Identification of valid anatomical landmarks to locate and protect recurrent laryngeal nerve during thyroid surgery: A cadaveric study

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Research Article

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Abstract

Purpose

Recurrent laryngeal nerve (RLN) is the most critical structure in terms of intricacy. Anatomic variations of the nerve may further make thyroid surgery cumbersome. The present study was undertaken to provide comprehensive knowledge about the soundness of commonly used anatomical landmarks such as Berry's ligament (BL), tracheoesophageal groove (TEG), inferior thyroid artery (ITA) and the midpoint of the posterior border of the thyroid gland in the identification of the nerve intraoperatively.

Methods

Thirty adult cadavers were dissected to identify the RLN in the neck and to locate it in relation to the aforementioned anatomical landmarks.

Results

The RLN/BL relationship: RLN was most often located superficial to the BL (88.3%), followed by deep to the BL in 8.4%, and piercing the BL in 3.3% of cases, respectively. The RLN/TEG relationship: the RLN was located inside the TEG in most cases (71.7%), followed by RLN lying outside the TEG in 28.3%. Outside the groove, it was most commonly found lateral to the TEG (64.7%). RLN/ITA relationship: the nerve was passing deep to the artery in most of the cases (65%), followed by superficial (30%) and rarely (5%) in-between the branches. RLN/ midpoint posterior border of thyroid relationship: In 57 (95%) cases, RLN was coursing in the area posterior to the midpoint of the posterior border of the gland with an average distance of 4.95±2.23 mm ranging between 2.21mm to 12.1mm.

Conclusions

Both the BL and TEG are potentially crucial for safeguarding RLN. Although in results, BL turns out to be more consistent than TEG, we propose the utilization of both these anatomical landmarks together for complication-free neck surgeries. Furthermore, the midpoint of the posterior border of the thyroid turns out to be the single most consistent landmark for identifying RLN during partial thyroidectomy.

Introduction

The recurrent laryngeal nerve (RLN) is a branch of the vagus. RLN may vary from the thorax to the larynx and is highly vulnerable during thyroid surgery. It has been observed that RLN enters the larynx after dividing into two or more branches. The prevalence of RLN injury is 0.1-8% during thyroid surgery and is associated with improper identification and difficult isolation due to adhesion. The course of injury to the recurrent laryngeal nerve is a critical but avoidable complication of thyroidectomy and other neck...
surgeries. This complication may be avoided by prior identification of the nerve with the assistance of reliable anatomical landmarks found along its course [11, 17]. These are imperative to avert postoperative complications such as hoarseness of voice and vocal cord paralysis. Intraoperatively, RLN can be identified by several techniques, such as palpation, intraoperative nerve monitoring (IONM), and direct inspection facilitated by crucial anatomical landmarks such as Berry's ligament (BL), the Tracheoesophageal Groove (TEG), Inferior thyroid artery (ITA) and the midpoint of the posterior border of the thyroid gland or Zukerkandl's tubercle (ZT). A volatile relationship exists among these parameters [13]. The lucid identification of these landmarks improves the sensitivity of IONM. BL is a fibrous structure that anchors the thyroid gland to the first three tracheal rings and is the most common site of injury to the RLN, where the nerve penetrates the larynx [1, 3]. Few authors have proposed BL as a reliable anatomical landmark to locate the RLN intraoperatively [5, 25]. However, this has yet to be widely accepted and implemented as standard practice [3]. Previous reports revealed capacious variations in the location of the RLN concerning the BL, the nerve coursing superficial to the BL ranges from zero to 100% [4, 6, 21], while the penetrating pattern varies between zero to 31.6% [4, 6, 16, 18, 24, 25]. A further thorough cognizance of the frequency with which nerves penetrate the BL will bring down the complications, as traction-related injuries are commonly linked with RLNs taking a piercing course [1, 16].

