Recurrent Laryngeal Nerve

A Plexus Rather Than a Nerve?

Claudio R. Cernea, MD; Flávio C. Hojaij, MD; Dorival De Carlucci Jr, MD; Renato Gotoda, MD; Caio Plopper, MD; Felipe Vanderlei, MD; Lenine G. Brandão, MD

Objectives: To analyze the frequency of extralaryngeal branching (ELB) of the recurrent laryngeal nerve (RLN) in a consecutive series of patients undergoing thyroidectomy by the same group of surgeons during an extended period and to compare our findings with the data available in the literature.

Design: Retrospective medical record study.

Setting: Academic research.

Patients: From March 1, 1983, to September 30, 2008, 2677 patients underwent thyroidectomy. Of these, 1638 patients had surgical information about at least 1 RLN. A total of 1081 patients underwent bilateral operations. During the last 5 years of the study, intraoperative laryngeal nerve monitoring was performed in selected patients using a commercially available system.

Main Outcome Measures: Information was obtained regarding 2154 RLNs.

Results: A total of 1390 RLNs (64.53%) had ELB. Among 447 patients in whom intraoperative laryngeal nerve monitoring was used, the anterior branches usually exhibited more electrophysiologic activity.

Conclusions: Extralaryngeal branching was found in 64.53% of RLNs in this case series. In recent patients with intraoperative laryngeal nerve monitoring, electrophysiologic activity was observed in the branches, particularly the anteriorly situated ones. Recognition of this frequent anatomical configuration and meticulous preservation of all branches are of paramount importance to decrease postoperative morbidity associated with thyroidectomy.


THE RECURRENT LARYNGEAL nerve (RLN) is the main motor nerve of all intrinsic laryngeal muscles except for the cricothyroid muscle. After leaving the superior mediastinum, the RLN courses toward the larynx on the tracheoesophageal groove, keeping a close anatomical relationship with the thyroid gland, as well as with the parathyroid glands and branches of the inferior thyroid artery. Immediately after crossing the Berry ligament, the RLN enters the larynx. Because of its peculiar anatomical relationships, the RLN is vulnerable during operations involving the thyroid gland (especially in the Berry ligament, Zuckerkandl tubercle, tracheoesophageal groove, and inferior and superior thyroid poles) and during dissections of level VI lymph nodes. Several anatomical variations of the RLN may be found, further increasing the jeopardy for inadvertent injury. These include a variable relationship with the branches of the inferior thyroid artery, the nonrecurrent inferior laryngeal nerve, and extralaryngeal branching (ELB).

The relationship between the RLN and the branches of the inferior thyroid artery is inconsistent.1,2 The RLN usually courses between the 2 branches; however, it is inadvisable to use the inferior thyroid artery as an anatomical landmark to identify the RLN because of anatomical unpredictability.

The most dangerous anatomical variation associated with complication risk during thyroidectomy is the nonrecurrent inferior laryngeal nerve. In 1823, Stedman was the first author to describe this anomaly.3 Because of an embryogenetic defect, the origin of the right subclavian artery is abnormal. In this disorder, there is no traction on the inferior laryngeal nerve, which then exits the vagus nerve directly toward the larynx. Conversely, the embryologic vascular anomaly on the left side (absence of the ductus arteriosus) is incompatible with survival of the fetus. Therefore, this variation is only found on the right side unless the patient has situs

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inversus totalis. In 1988, Henry et al reported 33 cases of nonrecurrent inferior laryngeal nerves, 2 of which were located on the left side in patients with complete visceral inversion. The largest series in the literature to date was published by the same group 15 years later, comprising 101 nonrecurrent inferior laryngeal nerves that were observed during thyroidectomies and carotid endarterectomies.

