Comparative study of the length of human laryngeal nerves and their variations: functional and clinical considerations

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SUMMARY

The difference in length between the laryngeal nerves on both sides is one of the factors that may affect the synchronicity of nerve impulses arrival to laryngeal muscles and therefore the synchronicity of vocal fold function. As there are very few studies on the length of these nerves, the goal of this work is to study the length and morphology of whole laryngeal nerves in a much larger human sample, taking into account side, gender and path variations. 111 necks from human embalmed cadavers were dissected (58 females, 53 males). All laryngeal nerves on both sides and their variations were measured and a statistical analysis of the results was carried out.

In reference to the side of corpses, significant differences were found between both recurrent inferior laryngeal nerves and both internal and external laryngeal nerves with the superior laryngeal nerves, being greater on the left side in all cases. In reference to the gender of the corpses, significant differences were found between the lengths of both external laryngeal nerves, being greater in males in all cases. A non-recurrent laryngeal nerve and an absence of superior laryngeal nerve were found. The intramuscular path of the external laryngeal nerve was analysed (Friedman's classification). All laryngeal nerves are significantly longer on the left side. These differences may affect the synchronicity of glottic opening and closure. Therefore, these results would have to be taken into account in functional studies (neurostimulation, electromyography) and in clinical procedures (reinnervation, denervation).

Key words: Laryngeal nerve – Length – Neurostimulation – Electromyography – Vocal fold – Larynx – Reinnervation

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INTRODUCTION

The length of motor laryngeal nerves is one of the morphological parameters involved in nerve conduction, which is essential for performing the different laryngeal functions (protection of the respiratory tract, swallowing, breathing, phonation, etc.) (Krmpotic, 1958; Shin and Rabuzzi, 1971; Steiss and Marshall, 1988; Prades et al., 2012). The difference in length between the right and left recurrent inferior laryngeal nerves (RLN) poses a controversial question about the synchronous (Shin and Rabuzzi, 1971; Harrison, 1981) or asynchronous (Atkins, 1973; Prades et al., 2012) arrival of nerve impulses to the muscles on both sides of the larynx, affecting glottic closure and opening. However, it is important to note that electromyographic studies in humans have shown that laryngeal muscles can receive a double innervation. Therefore, nerve impulses can arrive to them, not only through the external laryngeal nerve (ELN) or RLN, as classically described (Testut and Latarjet, 1972; Williams, 1995) but also from the internal laryngeal nerve (ILN) to the posterior cricoarytenoid muscle (Martín-Oviedo et al., 2019), from the ELN to thyroarytenoid, posterior cricoarytenoid, arytenoid and contralateral cricothyroid muscles (Martín-Oviedo et al., 2011; 2019) and from the RLN to ipsilateral and contralateral cricothyroid muscles (Martín-Oviedo et al., 2011; 2019). So, it could be thought that this double innervation of laryngeal muscles may intervene in the synchronicity of glottic closure too.

In the same way that nerve length has an important role in motor fiber nerve conduction, it also has a role in the sensory fibers that participate in the laryngeal closure and cough reflexes.

Despite all that has been said above, there are very few works that have studied the length of human laryngeal nerves, and these are based on small and non-homogeneous samples. No study about the entire laryngeal nerve length has been found in the literature consulted.

Therefore, the aim of our work is to study the length and morphology of all laryngeal nerves in a much larger human sample, taking into account side, gender and variations.

MATERIALS AND METHODS

The necks of 111 Caucasian human embalmed cadavers were dissected and examined (58 females, 53 males; 64-100 years of age). No pathology of the neck was observed. All cadavers were inside the size and weight range established by Cambridge University for the acceptance of body donation (weight 44.5-85 kg, height <180 cm), and all the donors were received under the auspices of the Anatomy Act 1984, whereby medical schools may accept a body for the purposes of anatomical education, teaching and research. The donors would have provided written consent for the use of their bodies for such purposes before decease. The 222 heminecks were partially dissected by Cambridge preclinical medical students and then further dissected by the authors using magnification. In order to measure the nerves in a correct way, the carotid arteries and the internal jugular vein were removed, as well as the anterior part of the rib cage and the clavicle. All measurements of nerves were made, on both sides, with the head in a centred supine position as follows:

- ***Vagus nerve (X cn):*** from the nodose ganglion to origin of RLN (Fig. 1. From 1 to 2 and 2').
- ***Recurrent inferior laryngeal nerve (RLN)***: from its exit from the vagus nerve to its entrance to the larynx at the inferior horn of thyroid cartilage. (Fig. 1. From 2 to 3 on the right side and from 2' to 3' on the left)
- ***Superior laryngeal nerve (SLN)***: from its exit from the vagus nerve to its division in its terminal branches (internal and external laryngeal nerves) (Fig. 1. From 1 to 4 on both sides).
- ***Internal laryngeal nerve or internal branch of superior laryngeal nerve (ILN)***: from SLN to the thyrohyoid membrane (Fig. 1. From 4 to 5).
- ***External laryngeal nerve or external branch of superior laryngeal nerve (ELN)***: from SLN to the cricothyroid muscle (Fig. 1. From 4 to 6).