The TEG is a deep sulcus formed by the concourse of the trachea anteriorly and oesophagus posteriorly. It provides a reasonably safe haven for the RLN as it ascends towards the larynx [24] and can also be used as a landmark for identifying the nerve [29]. The TEG must be routinely inspected during surgery for the presence of the nerve. Otherwise, it might be overlooked unwittingly [27]. Previous studies also revealed that the location and relationship of the RLN to the TEG varied widely. The reported presence of an RLN coursing within the TEG has ranged from 24.9–100% [8, 19].

ITA is another crucial landmark for recognizing the RLN intraoperatively. The anatomical relationship between the RLN and the ITA is volatile. RLN is related to the ITA differently on both sides. On the right side, RLN crosses ITA at the anterior aspect, but the same cross ITA at the posterior aspect on the left side. The clear visualization of the relationship between artery and nerve requires precise surgical technique to avoid damage to neurovascular structures.

The fourth landmark is the midpoint of the posterior border of the thyroid lobe, which points toward the TEG. Few authors have described this landmark as Zukerkandl's tubercle (ZT)[14, 15]. Usually, RLN travels in the area posterior to this landmark, but in a few instances, it can course anteriorly, making itself vulnerable to injury during partial thyroidectomy. In addition, RLN may have a very intimate relationship with the thyroid capsule along the posterior border. This relationship is a possible indicator in calculating the safe zone in deciding the line of incision in subtotal thyroidectomy or near-total thyroidectomy. Although the distance between the RLN and the posterior border of the thyroid is crucial, very little is mentioned in the literature.

The high variability of the data published to date precludes us from making factual statements about the robustness of these soft-tissue structures as valid and reliable anatomical landmarks for RLN
identification. Nevertheless, the high incidence of RLN injury, and the need to safeguard the structure during surgery, have persuaded substantial research in recent years. However, a reliable and uniform technique for identifying and safeguarding the nerve has yet to be conceived.

With such a background, the current work aimed to evaluate the reliability of the BL, TEG, ITA and the apex of the posterior border of the thyroid gland or ZT as anatomical landmarks for identifying the RLN. Reliable landmarks would help to alleviate the frequency of iatrogenic injury and long-term postoperative complications. Furthermore, RLN may have a very intimate relationship with the thyroid capsule at the apex of the posterior border, or ZT. This relationship guides the surgeon in deciding whether to perform a subtotal thyroidectomy or a near-total thyroidectomy. So, the distance between RLN and ZT is a possible indicator that is little mentioned in literature. Secondarily, the distance between RLN and ZT was investigated in cadaveric specimens, along with their anatomical relationship.

**Methods**

A total of 30 formalin-fixed adult cadavers (25 male and 5 female) aged between 45 and 75 years were dissected bilaterally over three years to investigate the anatomical relationship of the RLN to the BL, TEG, ITA, and the posterior border of the thyroid gland. The neck dissection was done as per Cunningham's practical manual for dissection. A wooden block with a slight central concavity was placed under the neck to keep the neck in an extended and fixed position without excessive movement during dissection. Afterwards, a midline vertical incision was given, starting from the symphysis menti and continuing downwards up to the sternal notch. Then the incision was extended laterally from the sternal notch up to the tip of the acromion along the anterior border of the subcutaneous clavicle. Subplatysmal skin flaps along with the superficial fascia and subcutaneous fatty tissue were then raised and reflected laterally for better exposure of the anterior triangle of the neck. The strap muscles (sternohyoid, sternothyroid, and omohyoid) lying in front of the thyroid gland were identified, transacted transversely through the middle of the muscle belly, and reflected upward and downward. The dissection was carried out until the thyroid gland was visible. Structures surrounding the gland (muscles, fatty and connective tissues) were kept away from the dissection area by applying mechanical traction with the help of a metallic hook or forceps. The RLN was visualized by applying slight medial traction on the trachea. Once the area was visible, the relationship of the nerve to the BL (superficial, piercing, or deep) was noted first. The nerve was then traced downwards to the TEG, and the position of the RLN concerning this groove was recorded (inside or outside, when outside: anterior, anterolateral, lateral, and posterior). After noting the position of the nerve with the BL, TEG, and ITA, its location and distance from the midpoint of the posterior border of the thyroid gland were also measured with the help of a digital vernier calliper (Mitutoyo, Japan). The distance between RLN and the midpoint of the posterior border was measured. The percentage prevalence of RLN variation was calculated. The descriptive statistics were computed for the distance between the posterior border of the thyroid and RLN with the help of Microsoft excel 2019.