Fewer publications specifically address the possibility of ELB of the RLN. Within the larynx, individual branches correspond to the intrinsic laryngeal muscles. However, this division may occur before the RLN enters the larynx near the Berry ligament or the inferior thyroid artery, increasing the possibility of iatrogenic damage to 1 or more of these branches. Moreover, its injury usually causes permanent paralysis of the corresponding intrinsic laryngeal muscle. Despite the scarcity of publications about this subject, ELB of the inferior RLN is a frequent finding. Authors have reported it in most of their patients undergoing thyroidectomy. In 1957, Gregg published a meta-analysis of the literature that included 669 RLNs, 61.3% with ELB. Katz described 721 RLNs, 58.3% with ELB. In a subsequent publication by the same group that included 1177 RLNs, Katz and Nemiroff reported 63.9% with ELB. Other authors have published the findings of clinical series of RLNs with proportions of ELB ranging from 14.63% to 76%. Yalcın et al performed an anatomical study about the branching of the RLN before it enters the larynx. They dissected 49 cadavers, including 96 sides of the neck. In 85% of the dissections, the RLN divided before entering the larynx. In 7% of the dissections, there were 3 branches.

The objectives of this study were to analyze the frequency of ELB of the RLN in a consecutive series of patients undergoing thyroidectomy by the same group of surgeons during an extended period and to compare our findings with the data available in the literature.

**METHODS**

This was a retrospective medical record study of a consecutive case series of 2677 patients who underwent thyroidectomy from March 1, 1983, to September 30, 2008, by the same surgical team (C.R.C., F.C.H., D.D.C., R.G., C.P., F.V., and L.G.B.). Of these, 1638 patients had surgical information about at least 1 RLN. A total of 1081 patients underwent bilateral thyroidectomies. Using a template to document the findings, we recorded demographic data, surgical extent and pathologic findings, and information regarding ELB of the RLN (including the number of branches when available). During the last 5 years of the study, intraoperative laryngeal nerve monitoring was performed in selected patients using a commercially available system (Xomed NIM System; Medtronic USA, Inc, Jacksonville, Florida). No statistical method was applied, because no population was compared within the study. This study received institutional review board approval.

**RESULTS**

There were 1256 female patients (76.68%) and 382 male patients (23.32%) (age range, 11-84 years [mean age, 47.3 years]. Most patients (61.6%) were of white race/ethnicity. Information regarding 2154 RLNs was obtained. Among these, 1390 RLNs (64.5%) had ELB. The number of branches was documented in 1117 RLNs (80.4%): 982 (87.9%) had 2 branches (Figure 1), 133 (11.9%) had 3 branches (Figure 2), and 2 (0.2%) had 4 branches (Figure 3).

During the last 5 years of the study, intraoperative laryngeal nerve monitoring was used in 447 patients. Of these, 250 patients had information about at least 1 RLN. Among 388 RLNs, 241 (62.1%) had ELB. The anterior branches usually exhibited more electrophysiologic activity on stimulation. Although not the main focus of this study, 14 nonrecurrent laryngeal nerves were found, all on the right side.

**COMMENT**

Thyroidectomy was considered a very dangerous operation until the end of the 19th century because of unacceptable morbidity and mortality. Samuel Gross, perhaps the most respected surgeon of that time, made the following statement in 1866:

Can the thyroid gland when in the state of enlargement be removed with a reasonable hope of saving the patient? Experi-
Because of its strange direct transverse course toward the nonrecurrent inferior laryngeal nerve on the right side, to find the RLN in its normal position may overlook a laryngeal nerve is an especially dangerous anatomical variation. The nonrecurrent inferior laryngeal nerve and a topical RLN was first described by Sanders et al and later confirmed by Katz and Nemiroff. It is somewhat difficult to explain this anomaly in light of the current embryologic knowledge about the genesis of the RLN. The presence of neural anastomoses between the RLN and the middle cervical ganglion, as suggested by Steinberg et al, may elucidate this apparent contradiction.

In contrast to the rarity of the nonrecurrent inferior laryngeal nerve, ELB of the RLN is a common anatomical variation. Surprisingly, the first mention about the possibility of division of the RLN before entering the larynx appeared only in the second half of the 20th century. In 1957, Gregg published a meta-analysis of the literature that included 669 RLNs, 61.3% with ELB. Confirming this observation, Katz described 721 RLNs, 58.3% with ELB. A follow-up study included a larger series of RLNs, 63.9% with ELB. Thereafter, some controversial results were published.