All these lengths were evaluated using a silk thread placed along the course of nerves, marking the proximal and distal ends of the nerve with tweezers, and later superimposing the silk thread marked by both forceps on a graduated ruler to measure the length.

Statistical analysis

To analyze relationships between the lengths of the laryngeal nerves, gender and side a two-factor experimental design was considered in this research and we used the Scheffés method to determine the number of groups. Significant differences between the average lengths of laryngeal nerves were analyzed using T tests. All tests were studied considering a significance level $\alpha = 0.05$.

RESULTS

For an easier understanding of the results obtained, the lengths of the RLNs are presented first, followed by those of the SLNs and its branches.

Recurrent inferior laryngeal nerve

The right RLN arose from the vagus nerve at 6.5-17.5 cm (average 13.990±1.682 cm) from the nodose ganglion. It then recurred below the left subclavian artery (SA) and entered the larynx at the level of the cricothyroid joint. The length of the right RLN from its origin to the larynx was 4-9.5 cm (average 6.740±1.111 cm) (Table 1A., Fig. 2A). A right non-recurrent inferior laryngeal nerve (non-RLN) was found on the right side in one female (0.9%, 1/111). It arose from the vagus nerve at the level of the cricothyroid joint and coursed 4 cm transversely to the larynx, above the level of the inferior thyroid artery (type 2A). In this case, the non-RLN was associated with a retroesophageal SA (lusoria artery).

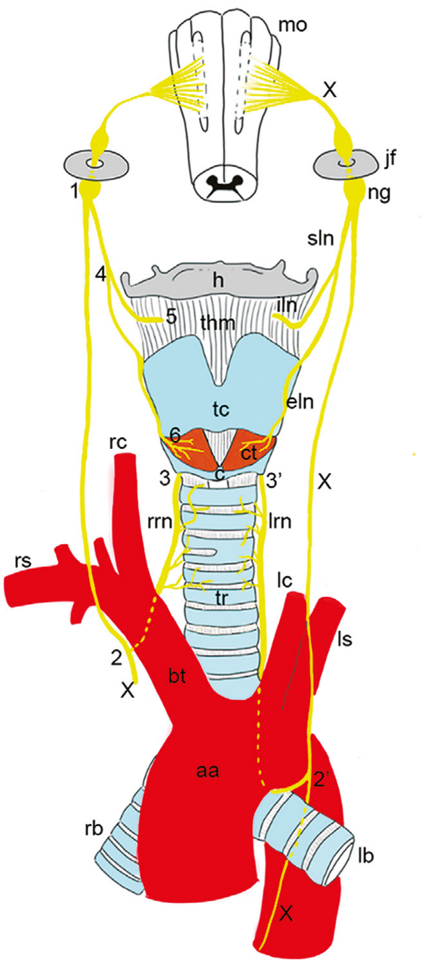

Fig. 1.- Drawing of laryngeal nerves and their measurement points. **aa**, aortic arch; **bt**, brachiocephalic arterial trunk; **c**, cricoid cartilage; **ct**, cricothyroid muscle; **eln**, external laryngeal nerve; **h**, hyoid bone; **iln**, internal laryngeal nerve; **jf**, jugular foramen; **lb**, left bronchi; **lc**, left common carotid artery; **lrn**, left recurrent inferior laryngeal nerve; **ls**, left subclavian artery; **mo**, medulla oblongata; **ng**, nodose ganglion; **rb**, right bronchi; **rc**, right common carotid artery; **rrn**, right recurrent inferior laryngeal nerve; **rs**, right subclavian artery; **sln**, superior laryngeal nerve; **tc**, thyroid cartilage; **thm**, thyrohyoid membrane; **tr**, trachea; **X**, vagus nerve. **1**, jugular foramen; **2**, origin right recurrent laryngeal nerve; **2'**, origin left laryngeal nerve; **3**, entry of RLN into the larynx; **4**, terminal division of SLN; **5**, entry of ILN into the larynx through the thyrohyoid membrane; **6**, entry of ELN to cricothyroid muscle.