**Results**
The present study was conducted on 30 formalin-fixed adult cadavers aged between 45 and 75 years. Amongst them, 25 (83.3%) were male, and 5 (16.7%) were female. The RLN was recognized reciprocally in all 30 cadavers (n = 60).

**RLN/BL relationship**

In 53 (88.3%) cases, the RLN was located superficial to the BL. In 5 cases, the nerve was piercing the ligament (Fig. 1) and, in 2 cases, coursing deep into it. The relationship was bilaterally symmetrical in 23 (76.7%) cadavers.

**RLN/TEG relationship**

In 43 (71.7%) cases, the RLN was coursing within the groove (Fig. 2), while in 17 (28.3%), the nerve was lying outside the groove (Fig. 1). When located outside the groove, it was most commonly found lateral to the TEG (11 nerves, 64.7%). The relationship was bilaterally symmetrical in 19 (63.3%) cadavers.

**RLN/ITA relationship**

The most common type of RLN was deep to the ITA (65%), while the second most common was superficial to the ITA (30%). The least common type was between the branches of the ITA, with an incidence of 5%. In addition, there were differences between the left and right sides, with the posterior type being the most common, occurring in 35.73% of the nerves on the left side and 20.78% on the right one. The relationship was bilaterally symmetrical in 13 (43.3%) cadavers.

**RLN/ midpoint of the posterior border of the thyroid**

In 57 (95%) cases, RLN was coursing in the area posterior to the midpoint of the posterior border of the gland (Fig. 3)

With an average distance of 4.95 ± 2.23 mm ranging between 2.21mm to 12.1mm. Almost all the nerves were found within 2 to 10 mm range except in two cases, where the distance was more than 10.00 mm. In three (5%) cases, the nerve was passing anteriorly to lie closely along the lateral surface of the gland. The relationship was bilaterally symmetrical in 23 (76.7%) cadavers. No significant differences were observed between subtypes based on TEG, ITA and BL. The data collected were not statistically sufficient in order to conclude any sex-related difference in the local anatomy of ITA and the RLN. The details of descriptive statistics are mentioned in Table 1 and Figures (4–6).
Table 1

<table>
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<tr>
<th>Relationship</th>
<th>Mean (in mm)</th>
<th>SD</th>
<th>N</th>
<th>Kruskal Wallis H test (P value &lt; 0.05)</th>
</tr>
</thead>
<tbody>
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<td>RLN/TEG</td>
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<td>4.96</td>
<td>2.35</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Outside anterolateral</td>
<td>5.20</td>
<td>1.48</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Outside lateral</td>
<td>4.74</td>
<td>2.22</td>
<td>11</td>
</tr>
<tr>
<td>RLN/ITA</td>
<td>Deep</td>
<td>5.07</td>
<td>2.48</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>In between</td>
<td>5.28</td>
<td>1.04</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Superficial</td>
<td>4.63</td>
<td>1.79</td>
<td>18</td>
</tr>
<tr>
<td>RLN/BL</td>
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<td>0.76</td>
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<td>5.81</td>
<td>0.70</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Superficial</td>
<td>5</td>
<td>2.34</td>
<td>53</td>
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</table>

Discussion

Outright comprehension of the surgical anatomy of RLN, including its variations, is crucial for a holistic approach to safe thyroid surgery. Full exposure to RLN is a prerequisite to avoiding nerve injury. The nerve lies more superficially in the last 2 cm of its course. Hence, this site is most vulnerable to iatrogenic lesions [16]. Anatomical landmarks may be of help in identifying the RLN intraoperatively. However, surgeons must be well versed in their consistency and reliability before using them in the operating theatre.

