerve, recurrent laryngeal nerve, neck circumference, anatomic variation

SUPERIOR LARENGEAL SINIRIN EKSTERNAL DALI VE REKÜRREN LARENGEAL SINIR VARYASYONLARI VE BOYUN ÇEVRESI ARASINDA İLIŞKI: KADAVRA ÇALIŞMASI

ÖZET

Giriş: Bu çalışmada erişkin kadavralarda superior laringeal sinirin eksternal dalı (SLSED) ve rekürren larengeal sinir (RLS) varyasyonları ve boyun çevresi arasında bir ilişki olup olmadığının araştırılması amaçlanmıştır.

Gereç ve Yöntem: 42 kadavrada (84 taraf) boyun diseksiyonu yapıldı; 31 erkek ve 11 kadın kadavranın ortalama yaşı 56.48 ± 10.10 yıl idi. SLSED Cernea ve ark. tarafından önerilen sistem kullanılarak, RLS'ler inferior tiroid arter ile olan ilişkileri açısından sınıflandırıldı.

Bulgular: SLSED ve RLS tipleri arasında istatistiksel olarak anlamlı ilişkiler bulduk. Tip 2b SLSED, tip B RLS'li hastalarda anlamlı olarak daha yaygın idi. Ayrıca, Tip 2a SLSED, tip A RLS'li hastalarda daha fazla bulundu (p = 0.018). Tip 2a ve 2b SLSED'ler haricinde, SLSED veya RLS tipi ve boyun çevresi arasında anlamlı bir ilişki bulamadık. Tip 2a SLSED olan olguların boyun çevresi, Tip 2b SLSED olanlardan daha düşüktü (p = 0.005).

Sonuç: Bu çalışmada tanımladığımız ilişkiler cerrahların SLSED'nı identifiye etmesine yardımcı olabilir.

Anahtar Sözcükler: Superior laringeal sinir, rekürren larengeal sinir, boyun çevresi, anatomik varyasyon

INTRODUCTION

The larynx is innervated by the superior laryngeal nerve (SLN) and the recurrent laryngeal nerve (RLN), both of which are branches of the vagus nerve. The SLN leaves the vagus nerve near the exit thereof from the jugular foramen of the skull base. At 1.5 cm in the caudal direction, the SLN divides into a thicker internal and a thinner external branch; the internal branch leaves the lateral thyrohyoid membrane (to deliver sensory afferent information from the supraglottis and vocal folds), whereas the external branch of the superior laryngeal nerve (EBSLN) descends dorsally to the carotid sheath and then crosses medially toward the larynx, delivering motor impulses to the cricothyroid muscle[1]. Innervation of all other intrinsic laryngeal muscles is provided by the RLN, which departs from the vagal nerve in the chest, extending into the tracheoesophageal groove in the cephalic direction and entering the throat near the cricothyroid joint [2].

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Iatrogenıc ınjury of nerves controlling phonation (the RLN and EBSLN) is a well-known complication of neck surgery. The clinical manifestations differ by the injured branch of the laryngeal nerve. Unilateral injury of the RLN can cause hoarseness, vocal fatigue, a persistent cough, aspiration, and dysphagia. Bilateral RLN palsy is associated with a potentially catastrophic scenario (dyspnea and glottal obstruction) [3,4,5]. The clinical features of EBSLN injury are wide-ranging but not specific; phonation may be affected by a hoarse/breathy voice, shortened phonation time, and reduced vocal frequency range, leading to various difficulties including poor vocal performance (particularly at high pitch and when singing) [6].

The EBSLN and RLN are the most common nerves that are injured iatrogenically, especially during thyroid surgery. The best way to avoid nerve injury is to understand the courses of the nerves, as well as their anatomical relationships to neighboring structures, especially the superior thyroid artery (STA) and the inferior thyroid artery (ITA); the nerves are usually injured during attempts to dissect, ligate, and divide these arteries. The prevalence of transient and permanent RLN damage ranges from 0–11% [7], but damage to the EBSLN occurs at a rate of up to 58% because of the slimness of the nerve and variations in the course [8].

Although several studies have explored the relationships between these nerves and the STA and ITA, no study has yet compared variations in the EBSLN and RLN. In this study, we explored these relationships in an effort to aid surgeons to identify (especially) the EBSLN. We also compared right- and left-sided nerves, and the relationships between neck circumference and both nerves.

