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A Novel Surgical Landmark to Identify the Recurrent Laryngeal Nerve

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Background: Although several surgical landmarks have been proposed to localize the recurrent laryngeal nerve (RLN), there is still no reliable landmark.

Aims: To validate the reliability of a novel reference point at the intersection of the inferior border of the cricopharyngeal muscle and the inferior cornu of thyroid cartilage for locating the RLN.

Study Design: Cadaver dissection study in the academic department of otolaryngology-head and neck surgery.

Methods: Sixty-four RLNs in cadavers were assessed, and measurements of different surgical landmarks in conjunction with the proposed surgical landmark were obtained. Descriptive statistics, Pearson's chi-squared test, and Student's t-test were performed to analyze the data using GraphPad Prism (version 9.4.1; Dotmatics, Boston, Massachusetts, USA).

Results: The average distance from the proposed landmark to the RLN was 2.3 ± 0.85 mm. The RLN was located just posterior to the reference point in 95.31% of the cadavers. The RLN passed under the inferior constrictor muscle in 90.63% of the cadavers. There was no statistically significant difference between right- and left-sided RLNs in terms of their relation with the reference point.

Conclusion: The proposed reference point can be used as a reliable landmark to locate the RLN. This reference point may help surgeons during difficult thyroidectomy surgeries by providing an additional anatomical landmark.

INTRODUCTION

Thyroidectomy is one of the most common surgical procedures in the head and neck region. The recurrent laryngeal nerve (RLN) should be accurately identified intraoperatively to prevent nerve damage and preserve the voice.[1,2] However, the RLN has several anatomic variations, and there is no single reliable landmark to localize it.[3] This can be especially challenging during revision or completion of thyroidectomies with distorted anatomy due to postoperative scarring from the primary surgery.

Several surgical landmarks have been used to localize the RLN, including the inferior thyroid artery, Berry's ligament, tracheoesophageal groove, inferior horn (cornu) of the thyroid cartilage (ICTC), inferior pharyngeal constrictor muscle, Zuckerkandl's tubercle, and carotid artery.[4-10] However, none of those landmarks can be used alone to precisely identify the RLN location because of its variable anatomic course.

The most identifiable landmark for RLN localization is its point of entry into the larynx, which typically lies posterior to the ICTC.[3] This entry point is reliable and constant regardless of anatomic variations or thyroid gland pathologies because it is based on a cartilaginous structure, which usually demonstrates less variations than soft tissue. This feature was first introduced as a surgical landmark by Wang[4] in 1975. Uen et al.[5] reported an average distance of 8 ± 4 mm between the ICTC and the point of entry into the larynx. However, this entry point is almost always covered by several layers of soft tissue, blood vessels, and the inferior constrictor muscle. Furthermore, the RLN may have anatomic variations such as extralaryngeal branches passing close to the entry point, which makes exposing it challenging and prone to unexpected complications. This landmark, like numerous others, only defines the nerve at this one point, predicting its superoinferior location.

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The inferior pharyngeal constrictor and cricopharyngeal muscles are other reliable landmarks that can be used to localize the RLN. Wafae et al.[6] reported that the RLN may pass under the cricopharyngeal muscle or pierce the muscular fibers. This landmark can also help surgeons predict the depth of the RLN. However, it is challenging to localize the nerve using this landmark alone because there is a risk of violating the RLN and its branches. Blind dissection of the inferior pharyngeal constrictor and cricopharyngeal muscles can lead to unwanted nerve complications.

A surgeon needs to be aware of how to precisely locate the RLN. Ideally, the surgical landmark needs to be safe, easy to identify, and reliable, have three-dimensional coordinates, and possess a stable relationship with the targeted anatomic structures. In this study, we aimed to identify an ideal surgical landmark or combination of landmarks to localize the RLN.

MATERIALS AND METHODS

This cadaveric study was designed to evaluate the possibilities of using a novel combination of two different reliable landmarks to localize the RLN with three-dimensional coordinates. The landmarks were as follows:

1. First landmark: The inferior rim of the cricopharyngeal muscle, which provides the *x*-axis to predict the vertical/craniocaudal location as well as the *z*-axis to predict the nerve depth (Figure 1).