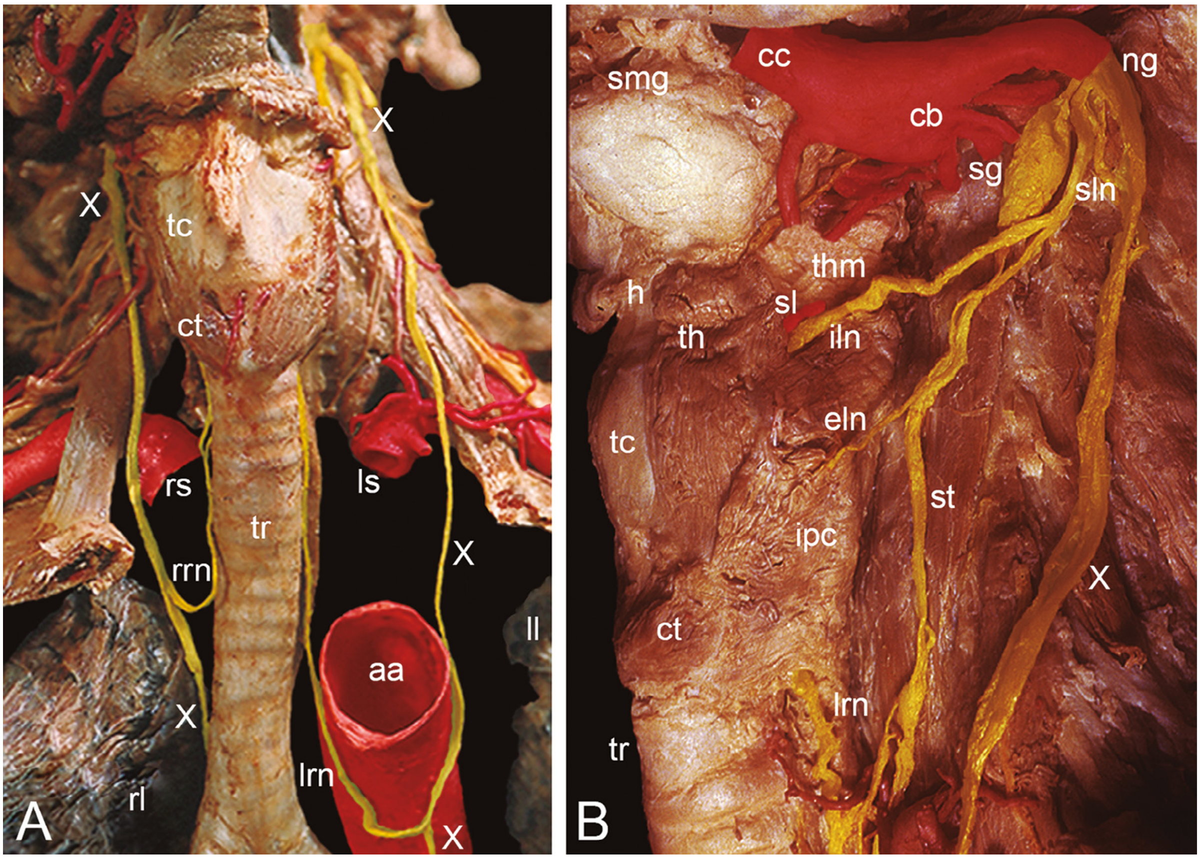

Fig. 2.- **A.** Origin and way of right and left recurrent inferior laryngeal nerves. Anterior view of neck and mediastinum. The heart, the ascending aorta, the proximal part of aortic arch and the carotid arteries have been removed. **B.** Origin and way of superior laryngeal nerve and its terminal branches. Left lateral view of neck. The common carotid artery has been sectioned proximally and reclined upward. **aa**, aortic arch; **cb**, carotid bifurcation; **cc**, common carotid artery; **ct**, cricothyroid muscle; **eln**, external laryngeal nerve; **h**, hyoid bone; **iln**, internal laryngeal nerve; **ipc**, inferior pharyngeal constrictor muscle; **ll**, left lung; **lrn**, left recurrent inferior laryngeal nerve; **ls**, left subclavian artery; **ng**, nodose ganglion; **rl**, right lung; **rrn**, right recurrent inferior laryngeal nerve; **rs**, right subclavian artery; **sg**, superior cervical sympathetic ganglion; **sl**, superior laryngeal artery; **sln**, superior laryngeal nerve; **smg**, submandibular gland; **st**, sympathetic trunk; **tc**, thyroid cartilage; **th**, thyrohyoid muscle; **thm**, thyrohyoid membrane; **tr**, trachea; **X**, vagus nerve.