MATERIAL and METHODS

After obtaining approval from the Committee of the Turkish Forensic Medicine Institution (approval number: 21589509/272) and local Ethics Committee of Bakırköy Dr. Sadi Konuk Education and Training Hospital, Istanbul, Turkey (approval number: 291), we examined 42 cadaver specimens (84 sides; 31 males and 11 females) who were 18–75 years of age at the time of death and had no history of neck surgery, head-and-neck trauma, deformities, or tumors.

After hyperextension of the head (45°), a midline longitudinal incision was made through the second layer of the cervical fascia that surrounded the strap muscles. The sternocleidomastoid and infrahyoid muscles were dissected and transected, exposing the thyroid gland. The strap muscles were separated from the underlying thyroid gland via blunt dissection. Upon retraction of the sternocleidomastoid muscle, the superior thyroid pole was exposed and dissected at the point where the STA and the vagus nerve were identified next to the carotid artery and the internal jugular vein; the SLN and its external branch were then dissected to the point of insertion into the cricothyroid muscle. Next, the inferior lobes of the thyroid gland were pulled forward to identify the RLN in the tracheoesophageal groove and at the point of crossing of the ITA; the nerve was then followed along the lower margin of the inferior pharyngeal constrictor muscle.

Classification

EBSLNs were classified using the system proposed by Cernea et al. [9,10] In this system, EBSLNs are classified based on the point of the STA at which the nerve crosses, thus changing from lateral to medial. Type 1 nerves cross the superior thyroid vessels > 1 cm above the upper edge of the superior pole of the thyroid; Type 2a nerves cross the vessels < 1 cm above the superior pole of the thyroid; and Type 2b nerves cross the vessels below the upper border of the superior thyroid pole (Figure 1).

RLNs were classified in terms of their relationship to the ITA [2]. Three variations are commonly recognized: Type A nerves run lateral to the artery and its branches; Type B nerves run between the branches of the artery; and Type C nerves run medial to the artery and its branches (Figure 2).

Statistical Analysis

We used the Number Cruncher Statistical System 2007 software (NCSS, Kaysville, UT, USA) for the statistical analysis. We present descriptive statistics [mean, standard deviation, median, first quarter (Q1), third quarter (Q3), frequency, percentage, minimum, and maximum]. Quantitative data were tested in terms of the normality of distribution using the Shapiro-Wilk and graphical tests. The Kruskal-Wallis test was used for between-group comparisons of quantitative variables that were not normally distributed, and Dunn-Bonferroni-corrected post-hoc evaluation was employed to identify the group responsible for the difference. Fisher’s exact test was used to compare qualitative data. Left- and right-sided evaluations of EBSLN and RLN classifications were performed with the aid of the marginal homogeneity test. The statistical significance was set at $p<0.05$.

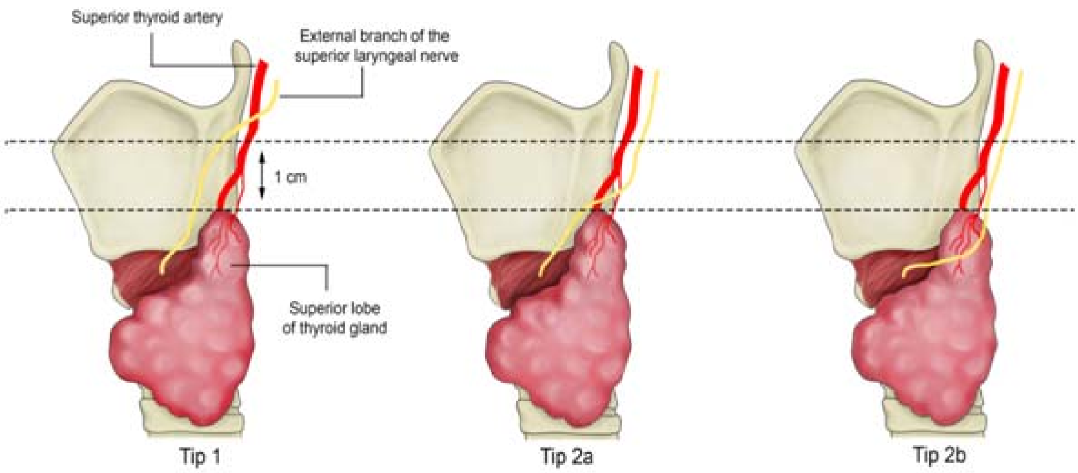

***Figure 1:** The Cernea classification system, which classifies the external branches of the superior laryngeal nerve by their location according to the superior thyroid artery*