2. Second landmark: A vertical line from the most prominent portion of the ICTC. This second landmark provides the *y*-axis to predict the anteroposterior location of the nerve (Figure 1).

The proposed reference point in this study was the intersection of the *x*- and *y*-axes (Figure 1). This reference point is also shown in the cadaveric specimen in Figure 2. The depth of the RLN from the reference point was defined by the cricopharyngeal muscle, which provided the *z*-axis. We hypothesized that the RLN can be precisely located by using the proposed reference point, regardless of thyroid pathologies, previous surgeries, or anatomic variations.

Specimens

Thirty-two embalmed human cadavers were appropriately acquired via the Willed Body Program at the Institute of Anatomical Sciences, Texas Tech University Health Sciences Center (TTUHSC), TX, USA, and they were approved for use by the Institutional Anatomical Review Committee. Cadaveric specimens were handled in accordance with university policy and the regulations determined by the Texas State Anatomical Board. This study was approved by the Institutional Anatomical Review Committee of Texas Tech University Health Sciences Center (approval number: #21-1221-R; date: 21.12.2021). This institutional review board does not consider research on cadavers to constitute human research. Thus, no informed consent was required. All State of Texas and University (TTUHSC OP 73.20) regulations were followed during the collection

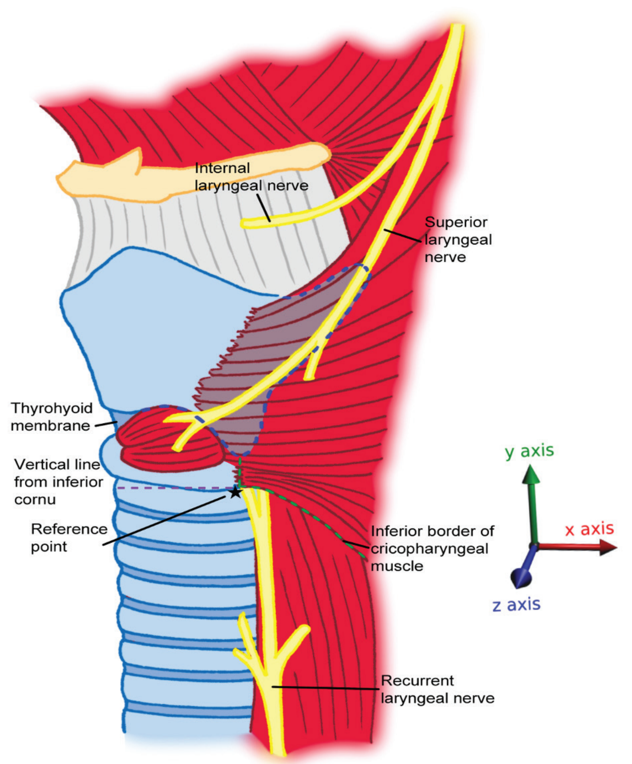

FIG. 1. Reference point (★) is the intersection of (a) the inferior border of cricopharyngeal muscle and (b) a line from the most prominent portion of the inferior cornu of the thyroid cartilage.

