

Research Article

A Cadaveric Study of the Course and Anatomical Relations of the Recurrent Laryngeal Nerve with the Inferior Thyroid Artery and Thyroid Gland

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ABSTRACT

Background: The recurrent laryngeal nerve (RLN) is a major motor nerve of the larynx and is closely related to structures routinely encountered during thyroid and other cervical operations. Variations in its course, branching pattern and relation to the inferior thyroid artery (ITA), thyroid gland, ligament of Berry and Zuckerkandl's tubercle may increase the difficulty of identification and preservation.

Methods: A gross anatomical dissection and observational study was performed on 25 embalmed human cadavers, providing 50 RLNs, 25 on each side. The origin and looping pattern, relation to the tracheo-oesophageal groove (TOG), angle with the TOG, extralaryngeal branching, relation to the ITA, thyroid gland, Zuckerkandl's tubercle, ligament of Berry and cricothyroid joint were recorded.

Results: All 50 RLNs arose from the vagus nerve. The right RLN looped around the first part of the right subclavian artery and the left RLN looped beneath the aortic arch lateral to the ligamentum arteriosum. The nerve was within the TOG in 60% of right and 80% of left sides. Extralaryngeal branches were present in 64% of nerves overall. Posterior relation to the ITA was observed in 66%, anterior relation in 24%, and passage between ITA branches in 10%. All nerves were free from the thyroid gland, superficial to the ligament of Berry and medial to the Zuckerkandl's tubercle; all passed posterior to the cricothyroid joint before entering the larynx.

Conclusion: The RLN demonstrates important side-to-side and individual anatomical variation. Identification of the nerve should not depend on a single landmark. The TOG, ITA, Zuckerkandl's tubercle, ligament of Berry and cricothyroid joint should be considered together during surgical dissection.

Keywords: Recurrent Laryngeal Nerve, Inferior Thyroid Artery, Tracheo-Oesophageal Groove, Zuckerkandl's Tubercle, Ligament Of Berry, Thyroid Surgery

INTRODUCTION

The recurrent laryngeal nerve (RLN), a branch of the vagus nerve, provides motor innervation to most of the intrinsic muscles of the larynx and is essential for normal phonation, airway protection and swallowing. Its close anatomical relationship with the thyroid gland makes it particularly vulnerable during thyroidectomy and other cervical surgical procedures, where injury may result in vocal-cord paralysis, dysphonia and, in bilateral cases, significant airway compromise [1,2]. The RLN has an

asymmetric course. On the right, it usually loops around the subclavian artery, whereas on the left it loops beneath the aortic arch before ascending toward the larynx. Developmental vascular variations may result in a non-recurrent laryngeal nerve, predominantly on the right side, representing an important anatomical variant with implications for surgical identification and preservation [2,3].

In the cervical region, the RLN commonly courses within or adjacent to the tracheo-oesophageal groove (TOG), although

substantial anatomical variation exists in its relationship to the trachea, oesophagus and thyroid gland [1,4,5]. Extralaryngeal branching is also common and may result in multiple nerve branches entering the larynx or supplying adjacent structures, increasing the possibility of inadvertent injury during dissection [4,7]. The relationship of the RLN with the inferior thyroid artery (ITA) is variable, with the nerve potentially passing anterior, posterior or between the arterial branches [4,6]. Consequently, the ITA and other surrounding structures should be regarded as useful surgical guides rather than invariant anatomical landmarks [6,8].

Other important anatomical relationships include the ligament of Berry and Zuckerkandl's tubercle. Variations in the relationship of these structures to the RLN may influence the ease and safety of nerve identification during thyroid surgery [6,8,9]. The superior approach to the RLN has also been described as an alternative strategy for nerve identification, particularly when the usual inferior course is obscured by anatomical or pathological factors [5]. Therefore, comprehensive knowledge of the origin, course, branching pattern and relationships of the RLN with adjacent structures remains essential for safe cervical surgery [7,10]. The present study was therefore undertaken to document the bilateral anatomy of the RLN in human cadavers and to assess its origin, course and relationships with the tracheo-oesophageal groove, inferior thyroid artery, thyroid gland, Zuckerkandl's tubercle, ligament of Berry and cricothyroid joint.

AIMS AND OBJECTIVES

Aim:

To study the anatomical course and variations of the recurrent laryngeal nerve (RLN) in human cadavers.

Objectives:

1. To determine the origin and looping pattern of the right and left RLNs.
2. To determine the position and angle of the RLN in relation to the tracheo-oesophageal groove.
3. To assess the site, level and pattern of extralaryngeal branching of the RLN.
4. To determine the relationship of the RLN with the inferior thyroid artery and its branches.