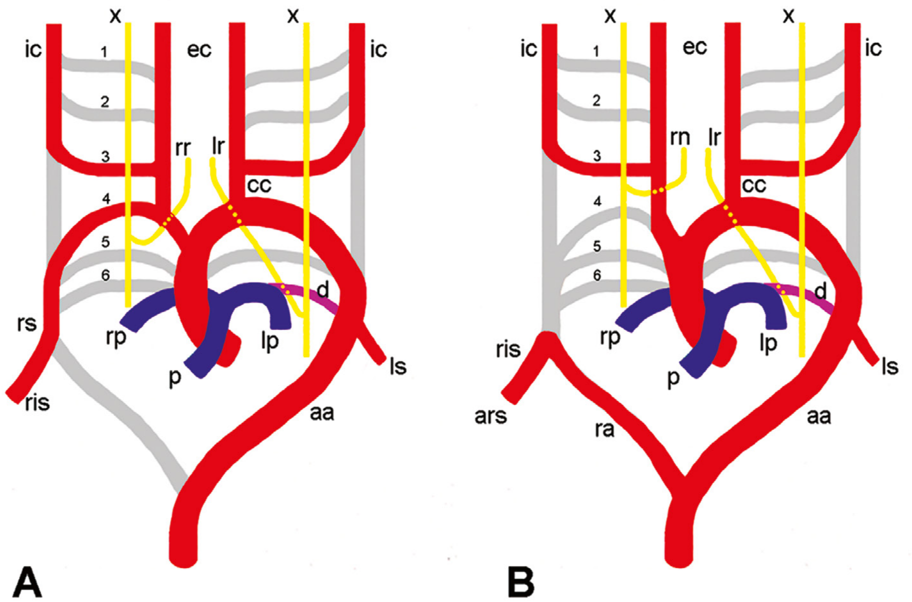

Fig. 3.- **A.** Drawing of development of right and left normal recurrent inferior laryngeal nerves. **B.** Drawing of development of right non-recurrent inferior laryngeal nerve associated with an aberrant subclavian artery and a normal left recurrent inferior laryngeal nerve. **aa**, aortic arch; **ars**, aberrant right subclavian artery; **cc**, common carotid artery; **d**, ductus arteriosus; **ec**, external carotid artery; **ic**, internal carotid artery; **ris**, part of subclavian artery from the right 7th intersegmentary artery; **lp**, left pulmonary artery; **lr**, left recurrent inferior laryngeal nerve; **ls**, left subclavian artery; **rn**, right non-recurrent inferior laryngeal nerve; **p**, pulmonary arterial trunk; **ra**, persistent portion of the right dorsal aorta artery **rp**, right pulmonary artery; **rr**, right recurrent inferior laryngeal nerve; **rs**, right subclavian artery; **X**, vagus nerve. **1-6**, aortic arches. The arches coloured in gray regress disappearing.

The left RLN arose from the vagus nerve at 15-23 cm (average 19.060±1.653 cm) of the nodose ganglion. It then recurred below the aortic arch and entered the larynx at the level of the cricothyroid joint. The length of the left RLN from its origin to the larynx was 9-17.5 cm (average 13.320±1.653 cm) (Table 1A., Fig. 2A).

The length of the extracranial course of their fibers (RLN+Vagus nerve) was between 11.3-26.2 cm (average 20.8±2.31 cm) on the right side and from 27 to 40.5 cm (average 32.4±2.56 cm) on the left side (Table 1A).

Significant differences in relation to the side of the neck were found in the lengths of RLNs (p-value≈0) and vagus nerves (p-value≈0), being longer on the left side on both cases. With respect to the gender of the corpses, no significant differences in the lengths of RLNs were found (p-value=0.509). Additionally, the vagus nerve was found to be significantly longer in males than in females (p-value=0.007). No significant differences were found in the total length of extracranial course RLNs fibers (RLN+vagus) with respect to the gender of the corpses (p-value=0.096) (Table 1A).

Table 1. Average and range (between brackets) of laryngeal nerves lengths (centimetres). Distribution by side and gender. **1-A**, Results of recurrent laryngeal nerve (RLN); **1-B**, Results of superior (SLN) and internal laryngeal nerve (ILN); **1-C**, Results of external laryngeal nerve (ELN). **e.m**, extramuscular path of ELN; **i.m**, intramuscular path of ELN; **1-D**, Results of Friedman's classification types for side and gender. Percentage of cases (%) and number of cases/number of sample (between brackets).

1-A	**RIGHT**			**LEFT**		
	MALE	**FEMALE**	**TOTAL**	**MALE**	**FEMALE**	**TOTAL**
RLN	6.99±1.06 [4.5;9.5]	6.53±1.12 [4;9]	6.740±1.111 [4;9.5]	13.36±1.97 [9;17.5]	13.28±1.33 [10.4;16.5]	13.320±1.653 [9;17.5]
VAGUS	14.64±1.37 [11;17.5]	13.43±1.73 [6.5;16.6]	13.990±1.682 [6.5;17.5]	19.56±1.52 [15;23]	18.61±1.65 [16,22]	19.060±1.653 [15;23]
RLN + VAGUS	21.63±2.1 [15.5;26.2]	19.97±2.23 [11.3;25.5]	20.8±2.31 [11.3;26.2]	32.92±2.77 [27;40.5]	31.89±2.29 [27;37]	32.4±2.56 [27;40.5]
1-B	**RIGHT**			**LEFT**		
	MALE	**FEMALE**	**TOTAL**	**MALE**	**FEMALE**	**TOTAL**
SLN	1.97±0.9 [0.3;4]	1.82±0.88 [0;4]	1.890±0.891 [0;4]	1.85±0.67 [0.5;3.5]	2.08±0.84 [0.5;4]	1.970±0.770 [0.5;4]
ILN	4.15±1.05 [1.8;6.5]	4.08±0.98 [2;7]	4.110±1.013 [1.8;7]	4.41±1.03 [2;6.5]	4.07±0.87 [2;6]	4.230±0.960 [2;6.5]
ILN+SLN	6.08±0.97 [3.5;8]	5.84±0.95 [3.5;9]	5.961±0.965 [3.5;9]	6.18±0.92 [4;8.5]	6.12±1.02 [4.4;8.5]	6.147±0.971 [4;8.5]
1-C	**RIGHT**			**LEFT**		
	MALE	**FEMALE**	**TOTAL**	**MALE**	**FEMALE**	**TOTAL**
ELN e.m path	6.65±1.01 [4;8.5]	6.36±0.92 [5;9.5]	6.5±0.97 [4;9.5]	7.18±0.84 [4.5;9]	6.43±0.92 [4.5;9.3]	6.8±0.95 [4.5;9.3]
ELN i.m path	1.35±0.51 [0.3;2.2]	1±0.41 [0.3;1.7]	1.17±0.9 [0.3;2.2]	1.18±0.42 [0.5;2]	1.17±0.47 [0.3;2]	1.17±0.44 [0.3;2]
ELN total path	7.83±0.99 [5.5;10]	6.93±0.96 [5.8;10]	7.42±1.06 [5.5;10]	8.34±0.73 [6.7;10]	7.28±0.79 [6;9.5]	7.81±0.92 [6;10]
ELN total path + SLN	9.87±1.04 [8;12]	8.98±1.08 [7.8;12]	9.47±1.13 [7.8;12]	10.16±0.99 [8.3;16]	9.41±1.17 [8.20;13]	9.78±1.13 [8.2;13]
1-D	**RIGHT**			**LEFT**		
	MALE	**FEMALE**	**TOTAL**	**MALE**	**FEMALE**	**TOTAL**
TYPE 1 (No i.m path)	0 [0/26]	4.2% [1/24]	2% [1/50]	0 [0/23]	0 [0/25]	0 [0/48]
TYPE 2 (≥ 1cm)	38.5% [10/26]	58.3% [14/24]	48% [24/50]	54.2% [13/24]	45.8% [11/24]	50% [24/48]
TYPE 3 (>1cm)	61.5% [16/26]	37.5% [9/24]	50% [25/50]	45.8% [11/24]	92.8% [13/24]	50% [24/48]