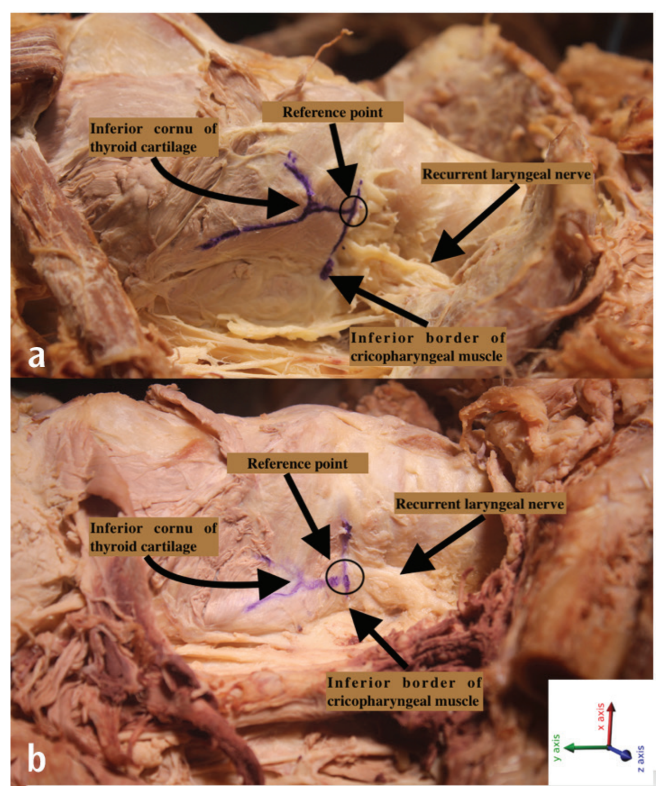

FIG. 2. Lateral view of the surgical landmarks and reference point. (a) The recurrent laryngeal nerve is located just (a) posterior or (b) anterior to the reference point.

of data. All cadavers were evaluated and excluded from the study if any or all of the following conditions were noted: congenital defects of the thyroid and/or RLN, previous neck surgery in planes that could have disrupted the thyroid and/or RLN, and existing neck wounds or obvious penetrating neck trauma.

The study was performed during the 2022 cadaver dissection course at the School of Health Professions, TTUHSC. The dissections were performed by the authors, under the supervision of the lead author, to ensure consistency. The necks of 32 white, human, adult, embalmed cadavers (18 males and 14 females) were examined. The age of the cadavers at the time of death ranged between 56 and 92 years (mean, 78.7 years). The gross pathology of the thyroid gland was not observed. All the cadavers were within the size and weight range established by the Institute of Anatomical Sciences' Willed Body Program for the acceptance of body donation (weight, 40.8-89.8 kg, mean, 64.3 kg; height, 149.9-193.0 cm, mean, 171.9 cm). The cadavers had been partially dissected by the students from the School of Health Professions, TTUHSC, during the academic year and were subsequently dissected by the authors.

If the cadaver met the inclusion criteria, the study personnel proceeded with identifying the thyroid and RLN. During the dissection, the cadaver was placed in a supine position without placing a roll under the shoulder. The cadaver heads were maintained in a neutral position to ensure consistency and eliminate potential variations that could arise from different head or neck positions. After the strap muscles were separated, the middle thyroid vein and superior thyroid artery pedicles were identified and sacrificed. Subsequently, the inferior constrictor and cricopharyngeal muscles and the ICTC were identified and marked. The proposed surgical reference point was marked, and the RLN was identified. The RLN was dissected proximally and distally to quantitatively determine its relationship with the other surgical landmarks. The following measurements were documented in relation to the RLN with the head in a centered supine position, without manipulating or retracting the surrounding structures:

- Distance from the proposed reference point,
- Distance from the ICTC,
- Relationship with the inferior constrictor muscle,
- Extralaryngeal branching of the RLN,
- Distance to Berry's ligament,
- Relationship with the inferior thyroid artery,
- Angle formed with the tracheoesophageal groove,
- Distance to the entry point into the larynx and the proposed landmark,
- Size of the thyroid gland.

Statistical analysis

Data are presented as means and standard deviations for numerical variables and as frequencies and percentages for categorical variables. The D'Agostino and Pearson tests indicated that the data were normally distributed. Relations between the quantitative variables were examined using the Pearson's chi-square test and Fisher's exact tests when the expected values in any of the cells of a contingency table were less than five. The Student's t-test was used to compare two groups, such as left vs. right side measurements. GraphPad Prism (version 9.4.1; Dotmatics, Boston, Massachusetts, USA) was used to perform all statistical analyses. A p value of < 0.05 was considered statistically significant.