In our cadaveric dissections, the RLN was coursing superficial to the BL in 53 cases (88.3%), which coincides with the prevalence of superficial RLN/BL relationships noted by Asgharpour et al (88.1%) [3]. Henry et al [13] also described the superficial RLN/BL relationship as the most common (78.2%) pattern in their meta-analysis. A piercing pattern of the RLN/BL relationship was seen in 8.3% of cases, which aligned with the findings of Kaisha et al [17]. During surgical intervention, such a pattern needs scrupulous attention because of the higher risk of lesions associated with glandular traction [1, 16]. RLN lying deep to the BL was seen least commonly (3.3%). Although in such a location, it is wearisome to visualize the nerve undoubtedly during glandular manipulation, the chances of injuring it are less in most cases. The nerve escapes the area by piercing the larynx at this level. Henry et al [13] noted substantial
ethical and geographical variability in RLN/BL relationship. Most Asian studies [16, 24, 25] have reported a lower prevalence of superficial relationships (59.3%) than their North American [4], African [20], and European counterparts [6, 18]. In most cases (76.7%), we noted symmetrical RLN patterns concerning the BL. This information is crucial for surgeons performing total thyroidectomies, as when one nerve is identified in a particular location, the exact location should be searched first on the contralateral side. In a meta-analysis by Henry et al [13], the RLN/BL relationship was bilaterally symmetrical in 75.5% of cases.

The symmetrical behavior of the RLN to the BL (76.7%) was more pronounced than the symmetrical pattern (63.3%) with TEG, according to the assessment of the bilaterally symmetrical behavior of the RLN to the BL and TEG. As a result, head and neck surgeons consider the BL to be one of the most trusted landmarks in neck surgery to prevent iatrogenic RLN damage [3, 11, 28]. Our results corroborate the same notion. As a result, "the rule of thumb" is that no structure should be dissected or ligated until the RLN is found, and the BL, as a constant anatomical marker, may be utilized to find the nerve intraoperatively.

It is also crucial for the surgeons to consider the less common piercing pattern or RLN lying deep to the BL for a hassle-free procedure. The piercing pattern, where the nerve can be intricately intertwined with the BL, poses a unique peril as, in such cases, nerve fibres can easily be severed while incising the ligament during thyroidectomy [30]. For obvious reasons, such patterns are associated with the highest morbidity of nerve palsy [30]. Serpell [26] highlighted that the substantial variability in the relationship of the nerve to the BL could arise from a lack of appropriate anatomical assessment of the ligament itself [30]. They also noted that the BL comprises two fascial layers. The outer one is false, and the inner one is true. In a few instances, the RLN can be found in the deeper fibrous layer (the "true" BL) [13, 26] and can lead to fallacious reporting of the penetrating pattern of the BL. Unfortunately, most studies reporting variations in the RLN/BL relationship have not made any lucid statements about such variants. In our cadaveric study, we have considered such phenomena while reporting piercing patterns. Furthermore, Serpell suggested that a meticulous dissection of the RLN posterolaterally helps to reduce nerve traction, allowing for safe BL division and a reduction in nerve palsies [26].

Our study results revealed that the reliability of TEG as an identifiable landmark for locating RLN is less established. Only in 71.70% of cases was the nerve coursing within the TEG throughout its course. Various authors have studied the location of RLN with the TEG amongst different geographic populations. Armstrong and Hinton dissected 40 cadavers in USA and found RLN within the groove in 60.0% of cases [2]. Chen et al [8] studied 90 Chinese cadavers and located RLN within the groove in all the cases. Lang et al dissected 43 cadavers and found RLN within the groove in 37.2% of cases. Henry et al [13] dissected 40 cadaveric necks and found RLN within the groove in 68.1% of cases. As far as the Indian subcontinent is concerned, no such studies have been done to assess RLN/TEG relations. A Meta-analysis conducted by Henry et al [13] showed a pooled prevalence of 63.7% of nerves coursing within the TEG. After reviewing available literature, we believe that the RLN/TEG relationship shows ethnical and geographical differences, with Asian studies generally reporting more RLNs coursing in the TEG (75.9%) than European ones (50.9%) [13].
The location of the RLN outside the TEG ranges from anterior, anterolateral, and lateral to posterolateral. In our cadavers, it was most commonly (63.3%) located lateral to the TEG, similar to the findings of Henry et al[13]. At the same time, the meta-analysis differed concerning the location of the RLN when it was outside the TEG. Most RLNs outside the TEG (45.7%) were located anteriorly in the meta-analysis ranging from anterior to lateral [13].