5. To assess the relationship of the RLN with the thyroid gland, capsule, Zuckerkandl's tubercle and Berry's ligament.
6. To determine the relationship of the RLN with the cricothyroid joint and identify reliable anatomical landmarks for nerve preservation during surgery.

MATERIALS AND METHODS

Study Design and Specimens

This was a descriptive observational cadaveric study conducted in the Department of Anatomy using embalmed human cadavers during March to December 2024. Twenty-five cadavers available during the study period were included, providing 50 recurrent laryngeal nerves (RLNs)—25 right-sided and 25 left-sided nerves. All available embalmed cadavers fulfilling the study protocol were included.

Dissection Technique

Dissection was performed according to standard anatomical procedures described in *Cunningham's Manual of Practical Anatomy*. A midline cervical incision was made from the chin to the suprasternal notch and extended laterally along the inferior border of the mandible. The skin, superficial fascia and platysma were reflected, followed by exposure of the deep cervical fascia and strap muscles. The pretracheal fascia was removed to expose the thyroid gland and trachea.

The thyroid lobes were carefully mobilized to expose the thyroid bed, ligament of Berry and expected course of the RLN. The cervical vagus nerve was identified and the RLN was traced from its origin to its entry into the larynx. On the right, the nerve was followed around the subclavian artery, while on the left it was traced around the aortic arch. The inferior thyroid artery (ITA) was dissected from its origin to its terminal branches, and its relationship with the RLN was recorded. Zuckerkandl's tubercle and Berry's ligament were identified wherever present.

Anatomical Parameters

The following parameters were recorded bilaterally:

1. Origin and looping pattern of the RLN.
2. Relationship with the tracheo-oesophageal groove (TOG).
3. Angle between the RLN and TOG, categorized as Type I (0–15°), Type II (16–30°) and Type III (31–45°).
4. Site and level of extralaryngeal branching.
5. Number of extralaryngeal branches.
6. Relationship with the ITA and its branches.

7. Relationship with the thyroid gland and capsule.
8. Presence, grade and morphology of Zuckerkandl's tubercle and its relationship with the RLN.
9. Relationship with Berry's ligament.
10. Relationship with the cricothyroid joint.

Statistical Analysis

Categorical anatomical findings were expressed as frequencies and percentages. Right- and left-sided categorical variables were compared using the chi-square test where applicable. A two-sided $P < 0.05$ was considered statistically significant. The reported chi-square values from the original dataset were retained without recalculation.

RESULTS

Study Population

A total of 25 embalmed cadavers were dissected, yielding 50 RLNs, with equal representation of right and left nerves. Twenty-one cadavers (84%) were male and four (16%)

were female. No non-recurrent laryngeal nerve was identified.

Origin and Looping Pattern

All 50 RLNs originated from the vagus nerve. On the right, all 25 nerves looped around the undersurface of the first part of the right subclavian artery. On the left, all 25 nerves looped beneath the aortic arch, lateral to the ligamentum arteriosum. Thus, the expected asymmetric looping pattern was consistently demonstrated.

Position in Relation to the Tracheo-Oesophageal Groove

The RLN was located within the TOG in 15 (60%) right-sided and 20 (80%) left-sided nerves. The remaining nerves were paratracheal, accounting for 10 (40%) right-sided and 5 (20%) left-sided nerves. No RLN was found in a para-oesophageal position. Thus, the TOG was the predominant location on both sides, with a higher proportion of left-sided nerves occupying the groove (Table 1).

Table 1. Position of the RLN in relation to the tracheo-oesophageal groove

Side	Within TOG, n (%)	Paratracheal, n (%)	Para-oesophageal, n (%)	Total
Right	15 (60.0)	10 (40.0)	0	25
Left	20 (80.0)	5 (20.0)	0	25
Total	35 (70.0)	15 (30.0)	0	50

Angle Between RLN and TOG

The left RLNs predominantly demonstrated a Type I angle ($0-15^\circ$), observed in 20 (80%) nerves, whereas the right side showed greater angular variation. On the right, 5 (20%) were Type I, 12 (48%) Type II and 8 (32%) Type III. Overall, Type I was the most frequent pattern

(50%), followed by Type II (34%) and Type III (16%). The reported chi-square value was 19.882 ($df=2$), indicating a significant difference in angular distribution between the two sides at the level reported in the original dissertation (Table 2).

Table 2. Angle formed by the RLN with the TOG

Side	Type I ($0-15^\circ$), n (%)	Type II ($16-30^\circ$), n (%)	Type III ($31-45^\circ$), n (%)
Right	5 (20.0)	12 (48.0)	8 (32.0)
Left	20 (80.0)	5 (20.0)	0
Total	25 (50.0)	17 (34.0)	8 (16.0)

Chi-square = 19.882; df = 2.