RESULTS

Thirty-two dissected fixed cadavers were used in this study, and 64 thyroid measurements were obtained. Table 1 summarizes the measurement data collected from the cadavers. The RLN was located at an average of 2.3 ± 0.85 mm from the reference point, 9.64 ± 2.48 mm from the ICTC, and 2.28 ± 0.88 mm from the Berry's ligament. The distance from the reference point to the point of entry of the RLN into the larynx averaged 9.44 ± 2.11 mm. Proximal extralaryngeal branching (before the inferior rim of the cricopharyngeal muscle) averaged 1.3 ± 0.66 branches per

TABLE 1. Characteristics and Distributions of the Anatomic Landmarks.

		Right side	Left side	*p*	Bilateral
Mean thyroid size	Length, mm	44.75 (7.59)	42.87 (10.88)	0.427	43.81 (9.35)
	Width, mm	29.31 (5.78)	28.21 (6.81)	0.540	29.19 (6.27)
Mean distance between landmark and RLN	Reference point, mm	2.25 (0.18)	2.34 (0.25)	0.662	2.30 (0.85)
	ICTC, mm	9.62 (2.62)	9.65 (2.36)	0.960	9.64 (2.48)
	Berry's ligament, mm	2.34 (1.0)	2.21 (0.75)	0.575	2.28 (0.88)
	Reference to point of entry of larynx, mm	9.62 (2.01)	9.25 (2.23)	0.483	9.44 (2.11)
Mean number of RLN branches	Before the reference point	1.25 (0.62)	1.34 (0.70)	0.573	1.30 (0.66)
	After the reference point	3.37 (0.49)	3.37 (0.40)	1	2.08 (0.45)
Mean angle formed between the tracheoesophageal groove and the RLN (degrees)		23.94° (8.60)	21.60° (8.75)	0.285	22.78° (8.69)

Data are presented as mean (standard deviations). RLN, recurrent laryngeal nerve; ICTC, inferior cornu of the thyroid cartilage.

RLN. Distal branching (after the inferior rim of the cricopharyngeal muscle) averaged 2.08 ± 0.45 branches. The reference point always laid within a few millimeters of the RLN in the neutral head position without any soft tissue retraction. In 95.31% of the specimens, the RLN was located just posterior to the reference point. The RLN passed under the inferior constrictor muscle in 90.63% of the cases.

The Pearson's chi-square test was used to compare the relationships between the various anatomical points on the right and left sides (Table 2). The mean angle between the tracheoesophageal groove and right-sided RLN averaged 23.9° and that between the groove and left-sided RLN averaged 21.6°. However, the differences were not statistically significant. With respect to the relationship with the inferior thyroid artery, the right- and left-sided RLNs exhibited significantly ($p = 0.003$) different patterns. The right-sided RLN passed over or between the branches of the inferior thyroid artery more often than the left-sided RLN.

DISCUSSION

The RLN innervates most of the laryngeal muscles, such as those responsible for opening (e.g., posterior cricoarytenoid muscles), closing, and tensioning the vocal cords. Thus, vocal paresis or paralysis due to intraoperative RLN damage can cause problems with speaking, such as dysphonia and aphonia, and even respiratory distress. These issues can be a source of patient dissatisfaction and malpractice litigations against the otolaryngology and endocrine surgery departments.[11] Thus, safely locating the RLN intraoperatively, particularly during revision surgery or other cases with a distorted anatomy, is crucial. This study provides a reliable method for locating the RLN that does not rely upon easily destroyed or distorted landmarks such as the Berry's ligament.

Vocal cord paresis or paralysis is a common complication associated with thyroid surgery.[12] The incidence of temporary paresis tends to be more prevalent than permanent paralysis. A large study by Chiang et al.[12] reported temporary paresis in 2% and 4% of the patients undergoing surgery for thyroid cancer and primary benign thyroid disease, respectively. The incidence of permanent paralysis was 0.7% and 0.2% in the cancer and benign groups, respectively. Similar incidences have been reported in several other studies.[13] The recent literature[13] suggests that incidences of RLN palsy or paresis may be more prevalent than previously reported in large studies because centers with unfavorable outcomes may not report their data. Furthermore, there is a lack of a routine laryngeal examination postoperatively. Often, the vocal cords are not evaluated at all postoperatively, accounting for the numerous cases of well-compensated unilateral paresis or paralysis going unnoticed. Incidences of temporary vocal palsy, which is associated with Graves' disease and reoperations, are noticeably higher. Chiang et al.[12] demonstrated that identifying the RLN is "the only way" to avoid injury. In their surgical approach, the RLN was not identified early in operation but as the dissection proceeded toward the Berry's ligament.[12] Similarly, Mohil et al.[13] demonstrated that RLN damage can be avoided by understanding the regional anatomy and routinely identifying the nerve during the surgery.