Superior laryngeal nerve

The SLN arose from the lower pole of the inferior ganglion of the vagus nerve (nodose ganglion) (Fig. 2B). After coursing 0.3-4 cm (average 1.933±0.831 cm), it divided into its terminal branches (Table 1B., Fig. 2B). In one case, on the right side of a female, the SLN was absent and the ILN and ELN arose directly from the nodose ganglion (0.45%, 1/222).

No significant differences in SLN lengths were found regarding the side (p-value =0.497) or gender (p-value=0.692) (Table 1B).

Internal laryngeal nerve

The ILN descends from its origin from SLN to enter into the larynx through the thyrohyoid membrane, in an anteromedial oblique course (Fig. 2B). The length of this pathway ranged from 1.8 to 7 cm (average 4.172±0.986 cm) and, considering it in conjunction with the SLN, the length ranged from 3.5 to 9 cm (average 6.054±0.970 cm) (Table 1B). In the case where the ILN arose directly from the vagus nerve its length was 4 cm.

No significant differences in ILN lengths were found regarding the side (p-value=0.367) or gender (p-value=0.128). However, when the lengths of the ILN and SLN were added, significant differences per side were found, being longer on the left side (p-value p≈0). No differences were detected in gender (p= 0.601) (Table 1B).

External laryngeal nerve

The ELN arose from the SLN as one of its terminal branches and descended describing an anterosuperior concavity, over the lateral surface of the inferior pharyngeal constrictor muscle (IPCM) (Fig. 2B). It then bended to go medially towards the cricothyroid muscle. The length of this pathway was between 5.5-10 cm (average 7.6±1.01 cm) (Table 1C). It should be noted that a variable part of its path coursed between the fibres of IPCM (intramuscular path), in some cases (Table 1C., Fig. 2B). Based on the length of this intramuscular path, the ELN was grouped in three different types, according to Friedman's classification; Type 1, the nerve runs superficial to the IPCM in all its pathway; Type 2, it has a distal intramuscular course of 1 cm or less and Type 3, with an intramuscular course of more than 1 cm (Friedman et al., 2002) (Table 1D).

Significant differences in the total path of ELN were found regarding the corpse's gender (p-value ≈0), being larger for males (8.07±0.905 cm) than females (7.11±0.881 cm), but no significant differences were found with respect to the corpse's side (p-value=0.067) (Table 1C). However, when the lengths of the ELN and SLN were added, significant differences per side were found, being longer on the left side (p-value p=0.01) and gender being greater on males (p= 0.001) (Table 1C).

The ELN extramuscular path presented significant differences with respect to the corpse's gender (p-value≈0), being larger for males (6.91±0.96 cm) than females (6.39±0.917 cm) ,and the corpse's side (p-value=0.034), being larger for the left side (6.78±0.954 cm) than the right side (6.5±0.973 cm). No significant differences were found by gender (p-value=0.058) or side (p-value=0.94) for the ELN intramuscular way. In relation to Friedman's classification, no significant differences were found regarding the gender (p-value=0.687) and side (p-value=0.789) of the corpse.

DISCUSSION

Electromyographic studies in humans have shown that all laryngeal nerves, including the ILN, can supply a secondary innervation to other laryngeal muscles, so that all of them can receive nerve impulses from two different laryngeal nerves and some of them from three (posterior cricoarytenoid and cricothyroid muscles) or four (cricothyroid muscle). It should be noted that in the case of the cricothyroid muscle, part of this innervation comes from the contralateral ELN and RLN (Martín-Oviedo et al., 2011; 2019).