Extralaryngeal Branching

Extralaryngeal branching was observed in 32 (64%) of the 50 nerves. It was present in 15 (60%) right and 17 (68%) left nerves. Branching occurred most commonly within 2 cm of the laryngeal entry point, accounting for 15

(30%) nerves overall. Eighteen nerves (36%) entered the larynx as a single trunk, while 16 (32%) bifurcated, 12 (24%) trifurcated and 4 (8%) demonstrated more than three branches (Tables 3 and 4).

Table 3. Site and level of extralaryngeal branching

Side	Single trunk	<1 cm	<2 cm	<3 cm	<4 cm
Right	10 (40%)	1 (4%)	8 (32%)	5 (20%)	1 (4%)
Left	8 (32%)	2 (8%)	7 (28%)	6 (24%)	2 (8%)

Total	18 (36%)	3 (6%)	15 (30%)	11 (22%)	3 (6%)
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Table 4. Number of extralaryngeal branches

Side	Single	Bifurcating	Trifurcating	>3 branches
Right	10 (40%)	7 (28%)	6 (24%)	2 (8%)
Left	8 (32%)	9 (36%)	6 (24%)	2 (8%)
Total	18 (36%)	16 (32%)	12 (24%)	4 (8%)

Relationship with the Inferior Thyroid Artery

The RLN was posterior to the ITA in 33 (66%) nerves, anterior in 12 (24%) and between arterial branches in 5 (10%). Posterior positioning was observed in 64% of right and

68% of left nerves. The reported side-wise comparison showed $\chi^2 = 0.564$, $df = 2$, indicating no significant difference in the RLN-ITA relationship between the two sides (Table 5).

Table 5. Relationship of the RLN with the inferior thyroid artery

Relationship	Right, n (%)	Left, n (%)	Total, n (%)
Anterior	7 (28.0)	5 (20.0)	12 (24.0)
Posterior	16 (64.0)	17 (68.0)	33 (66.0)
Between branches	2 (8.0)	3 (12.0)	5 (10.0)
Total	25 (100)	25 (100)	50 (100)

Chi-square = 0.564; df = 2.

Other Anatomical Relationships

All 50 RLNs were **free from the thyroid gland and its capsule**. Zuckerkandl's tubercle was identified on 33 sides. Among these, 19 were sessile and 7 were pedunculated according to the recorded observations. The RLN was medial to the Zuckerkandl's tubercle in all 50 dissected sides.

All 50 RLNs were located superficial to Berry's ligament and passed posterior to the cricothyroid joint before entering the larynx.

cases, with the remainder located outside the groove.

Henry et al. also demonstrated substantial variability in this relationship, with pooled data showing the RLN within the tracheo-oesophageal groove in approximately 63.7% of sides. Thus, the present finding of 70% is consistent with previously reported anatomical variability and supports the use of the TOG as a guide rather than an absolute landmark [11,12].

DISCUSSION

The present study evaluated 50 RLNs from 25 human cadavers and demonstrated considerable variation in their cervical course, relationship to the TOG and ITA, and extralaryngeal branching pattern. These findings reinforce the importance of direct anatomical identification of the RLN during thyroid and other cervical procedures.

Relationship with the Tracheo-Oesophageal Groove

In the present study, 70% of RLNs were located within the TOG, with a higher frequency on the left side (80%) than on the right (60%). The remaining nerves were paratracheal, and no para-oesophageal nerve was observed. This finding is consistent with anatomical literature showing that although the TOG is a useful guide, the RLN does not invariably occupy the groove. A cadaveric study of 30 specimens reported the RLN within the TOG in 71.7% of

Angle of the RLN with the TOG

A marked side-to-side difference was observed in the angular relationship of the RLN with the TOG. Most left-sided nerves demonstrated a shallow Type I angle, whereas right-sided nerves more frequently showed Type II and Type III configurations. The significant difference in angular distribution suggests that the spatial orientation of the RLN cannot be assumed to be symmetrical. This observation is clinically relevant because the nerve may deviate laterally from the expected groove during thyroid mobilization. Recognition of such variation may reduce the possibility of mistaking adjacent connective tissue or vascular structures for the RLN during dissection [12].

Relationship with the Inferior Thyroid Artery

The RLN was posterior to the ITA in 66%, anterior in 24% and between its branches in 10% of nerves. Similar predominance of a posterior relationship has been reported in

cadaveric investigations. A recent cadaveric study reported the RLN predominantly posterior to the ITA, although the precise relationship varied among specimens.

The present findings emphasize that the ITA should be considered a useful orientation point but not a constant anatomical landmark. The nerve may pass anterior or between arterial branches, creating a potential risk during ligation of the ITA. Earlier anatomical work has similarly demonstrated substantial variability in the relationship between the RLN and ITA [13,14].