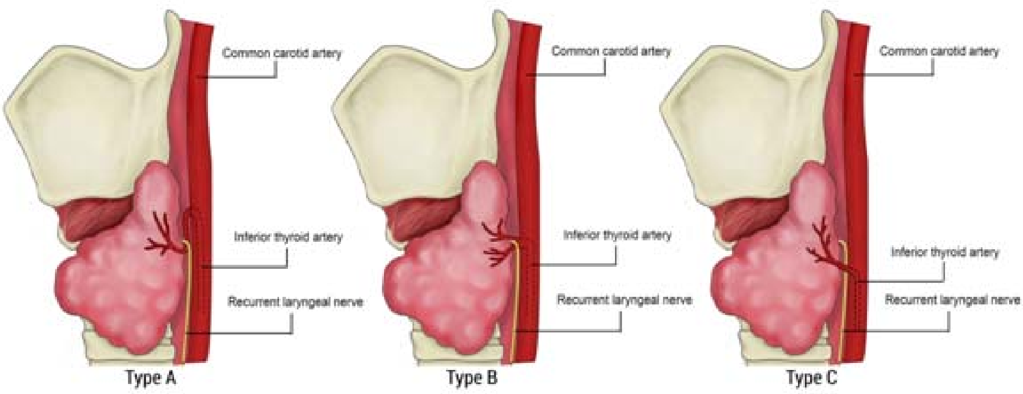

***Figure 2:** Classification of recurrent laryngeal nerve in terms of its relationship to the inferior thyroid artery*

RESULTS

Bilateral neck dissections were performed on 42 cadavers (84 sides); 31 males and 11 females with a of mean age 56.48 ± 10.10 years. The demographic characteristics of the cadavers are summarized in Table 1.

Of all cases, 64.3% (n = 54) EBSLNs were classified as Type 1, 22.6% (n = 19) as Type 2a, and 13.1% (n = 11) as Type 2b. 19% (n =16) RLNs were classified as Type A, 11.9% (n =10) as Type B, and 69% (n =58) as Type C (Figure 2,3).

Comparison of right- and left-sided EBSLNs

On the right side, 69% (n = 29) EBSLNs were classified as Type 1, 21.4% (n = 9) as Type 2a, and 9.5% (n = 4) as Type 2b. On the left side, 59.5% (n = 25) were classified as Type 1, 23.8% (n = 10) as Type 2a, and 16.7% (n = 7) as Type 2b. Of all cases, 69.1% (29) were of the same type on both sides. We found no significant difference (p=0.108) between the right- and left-sided classifications (Table 2).

Comparison of right- and left-sided RLNs

On the right side, 19% (n = 8) of RLNs were classified as Type A, 9.5% as Type B (n = 4), and 71.4% as Type C (n = 30). On the left side, 19% (n = 8) were classified as Type A, 14.3% (n = 6) as Type B, and 66.7% C (n = 28) as Type C. Of all cases, 71.4% (n = 30) were the same on both sides. We found no significant difference (p=0.715) between the right- and left-sided classifications (Table 3).

Neck circumference and EBSLN and RLN types

We explored the proportions of various EBSLN Types by neck circumference; the only significant difference was between Types 2a and 2b. The neck circumference of cases of Type 2a was significantly less than that of those with Type 2b (p=0.005). No other association was noted (p>0.05). No significant association (p>0.05) was found between the RLN Type and neck circumference (Table 4,5).

Comparison of EBSLN and RLN Types

We found significant associations between the three RLN Types and the EBSLN Types. In terms of differences in RLNs Types A and B, those with EBSLNs of Type 2b more often had RLNs of type B (p=0.015) than Type A. When differences in terms of the RLNs of Types B and C were examined, those with EBSLNs of Type 2b more often had RLNs of Type B than Type C (p=0.037). No other significant association between EBSLN and RLN Type was apparent (Table 6).