The length of these motor laryngeal nerves is one of the morphological parameters involved in nerve conduction, which is essential for performance of laryngeal functions (Krmpotic, 1958; Shin and Rabuzzi, 1971; Steiss and Marshall, 1988; Prades et al., 2012). The existence of muscular double innervation and the difference in length between the laryngeal nerves on both sides may affect the synchronicity of nerve impulse arrival to laryngeal muscles, and therefore the synchronicity of vocal fold function. In the same way, the length of sensory nerve fibers may have an important role in laryngeal closure and cough reflexes.

Nonetheless, there are very few studies about the length of laryngeal nerves.

The discussion of results obtained in this study will be carried out following the same order as presented.

Recurrent inferior laryngeal nerve

The length of the RLN has been studied with more detail in only three works, one of them being one of our previous studies (Asgharpour et al., 2012). All authors measured both RLNs from its origin at the vagus nerve to their entry into the larynx, obtaining similar results (Table 2). The length of the extracranial pathway of both RLNs fibres (RLN+vagus) has not been reported by the authors of the bibliography consulted.

Comparison of the results based on gender is not feasible because one of the authors did not specify the gender of the samples (Liebermann-Meffert et al., 1999) and the other has only used females in his work (Prades et al., 2012). In our study, no statistically significant differences have been found between males and females ($p=0.509$) as in our previous study (Asgharpour et al., 2012).

The difference between the lengths of both RLNs ($p \approx 0$) is due to the fact that, in the human embryo, the ductus arteriosus drags the left RLN down when the heart descends and the neck elongates, lengthening it (Fig. 3A). However, on the right side the distal part of right sixth aortic arch involutes completely, to the extent that the fifth aortic arches also disappear; when the heart descends and the neck elongates, no vascular structure pulls down the right RLN. It migrates freely into the neck, and curves around the proximal portion of right SA derived from fourth aortic arch, the proximal right dorsal aorta and the seventh intersegmental artery (Gray et al., 1976; Sadler and Langman, 2012) (Fig. 3A). Therefore, as the course of RLN is determined by the arterial development, its alterations give rise to anatomical variations that can affect the length of RLNs such as non-RLN (Gray et al., 1976; Sadler and Langman, 2012). The non-RLN is more common on the right side (0%-4.76%) (Sturniolo et al., 1999; Monfared et al., 2002) than on the left (0-0.04%) (Henry et al., 1988) The right non-RLN has been reported in association with absence of the brachiocephalic trunk and existence of an aberrant SA (lusoria artery), which arises from aortic arch, after the origin of the left subclavian artery (89.3% of cases) (Henry et al., 2017). To reach the right upper limb, the course of the aberrant SA may be retroesophageal (80%), tracheo-esophageal (15%) or pretracheal (5%) (Vuillard et al., 1978), being in our case retroesophageal. Due to these pathways in front of or behind the esophagus, the aberrant SA may compress the oesophagus causing dysphagia, known as dysphagia lusoria (Lam et al., 2020).

The aberrant development of right SA and therefore of a non-RLN, is caused on one hand by the involution of right fourth aortic arch and the proximal right dorsal aorta and on the other by the persistence of a distal right dorsal aorta and the right seventh intersegmental artery (Gray et al., 1976; Sadler and Langman, 2012) (Fig. 3B).

The left non-RLN is associated with a situs inversus, a retroesophageal left subclavian artery

Table 2. Length of RLNs: results of previous authors (centimetres).

AUTHORS	SAMPLE		RANGE		AVERAGE	
	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
Liebermann-Meffert et al. (1999)	23	23	6 - 8	12 - 14	7	13
Asgharpour et al. (2012)	108	106	4 - 9.5	9 - 17.5	6.7	13.3
Prades et al. (2012)	6	6	6.5 - 9	11.5 - 14.5	7.5	13.7
Our study. (2021)	111	111	4 - 9.5	9 - 17.5	6.76	13.32

and right ligamentum arteriosus. The complexity of these vascular variations would explain its lower incidence (0.04%, 2/4673) (Henry et al., 1988).

The coexistence of right or left non-RLN and variations of great arteries allows a preoperative diagnosis of them using radiological techniques such a computed tomography (Watanabe et al., 2016) or ultrasonography (Citton et al., 2016).

The right non-RLN is more frequent in females (88%, 15/17; 90%, 28/31) than in males (12%, 2/17; 10%, 3/31) (Avisse et al., 1998; Toniato et al., 2004) in accordance with our results.