In this cadaveric study, we evaluated the reliability of the proposed reference point, which is now being routinely used for both revision thyroid surgeries and selected primary cases at our institution. This approach contributes to the easier identification of the RLN, regardless of the presence of a distorted anatomy from previous surgeries or thyroid pathologies. The surgical steps are as follows: i) skin incision and flap elevation, ii) separation of the strap muscles, iii) subcapsular dissection and delineation of the thyroid, iv) superior pole dissection and identification/preservation of the superior laryngeal nerve, v) ligation of the superior thyroid vessels, vi) retraction of the thyroid antero-medially and its delivery via the neck incision, vii) identification of the RLN and superior parathyroid gland, viii) ligation of the inferior thyroid vessels adjacent to the thyroid capsule, ix) dissection of the thyroid from the Berry's ligament and trachea, and x) bleeding control and closure. RLN can be found in several ways, including the lateral approach, inferior approach (at the Lore's triangle), and medial-to-lateral approach (at the point of entry into the larynx). All conventional techniques for RLN localization rely on soft tissue landmarks. However, previous surgeries may be associated with a destruction of the relevant surgical landmarks. The surgeons at our institution have been utilizing the proposed surgical landmark for RLN localization for a considerable

TABLE 2. Relationship Between the Specified Anatomical Landmarks.

		Right side, n (%)	Left side, n (%)	p	Bilateral, n (%)
Relationship of the RLN to the reference point	Anterior	1 (3.13%)	2 (6.25%)	0.5	3 (4.69%)
	Posterior	31 (96.88%)	30 (93.75%)		61 (95.31%)
Relationship of the RLN to the inferior constrictor muscle	Under	29 (90.63%)	29 (90.63%)	0.223	58 (90.63%)
	Penetrates	0 (0.00%)	2 (6.25%)		2 (3.13%)
	Over then penetrates	3 (9.38%)	1 (3.13%)		4 (6.24%)
Extralaryngeal branching	Yes	29 (90.63%)	29 (90.63%)	0.664	58 (90.63%)
	No	3 (9.38%)	3 (9.38%)		6 (9.38%)
Relationship of the RLN to the inferior thyroid artery	Under	20 (59.38%)	31 (96.88%)	0.003*	51 (79.69%)
	Between	8 (28.13%)	1 (3.13%)		9 (14.06%)
	Over	4 (12.50%)	0 (0.00%)		4 (6.25%)

Data are presented as number and percentage. RLN, recurrent laryngeal nerve.

period of time, and they have found it to be highly consistent in both primary and revision thyroidectomy surgeries. The proposed reference point can be identified by palpating the ICTC and drawing a line from the ICTC to the inferior border of the cricopharyngeal muscle. The ICTC can easily be palpated, and the identification of the inferior border of the cricopharyngeal muscle is also relatively straightforward, even in revision cases. A previous thyroid surgery may be associated with the removal of the Berry's ligament and/or thyroid vessels. However, the ICTC and inferior border of the cricopharyngeal muscle should still be present and not distorted in most patients. Furthermore, our approach for identifying the RLN may be useful during endoscopic thyroidectomies that proceed from superior to inferior, as the ICTC will be encountered relatively early during the operation. The intersection of the two landmarks is our main reference point, with which the nerve can be easily found. The nerve is usually located just posterior to the reference point. Thereafter, it passes under the cricopharyngeal muscle and pierces the cricoarytenoid joint. The surgeons should also be aware of extralaryngeal branching. The main nerve almost always gives off one branch before it passes under the cricopharyngeal muscle.