Hisham and Lukman evaluated 502 RLNs in a clinical series of 325 thyroidectomies. The RLN was clearly identified in 97.8% of dissections; 33.4% had 2 branches and 0.6% had 3 branches.

Page et al reported their findings in a clinical series of 251 patients undergoing thyroid surgery. The RLN was divided on the right side in 23.8% of women and in 21.6% of men. The RLN was divided on the left side in 15.3% of women and in 14.6% of men. They concluded that there were proportional differences in ELB of the RLN related to side (more common on the right side) and sex (slightly more frequent among women).

Wang et al published the findings of a small clinical series of 56 patients who underwent thyroidectomy, in whom 63 RLNs were identified. Bifurcation was present in 48 RLNs (76%).

Beneragama and Serpell analyzed 213 RLNs in 137 patients who underwent thyroid or parathyroid operations. Seventy-seven RLNs (36.1%) bifurcated or trifurcated before entering the larynx. Bifurcations were more common on the right side (43.6%) than on the left side (28.1%) \((P = .05)\). Trifurcations were seen in 8 RLNs, 7 on the right side and 1 on the left side \((P = .05)\). Bilaterally branched RLNs were observed in 14 of 77 patients (18%) undergoing a bilateral procedure. The authors also evaluated the median distance from the cricothyroid joint to the point of division, which was 18 mm on the right side and 13 mm on the left side.

Curiously, the highest percentages of ELB of the RLN were observed in series involving anatomical cadaver dissection. Yalcın et al performed an anatomical study on the branching of the RLN before entering the larynx. They dissected 49 cadavers, comprising 96 aspects of the neck. In 82 dissections, the RLN divided before entering the larynx. In 7 dissections, there were 3 branches. In a follow-up study, the same group expanded their experience to 110 RLN dissections, observing 93.6% with ELB.

To our knowledge, the present study represents the largest published case series focusing specifically on ELB of the RLN. Of 2154 RLNs, 1390 (64.5%) had ELB. This proportion was similar to the results obtained by Gregg (61%), Katz (58%), Katz and Nemiroff (63%), and Wang et al (76.2%), but it was higher than the results obtained by Page et al (23.81% of women and 21.62% of women and 21.62% of men).

At the end of that century, Emil Theodor Kocher established the technical principles of thyroid surgery, transforming it into a safe procedure. The main complications that can occur during or after a thyroidectomy are upper airway obstruction, unaesthetic scars, injuries to the laryngeal nerves, and hypoparathyroidism.

The first description of the RLN is attributed to Galen (second century BC): “a nerve that descended from the brain to the heart, then reversed the course and ascended to the larynx and caused the vocal cords to move.” Despite this ancient description of the RLN, it was only after the landmark publications by Kocher that morbidity associated with thyroidectomy approached safe levels. A cornerstone of the recommended surgical technique of thyroidectomy is the active search for and positive identification of the RLN at the beginning of the ipsilateral thyroid lobectomy. According to most published series, visual control and gentle dissection of the RLN are imperative. To minimize the complication rate, the head and neck surgeon must be aware of the possible anatomical variations of the RLN, including the variable relationship with the branches of the inferior thyroid artery, the nonrecurrent inferior laryngeal nerve, and ELB. The nonrecurrent inferior laryngeal nerve is an especially dangerous anatomical variation for obvious reasons. The surgeon who always expects to find the RLN in its normal position may overlook a nonrecurrent inferior laryngeal nerve on the right side because of its strange direct transverse course toward the larynx. However, this anatomical variation is exceedingly uncommon. Its reported incidence ranges from 0.3% to 1.5%. The coexistence of a nonrecurrent inferior laryngeal nerve and a topical RLN was first described by Sanders et al and later confirmed by Katz and Nemiroff. It is somewhat difficult to explain this anomaly in light of the current embryologic knowledge about the genesis of the RLN. The presence of neural anastomoses between the RLN and the middle cervical ganglion, as suggested by Steinberg et al, may elucidate this apparent contradiction.