The TEG is a valuable landmark for identifying the RLN. It represents an asylum to safeguard the nerve inside the groove. Operating surgeons may quickly fail to spot the nerve while lying inside the groove, but its presence can be confirmed by simple palpation [7]. This landmark has been proven reliable in identifying RLN in laparoscopic procedures of the neck [7]. In a series by Chang, the RLN was identified in 100% of laparoscopic thyroid procedures using the TEG [7].

We advocate that every time an attempt is made to identify and locate the RLN in the TEG, the course of the nerve should be traced upwards up to the level of BL. Once the BL confirms its position, surgical manipulation is to be done. We believe surgeons must stick to the dictum of "no manipulation until and unless the RLN/BL relationship is well established". However, such an identification method can get complicated due to local pathologies (e.g., large thyroid goitre) or anatomical nerve variations, such as extra laryngeal branching of the RLN. Henry et al reported that 76.6% of RLNs branch before entering the larynx [13]. In recent years, intraoperative nerve monitoring (IONM) has appeared as an alternative to identifying RLN intraoperatively. However, it has yet to be proven superior to concrete anatomical landmarks [7, 13]. That being said, IONM can be beneficial in cases where pathology does not permit these at-risk structures to be adequately visualized and identified. The use of the BL and TEG in nerve identification is valuable regardless of whether procedures are of primary or secondary nature and can provide valuable surgical information, allowing for the reduction of iatrogenic nerve injuries.

Although the anatomical relationship between RLN and ITA is primarily volatile, it still holds a position amongst head and neck surgeons as an essential landmark in identifying the nerve intraoperatively. The relationship between the artery and the nerve has been studied over the past century and several classification systems have been developed [21]. We concluded that the RLN usually ran deep to the ITA, with a prevalence of 65%. In addition, there were differences between the left and right sides of the thyroid gland, with the deep type being more common on the left, representing an occurrence of 67%. Uen et al studied 120 cadavers and reported posterior position in 65.8%, 70% being left posterior [28].

Fowler and later, Skandalakis et al [27] concluded that injury to the RLN is more common when the nerve lies anterior to or between the ITA. Surgeons should also take care when performing thyroid operations on the right side because of the predominance of the anterior configuration [10, 22]. Some studies suggest that intraoperative nerve monitoring (IONM) has not proven more effective than direct nerve visualization [9, 12]. However, when there is an anatomical variant, reoperation of the thyroid gland, or obscured pathology, IONM should be used to prevent iatrogenic injury of the RLN [23].

Henry et al (2016) reviewed multiple literatures and documented a symmetrical relationship with ITA only in 36.6% (95% CI 31.5–41.9). The current study found symmetrical bilateral relationships in 63% of
cadavers, and the difference may be attributed to population differences or smaller sample sizes [15]. Two earlier systematic reviews by Henry et al (2016) and Noussios et al (2020) presented relatively different pictures [15, 21]. Henry et al (2016) observed an asymmetrical pattern predominantly (posterior configuration) with ITA in which posterior configurations were common on the left and anterior configurations were on the right sides [13, 14]. Noussios et al (2020) found that posterior configuration was more common on both sides.

Due to the substantially higher incidence of the anterior and between patterns of the RLN/ITA connection on the right side, more caution is required during operations. In bilateral operations, symmetry must not be presumed, and the RLN must be positively recognized on both sides. The significant incidence of RLN/ITA variation must be considered while planning, exposing, and performing neck procedures [21].