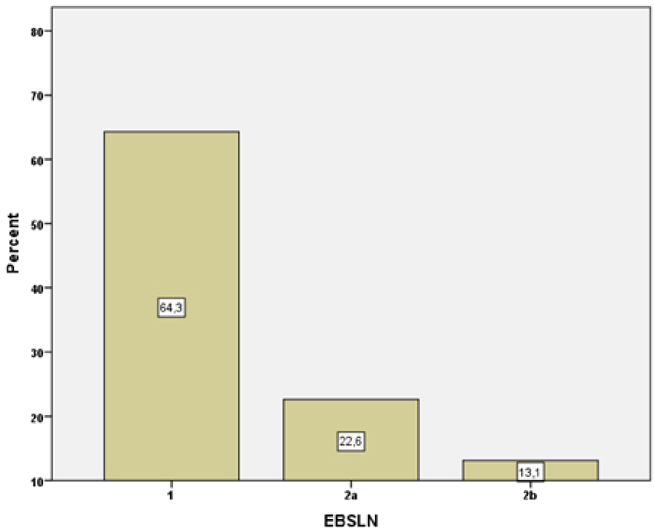

Figure 3: *External branch of the superior laryngeal nerve (EBSLN) types*

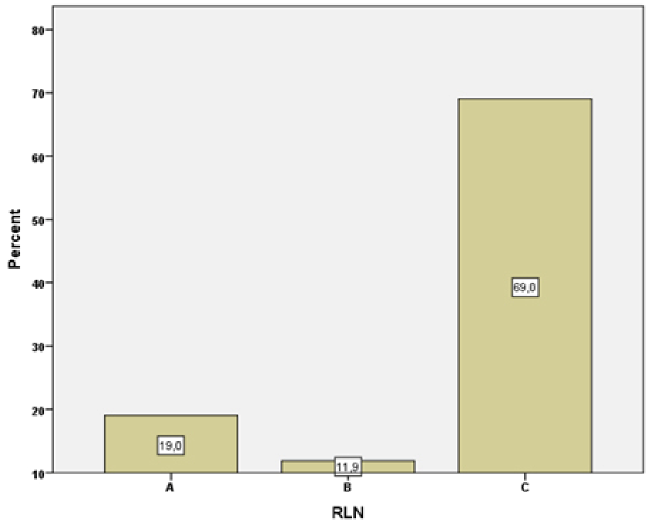

Figure 4: *Recurrent laryngeal nerve (RLN) types*

Table 1. The demographic characteristics of the cadavers

(n:42)		Min-Max	Mean±sd
Age		38-75	56.48±10.10
Neck circumference		33-49	41.74±4.42
		n	**%**
Gender	Male	31	73.8
	Female	11	26.2

Table 2. Comparison of right- and left-sided external branch of the superior laryngeal nerves

EBSLN		**Right**			
		1	**2a**	**2b**	**Total**
Left	**1**	***23 (54.8)***	2 (4.8)	0	**25 (59.5)**
	2a	4 (9.5)	***4 (9.5)***	2 (4.8)	**10 (23.8)**
	2b	2 (4.8)	3 (7.1)	***2 (4.8)***	**7 (16.7)**
	Total	**29 (69)**	**9 (21.4)**	**4 (9.5)**	**42 (100)**

Table 3. Comparison of right- and left-sided recurrent laryngeal nerves

RLN		**Right**			
		A	**B**	**C**	**Total**
Left	**A**	***4 (9.5)***	2 (4.8)	2 (4.8)	**8 (19)**
	B	0	***2 (4.8)***	4 (9.5)	**6 (14.3)**
	C	4 (9.5)	0	***24 (57.1)***	**28 (66.7)**
	Total	**8 (19)**	**4 (9.5)**	**30 (71.4)**	**42 (100)**

Table 4. Comparison of neck circumference and external branch of the superior laryngeal nerve types

(n:84)	**EBSLN**			
	1 (n:54)	**2a (n:19)**	**2b (n:11)**	**p**
	Median (Q_1, Q_3)	**Median (Q_1, Q_3)**	**Median (Q_1, Q_3)**	
Neck circumference	43 (39, 45)	36 (34, 45)	46 (42, 46)	[a]0.005**

[a]Kruskal-Wallis test [b]Fisher's exact test *p<0.05 **p<0.01

Table 5. Comparison of neck circumference and recurrent laryngeal nerve types

(n:84)	**RLN**			
	A (n:16)	**B (n:10)**	**C (n:58)**	**p**
	Median (Q_1, Q_3)	**Median (Q_1, Q_3)**	**Median (Q_1, Q_3)**	
Neck circumference	42.5 (36.5, 46)	39 (38, 42)	44 (39, 45)	[a]0.758