Our study results indicate that the proposed reference point is a reliable landmark, with the RLN located within 2.3 mm from the reference point. In 95.3% of the cadavers, the RLN was located immediately posterior to the reference point. Thereafter, in 90.6% of the cadavers, the RLN passed under the cricopharyngeal muscle. There were no statistically significant variations between the right- and left-sided RLN in relation to the proposed reference point. The right-sided RLN did have a statistically significant relationship with the inferior thyroid vessels ($p = 0.003$). This may be attributed to the fact that the right-sided RLN has a more complicated embryological course than the left-sided RLN.[14]

Tissue shrinkage is inevitable in cadaveric studies, which depends on the fixation methods employed. The degree of tissue shrinkage is minimal in fresh frozen cadavers compared to cadavers fixed with formalin or similar methods (10-40%).[15,16] Kansu et al.[17] reported a longitudinal shrinkage of 3% and transverse shrinkage of 2.4% in animal cervical tissue after being fixed in formalin (8%) for 24 h. Our study was conducted in a large dissection lab at the Institute of Animal Sciences, and formalin-fixed cadavers were exclusively used. Thus, we estimate that there may have been a tissue shrinkage of 10-20% in our cadaver study. The position of soft tissue landmarks may change with neck extension and rotation as well as with soft tissue retraction during actual surgeries. In our current study, we adopted a neutral anatomical position and eliminated soft tissue retractions to standardize the measurements. However, surgeons should be aware that the position of anatomic landmarks can change with neck extension, rotation, and soft tissue retraction during live surgeries. The extent of positional changes depends on the amount of soft tissue retraction and neck extension/rotation applied. However, the relative positioning of surgical landmarks remains consistent regardless of changes in neck position, despite alterations in measurements. Upon identifying the RLN, the surgeons should also consider the curvature and angle of the nerve during its dissection. Soft tissue and thyroid retraction may alter the course of the nerve during live surgeries.

This study has various limitations. The cadavers used were obtained via convenient sampling of voluntary donors of the Willed Body Program. Thus, the cadavers were predominately white. Therefore, these results cannot not be generalized to other ethnicities without further studies. The sex of the cadaver and the length and width of the neck may affect the measurements. However, these data were not collected. Another limitation of the study is the absence of clinical or intraoperative correlation. These limitations should be addressed in future studies to assess the reliability of the proposed surgical landmark in live thyroidectomy surgeries. However, the cadaver dissection provided valuable opportunities to explore additional structures and analyze relationships beyond the scope of standard thyroidectomy surgeries. These included dissecting RLN branches, exploring the ICTC, and tracing the RLN up to the cricoarytenoid unit. Another limitation of the study is the absence of cadavers with a previous history of undergoing thyroidectomy. Having data from revision surgeries would be highly beneficial. Furthermore, a multivariate regression analysis would have provided a more robust justification for the study's results. However, as this was a small pilot study, the limited data did not support a multivariate regression analysis.

In conclusion, we propose a novel landmark to identify the RLN. The proposed point can be identified by palpating the ICTC and following a line down from the ICTC to the inferior border of the cricopharyngeal muscle. Using this method, the RLN can be easily and safely found. The RLN should be located immediately posterior to and within 2.3 mm from the reference point. Knowledge of RLN's relationship to the proposed point may help guide surgeons identify the RLN, particularly during tricky revision surgeries, in which the anatomy may be distorted, and when landmarks may be missing. We aimed to provide a novel surgical landmark in addition to previously defined landmarks to located the RLN. Surgeon should utilize all defined landmarks for RLN localization to minimize the risk of complications.

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Ethics Committee Approval: This project was approved by the Texas Tech University Health Sciences Center, Institutional Anatomical Review Committee (approval number: #21-1221-R, date: 21.12.2021).

Data Sharing Statement: The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

Authorship Contributions: Concept- Y.D.; Design- Y.D.; Data Collection or Processing- Y.D., C.M.S., M.L., T.Q.N., K.K.G., D.H.S., N.T., J.C.; Analysis or Interpretation- C.M.S.; Writing- Y.D., C.M.S.; Critical Review- Y.D., C.M.S., M.L., T.Q.N., K.K.G., D.H.S., N.T., J.C.

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