The course of non-RLNs from the vagus nerve to the larynx is highly variable, and different classifications have been described in relationship to the level where it originates and the shape of its course (Stewart et al., 1972; Soustelle et al., 1976; Abboud and Aouad, 2004; Hong et al., 2014). The most popular classification distinguishes two different types; in type 1 or high, the non-RLNs arise from the vagus nerve at or above the level of the laryngotracheal junction and run a short and transversal path to the cricothyroid joint (0%-73.3% of non-RLN) (Stewart et al., 1972; Soustelle et al., 1976; Vuillard et al., 1978; Proye et al., 1982; Henry et al., 1988; Avisse et al., 1998; Toniato et al., 2004; Dolezel et al., 2015; Watanabe et al., 2016) while in the type 2 or low, the non-RLNs arise from the vagus below the laryngotracheal junction and run an oblique course to the cricothyroid joint (0%-100% of non-RLN) (Stewart et al., 1972; Soustelle et al., 1976; Vuillard et al., 1978; Proye et al., 1982; Henry et al., 1988; Avisse et al., 1998; Monfared et al., 2002; Toniato et al., 2004; Dolezel et al., 2015; Watanabe et al., 2016). This last type has been subdivided in type 2A, when the nerve courses above the inferior thyroid artery (64.5%-100% of non-RLN), and type 2B, when the nerve courses below this artery (0-19.35% of non-RLN) (Abboud and Aouad, 2004; Toniato et al., 2004; Prades et al., 2012; Watanabe et al., 2016) Therefore, type 2 is longer than type 1, and subtype 2B longer than 2A. The case in our study corresponded to type 2A.

A good knowledge of non-RLN is essential to avoid injuring this nerve during neck surgical procedures and to avoid the complications of vocal fold dysfunction derived from this (dysphonia, aspirations, pneumonia) (Avisse et al., 1998; Hong et al., 2014; Watanabe et al., 2016).

Superior laryngeal nerve

The length of the SLN has been measured from its origin in the nodose ganglion to its bifurcation in its terminal branches by all of authors, ranging from 0 to 4.18 cm (Durham and Harrison, 1964; Kambic et al., 1984; Lang et al., 1987; Melamed et al., 2002; Furlan et al., 2003; Kiray et al., 2006; Oliveira and Silva, 2007). Only three authors have provided more detailed information about this topic (Table 3). None of them found significant differences in the lengths of the SLN in relation to the side of corpse in agreement with our results (Furlan et al., 2003; Kiray et al., 2006; Oliveira and Silva, 2007). Two authors have analyzed the length of the SLN with respect to corpses' gender (Furlan et al., 2003; Oliveira and Silva, 2007). One of them found significant differences, being longer in males than females ($p = 0.01$) (Furlan et al., 2003), while the other did not find them (Oliveira and Silva, 2007), in agreement with our results. Greater length was found in corpses over 25 years of age ($p<0.05$) (Oliveira and Silva, 2007), while in relation to height ($p=0.33$) and ethnic group ($p=0.24$), no significant differences were found (Furlan et al., 2003).

Absence of the SLN has been reported between 5% (4/80) (Kambic et al., 1984) and 6% (6/100) of cases (Furlan et al., 2003), being our incidence lower (0.45%, 1/222).

Internal laryngeal nerve

The length of the ILN has been measured from its origin to the thyrohyoid membrane by most authors, being between 2.1 cm and 8.49 cm (Lang et al., 1987; Espinoza et al., 1989; Furlan et al., 2003; Kiray et al., 2006; Oliveira and Silva, 2007). Studies of length of ILN in relation to age (Oliveira and Silva, 2007), gender (Furlan et al., 2003; Oliveira and Silva, 2007), side (Furlan et al., 2003; Kiray et al., 2006; Oliveira and Silva, 2007) or ethnic group (Furlan et al., 2003) did not find any significant difference ($p<0.05$). In agreement with these authors, our study shows no significant differences for side and gender

(Table 3). In relation to corpse's height, there are discrepancies since one study reported that the increase in height is accompanied by an increase in ILN length (Oliveira and Silva, 2007), while this was not observed in the other study (p=0.71) (Furlan et al., 2003).

The total length of the SLN+ILN reported was 7.1 cm (Kiray et al., 2006), being slightly shorter in our results (6.054±0.970) (Table 3).

External laryngeal nerve

The length of the ELN from its origin to its entry into the cricothyroid muscle has been measured by various authors, ranging from 4 cm to 12 cm (Kambic et al., 1984; Lang et al., 1987; Espinoza et al., 1989; Furlan et al., 2003; Oliveira and Silva, 2007) (Table 3).

No significant difference has been found in the length of the ELN for sides (p=0.26) and gender (p= 0.69) in agreement with our results, nor for ethnicity (p=0.42) (Furlan et al., 2003). In relation to the height, there are discrepancies since one study reported that the increase in height is accompanied by an increase in ELN length (Oliveira and Silva, 2007), but this was not observed in the other study (p=0.96) (Furlan et al., 2003).

The intramuscular course of the ELN has been reported by several authors following Friedman's classification (Table 4). Most of them have found type 1 as the most frequen. However, in our study it was the type 2, being type 1 the least frequent (Table 4). The different types were not affected by genders on both sides (p =0.519 on the right and p = 1.000 on the left) (Taytawat et al., 2010), as in our study (p-value= 0.695 on the right, p-value= 0.864 on the left). In addition, no significant differences for side have been found in the present work (p-value= 0.687).