Extralaryngeal Branching

Extralaryngeal branching was identified in 64% of the RLNs in the present study. The most frequent pattern was bifurcation, followed by trifurcation, while 36% entered the larynx as a single trunk. Branching was most frequently observed within 2 cm of laryngeal entry.

These findings are consistent with the large meta-analysis by Henry et al., which reported extralaryngeal branching in approximately 60% of 28,387 nerves, with cadaveric studies demonstrating even higher rates. Bifurcation was the most common branching pattern and branching most frequently occurred 1–2 cm before laryngeal entry.

The relatively high frequency of branching in the present study is therefore anatomically plausible. Failure to identify and preserve all branches may result in incomplete neural preservation despite apparent identification of the main RLN trunk. Studies of cadaveric and surgical specimens similarly emphasize the importance of tracing all branches toward their laryngeal entry points [15,16].

Zuckerkindl's Tubercle

Zuckerkindl's tubercle was identified in 33 sides, and the RLN was medial to the tubercle in the present series. Zuckerkindl's tubercle is widely recognized as an important anatomical landmark during thyroid surgery. Henry et al., in a cadaveric study and meta-analysis, reported a pooled prevalence of approximately 70% and demonstrated a consistent relationship between the tubercle and RLN in most specimens.

The present findings support the use of Zuckerkindl's tubercle as an adjunctive landmark for locating the RLN. However, its variable presence and morphology mean that it should not be used in isolation [17].

Berry's Ligament

All RLNs in the present study were superficial to Berry's ligament. This finding agrees with anatomical studies showing that the RLN is most commonly superficial to the ligament. A systematic review and meta-analysis reported a pooled prevalence of approximately 78% for a superficial RLN–Berry's ligament relationship. Similarly, a recent cadaveric study found the RLN to be superficial to Berry's ligament in 88.3% of cases, although deep and piercing relationships were also observed. These findings indicate that Berry's ligament is a useful surgical landmark, but direct identification of the nerve remains essential [18,19].

Relationship with the Cricothyroid Joint

All 50 RLNs in the present study passed posterior to the cricothyroid joint before entering the larynx. The cricothyroid region therefore represents a useful distal landmark during final identification of the nerve. Because the RLN approaches the larynx in a confined anatomical region, careful dissection around the inferior thyroid pole, Berry's ligament and cricothyroid joint is particularly important for preserving the terminal branches.

Recent anatomical literature similarly emphasizes the importance of multiple complementary landmarks rather than relying on a single structure for RLN identification [20].

Surgical Implications

The principal surgical implication of the present study is that no single anatomical landmark reliably predicts the position of the RLN in every case. The TOG, ITA, Berry's ligament, Zuckerkindl's tubercle and cricothyroid joint should therefore be considered collectively. The high frequency of extralaryngeal branching further emphasizes the need to trace the nerve completely and identify all branches before thyroid tissue or adjacent vascular structures are divided. Recent surgical studies likewise demonstrate considerable variability in the relationships of the RLN with the ITA, Berry's ligament, TOG and Zuckerkindl's tubercle.

Strengths and Limitations

The principal strength of this study was bilateral direct dissection of the RLN in the same cadavers, allowing comparison of right- and left-sided anatomical relationships. The study also evaluated multiple surgical landmarks simultaneously.

The limitations include the relatively small sample size of 25 cadavers, use of embalmed

specimens and absence of clinical correlation with postoperative nerve function. In addition, anatomical measurements obtained from cadavers may not completely reproduce relationships observed during live surgery. The findings should therefore be interpreted as descriptive anatomical observations rather than direct estimates of surgical complication risk.

CONCLUSION

The present cadaveric study demonstrated considerable anatomical variation in the course and relationships of the recurrent laryngeal nerve (RLN). Although the origin and looping patterns were consistent with the classical right-sided subclavian and left-sided aortic courses, variations were observed in the relationship of the nerve to the tracheo-oesophageal groove, its angulation and extralaryngeal branching. The RLN was predominantly posterior to the inferior thyroid artery, while extralaryngeal branching was observed in 64% of nerves. The consistent relationships with the Zuckerkandl's tubercle, Berry's ligament and cricothyroid joint provide useful additional surgical landmarks. These findings emphasize that direct identification of the RLN, supported by multiple anatomical landmarks, is essential for safe thyroid and cervical surgery and for minimizing the risk of nerve injury.

DECLARATIONS

Ethics Approval

The study was conducted on embalmed human cadavers available in the Department of Anatomy according to the institutional dissertation protocol. Institutional Ethics Committee approval was obtained.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

All authors contributed to the study conception, cadaveric dissection, data collection, analysis and interpretation, manuscript preparation, and critical revision of the final manuscript. All authors approved the final version of the manuscript.

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