The midpoint of the posterior border of the thyroid gland could be another possible landmark. Moreover, few authors have defined this landmark as TZ, which is present only in 63–78% of subjects [10, 13, 22]. Henry et al conducted a cadaveric dissection and meta-analysis to determine the relationship between TZ and RLN, the pooled prevalence of TZ was 70.2%, the majority of which were considered Grade 0 tubercles (< 1.0cm). RLN ran posteromedially to the ZT in 82.7% of cases [14]. According to Gauger et al, in 93% of the cases, the RLN was located near this landmark on the tracheal surface or buried in the glandular capsule, while in the other cases, the nerve was placed lateral to the posterior border of the gland [14].

The limited frequency and its dubious grading system makes TZ a doubtful landmark, hence to avoid such uncertainty, we have taken the midpoint of posterior border as a valid anatomical landmark and studied the topography of the RLN. Almost in all the cases (95%), RLN was travelling in the area posterior to this landmark, with an average distance of 4.95 ± 2.23 mm ranging between 2.21mm to 12.1mm. However, in a few instances (5%), it was coursing anteriorly along the gland's lateral surface, making itself vulnerable to injury during partial thyroidectomy. RLN may have a very intimate relationship with the thyroid capsule along the posterior border. This distance is thus a possible indicator in calculating the safe zone in deciding the line of incision in subtotal thyroidectomy or near-total thyroidectomy. Although the distance between the RLN and the posterior border of the thyroid is crucial for hassle-free thyroid surgery, specifically deciding the plane of incision in partial thyroidectomy, very little is mentioned in the literature. Hence, we could not compare the measured distance with previous literature.

**Limitations**

The small number of female cadavers (5) compared to males (25) did not allow us to compare our findings to study the effect of gender on the study results. Therefore, additional research, such as clinical trials, must be conducted to assess the BLs and TEG's intraoperative viability as landmarks for identifying the RLN. Only then can the actual validity of these structures as trustworthy landmarks for at-risk neural structures be established.
Conclusion

Both the BL and TEG are potentially crucial for the safeguarding of RLN. Although, in results, BL turns out to be more consistent than TEG, we propose the utilization of both these anatomical landmarks together for complication-free neck surgeries. In contrast, the midpoint of the posterior border of the thyroid turns out to be the single most consistent landmark for identifying RLN. The development of a uniform and consistent procedure, such as identifying the RLN in the TEG and tracing it upwards to the BL for confirmation, will help to preclude iatrogenic injuries and avoid complications. Confirming reliable landmarks on which to base those procedures is the first step for complication free thyroid surgery.

Declarations

Ethics approval: compliance with ethical standards

Competing interests: Authors declare no competing interests

Consent for publication: Not applicable

Availability of data and materials: All data are presented in the manuscript.

Author contributions:

A Patra: project development, Data collection, Manuscript writing

A Asghar: Project development, Literature review, Manuscript writing

P Chaudhary: Manuscript writing, editing and critical revision

KS Ravi: Manuscript writing, editing and critical revision

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References


Figures
Figure 1

Right lateral view of the dissected neck showing the RLN piercing through the ligament of Berry (LB) while lying outside the tracheophageal groove (TEG) in the lower part.
Figure 2

Left lateral view of the dissected neck showing the RLN coursing within the tracheo-esophageal groove (TEG)
Figure 3

Right lateral view of the dissected neck showing the course of the RLN in the area posterior to the midpoint (red dot) of the posterior border (white curved line joining the two poles of the gland).
Figure 4

Boxplots showing the descriptive statistics between the RLN-midpoint of posterior border of thyroid gland distance and RLN/BL
Figure 5

Boxplot showing the descriptive statistics between the RLN-midpoint of posterior border of thyroid gland distance and RLN/TEG.
Boxplot showing the descriptive statistics between the RLN-midpoint of posterior border of thyroid gland distance and RLN/ITA.