[a]Kruskal-Wallis test [b]Fisher's exact test *p<0.05 **p<0.01

Table 6. Comparison of EBSLN and RLN Types

		EBSLN			
		1	**2a**	**2b**	**p**
		n (%)	**n (%)**	**n (%)**	
RLN	**A**	8 (9,5)	8 (9,5)	0	[b]0.004*
	B	4 (4,7)	2 (2,4)	4 (4,7)	
	C	42 (50)	9 (10,7)	7 (8,3)	

[b]Fisher's exact test *p<0.05

DISCUSSION

Anatomical and functional maintenance of the EBSLN and RLN are required to retain vocal cord function, especially during thyroid surgery. The EBSLN and RLN run close to the superior and inferior thyroid vessels, and are thus in danger of severance during thyroid surgery. Although visual identification of the RLN is the gold standard in terms of injury prevention, no standard technique is yet available to ensure EBSLN preservation, and no consensus on the surgical protocol for EBSLN identification has been formulated [11]. The incidence of EBSLN injury can attain 58% [8]. EBSLN injury is the most underestimated complication after thyroid surgery [12].

In recent years, several studies have described the anatomical relationships of the ESBN and surgical techniques seeking to preserve the nerve during dissection of the superior thyroid pole; however, the risk of EBSLN injury remains high [12]. When the EBSLN cannot be identified, surgeons can only hope that the nerve was not damaged during ligation of the STA. The use of (popular) thermal sealing devices threatens preservation of the EBSLN[13]. Intraoperative neuromonitoring alone is not sufficient for nerve identification; visual confirmation is necessary because non-neural or tendinous fibers of regional muscles can be admixed with the EBSLN [14]. Therefore, in the present study, we explored whether a relationship was evident between the RLN and EBSLN Types and neck circumference, and defined statistically significant associations; this may help surgeons identify (especially) the EBSLN.

Various anatomical EBSLN classification systems have been proposed, including the Cernea, Friedman, and Kierner classifications [12]. The Cernea classification is most commonly employed to evaluate the risk of damage to the EBSLN during thyroid surgery. In the original article, Cernea et al. reported that 68% of EBSLNs were of Type 1, 11% of Type 2a, and 14% of Type 2b [9]; however, other studies reported ranges of 17–60% for Type 1, 17–59% for Type 2a, and 10–56% for Type 2b [15,16,17,18]. All Types, but principally Type 2b, are at risk of injury because they run close to the STA. Type 2b is associated with the greatest risk, even during attempts to place a tie directly onto the thyroid pole[9,12]. Our results are similar to those of Cernea et al. (64.3% Type 1, 22.6% Type 2a, and 13.1% Type 2b). Thus, 35.7% of cases were at increased risk of EBSLN injury.

Although visual identification of the RLN is the gold standard when seeking to prevent injury [19], the prevalence of temporary and permanent RLN injury after thyroid surgery may reach 11% because of anatomical variations [8]. We found that, in 69% of cases, the RLN lay medial to the ITA, consistent with the findings of many other studies.

Unlike other studies, we compared the right and left sides and found that Type 2a and 2b EBSLNs were somewhat more common on the left than the right side, but statistical significance was not attained. The most frequent EBSLN Type was Type 1. We found no significant difference between right- and left-sided RLN Types. The most common RLN Type was Type C.

We found no significant association between EBSLN or RLN Type and neck circumference, except for Type 2a and 2b EBSNs. The neck circumference of cases with Type 2a EBSLNs was less than that of those with Type 2b EBSLNs (p=0.005).

We found significant associations between RLN and EBSLN Types (p=0.004). EBSLN Type 2b was significantly more common in patients with type B RLNs compared with type A RLNs (p=0.015) and in patients with type B RLNs compared with type C

RLNs (p=0.037). Also, EBSLN Type 2a was significantly more common in patients with type A RLNs compared with type C RLNs (p=0.018).

In RLN Type B cases, 40% of EBSLNs were of Type 1, 20% of Type 2a, and 40% of Type 2b. Thus, patients with Type B RLNs may be at an increased risk of EBSLN injury. Of these cases [6], 60% had Type 2a or 2b EBSLNs.

Our small sample size was the principal limitation of the study.

In conclusion, we found statistically significant associations between EBSLN and RLN Types, which may reflect the risk of EBSLN injury during thyroid surgery. A good understanding of the anatomy around the EBSLN and RLN may reduce the possibility of surgical complications. The relationships between the EBSLN and RLN that we have identified may aid surgeons to identify the EBSLN.

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