Table 3. Length of SLN, ILN and ELN: results of previous authors in centimetres (average and range between brackets). (A= Pheoderma, B= Melanoderma).

SLN	MALE	FEMALE	RIGHT	LEFT	WHITE	NOWHITE
Furlan et al. (2003)	1.85±0.11	1.38±0.11	1.68±0.14	1.67±0.12	1.72±0.11	1.61±0.16
Kiray et al. (2006)	?	?	1.48±0.44	1.35±0.4	?	?
Oliveira & Silva (2007)	2.5±0.6 [1.0;3.0]	0	2.5±0.6 [1.0;3.0]	2.5±0.6 [1.0;3.0]	2.5±0.5 [1.5;3.0]	A: 2.4±0.8 [1.0;4.0] B: 2.6±0.5 [2.0;3.0]
Our study (2021)	1.91± 0.792 [0.3;4]	1.95± 0.868 [0;4]	1.9±0.891 [0;4]	1.96±0.770 [0.5;4]	1.93±0.831 [0.3;4]	0
ILN	**MALE**	**FEMALE**	**RIGHT**	**LEFT**	**WHITE**	**NOWHITE**
Furlan et al. (2003)	4.5±0.16	4.48±0.14	4.57±0.14	4.4±0.16	4.39±0.14	4.64±0.16
Kiray et al. (2006)	?	?	5.8±0.82	5.63±0.74	?	?
Oliveira & Silva (2007)	5.4±.1.0 [4;7.5]	0	5.3±0.9 [4;7]	5.3±0.9 [4;7]	5.4±1.1 [4;7.5]	A: 5.3±0.8 [4.5;7.2] B: 6.2±0.9 [4.5;7.0]
Our study (2021)	4.28±1.045 [1.8;6.5]	4.075±0.922 [2;7]	4.11±1.013 [1.8;7]	4.27±0.960 [2;6.5]	4.17±0.986 [1.8;7]	0
ELN	**MALE**	**FEMALE**	**RIGHT**	**LEFT**	**WHITE**	**NOWHITE**
Furlan et al. (2003)	6.3±0.12	6.2±0.23	6.13±0.17	6.39±0.16	6.19±0.12	6.38±0.24
Oliveira & Silva (2007)	7.2±1.1 [4.0;9.5]	0	7.0±1.0 [5.0;9.0]	7.0±1.0 [5.0;9.0]	7.1±1.2 [4.0;9.5]	A: 7.0±0.8 [5.0;8.0] B: 8.4±0.6 [7.5;9.0]
Our study (2021)	8.08±0.60 [5.5;10]	7.1±0.917 [5.8;10]	7.38±0.974 [5.5;10]	7.81±0.954 [6;10]	7.6±0.971 [5.5;10]	0

Table 4. Distribution of Friedman's classification types for sides. Results of previous authors (Percentage of cases and number of cases/number of sample).

AUTHORS	TYPE 1			TYPE 2			TYPE 3		
	RIGHT	LEFT	TOTAL	RIGHT	LEFT	TOTAL	RIGHT	LEFT	TOTAL
Ozlugedik et al. (2007)	?	?	22.5% [9/40]	?	?	67.5% [27/40]	?	?	10% [4/40]
Taytawat et al. (2010)	95.5% [63/66]	94.1% [64/68]	94.78% [127/134]	4.5% [3/66]	5.9% [4/68]	5.22% [7/134]	0% [0/66]	0% [0/66]	0% [0/134]
Patnaik et al. (2012)	53% [9/17]	47% [8/17]	50% [17/34]	35.3% [6/17]	35.3% [6/17]	35.3% [12/34]	11.7% [2/17]	17.6% [3/17]	14.7% [5/34]
Gavid et al. (2017)	?	?	50% [4/8]	?	?	25% [2/8]	?	?	25% [2/8]
Uludag et al. (2017)	?	?	59.7% [126/211]	?	?	11.3% [24/211]	?	?	29% [61/211]
Cheruiyot et al. (2018)	?	?	50% [250/500]	?	?	35% [175/500]	?	?	15% [75/500]
Our study (2021)	2% [1/50]	0 [0/48]	1% [1/98]	48% [24/50]	50% [24/48]	49% [48/98]	50% [25/50]	50% [24/48]	50% [49/98]

It should be noted that during thyroid surgery, type 1 has the greatest risk of injury and type 3 the least, since the IPCM protects the ELN in most of its pathway. On the other hand, this fact makes the ELN must be identified by intraoperative neurostimulation (Friedman et al., 2002; Ozlugedik et al., 2007).

CONCLUSIONS

All laryngeal nerves are significantly longer on the left side (RLN, ILN+SLN, ELN+SLN, and extramuscular path of ELN) and the ELN (extramuscular path, total path and ELN+SLN) is significantly longer in males than females. These differences may affect the synchronicity of nerve impulse arrival to laryngeal muscles, and therefore the synchronicity of vocal fold function. In the same way, the length of sensory nerve fibers may have an important role in laryngeal closure and cough reflexes. In addition, these results would have to be taken into account in functional studies (neurostimulation, electromyography) and in some clinical procedures (reinnervation, denervation).

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