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men on the right side) and by Beneragama and Serpell12 (36.2%) (Table). A possible explanation for the discrepancy could be the use of magnifying loupes. We used 2.5× wide-angle loupes up to 1987 and 3.5× wide-angle loupes thereafter. Although it was impossible to obtain information about the use of magnification in the present study because of its retrospective nature, we believe that adding magnification has markedly improved our ability to detect ELB, especially around the area of the Berry ligament (Figure 4).

Regarding the number of branches, most divided RLNs had 2 branches, in concurrence with the findings by Hisham and Lukman9 and by Beneragama and Serpell,12 but the proportion of trifurcations in the present study (11.90%) was higher, and 2 RLNs with 4 branches were identified. Again, perhaps the addition of magnifying loupes might have enhanced the identification of 3 or more branches.

The use of intraoperative laryngeal nerve monitoring during thyroidectomy has been described and adopted by some surgeons.24,25 In a series of 579 patients undergoing thyroidectomy or parathyroidectomy, Serpell et al26 used intraoperative laryngeal nerve monitoring to document the position of the motor fibers of 176 RLNs. Forty-one (23.3%) were bifurcated RLNs. In all 41 cases, motor fibers for adduction and abduction of the vocal folds were located exclusively in the anterior branches of the RLN. The authors stated that great care is required following presumed identification of the RLN to ensure that no unidentified anterior branch is inadvertently cut. During the last 5 years of the present study, intraoperative laryngeal nerve monitoring was used in 241 RLNs with ELB. The anterior branch usually exhibited more electrophysiologic activity on stimulation, confirming the observation by Serpell et al.26 However, Sasaki and Mitra27 suggested that posterior branches of the RLN may also provide innervation to the cricoarytenoideus muscle, interfering with the swallowing process and with phonation.

What would be the functional consequences of inadvertent sectioning of a nonrecognized branch of the RLN? In other words, would the presence of ELB of the RLN have an effect on surgical morbidity associated with thyroidectomy? Casella et al28 specifically addressed this issue. They prospectively assessed the prevalence of ELB of the RLN and its effect on the incidence of postoperative transient or permanent nerve palsy in 115 patients with a total of 195 RLNs. Thirty-six of 195 RLNs (18.5%) showed ELB. There were 4 cases of unilateral permanent RLN palsy (2.1%), 8 of unilateral transient nerve palsy (4.1%), and 1 of bilateral transient RLN injury (0.6%). The comparative analysis of postoperative outcomes between branched and nonbranched RLNs revealed that the anatomical variation was more frequently associated with unilateral permanent RLN palsy (relative risk, 13.25; 95% confidence interval, 1.42-123.73; \( P = .02 \)) and with unilateral transient RLN palsy (7.36; 1.84-29.4; \( P = .006 \)). Branched RLNs represented a risk factor for transient and permanent RLN palsy after surgery. The authors emphasized that awareness of this anatomical variation and its routine investigation are essential during thyroid surgery to minimize outcomes of postoperative RLN injury.

In conclusion, in the present case series comprising 2154 RLNs, the frequency of ELB was 64.53%. This result was within the reported range in the literature (19%-85%). A possible reason for this wide range could be the use of magnification. In our experience and in most previously published series, the finding of a single RLN is the exception rather than the rule. Especially near the

### Table. Frequency of Recurrent Laryngeal Nerves (RLNs) With Extralaryngeal Branching (ELB) in Published Series

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of RLNs</th>
<th>ELB, %</th>
<th>Type of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregg,6 1957</td>
<td>669</td>
<td>61.3</td>
<td>Meta-analysis</td>
</tr>
<tr>
<td>Katz,7 1986</td>
<td>721</td>
<td>58.3</td>
<td>Clinical</td>
</tr>
<tr>
<td>Katz and Nemiroff,8 1993</td>
<td>1177</td>
<td>63.9</td>
<td>Clinical</td>
</tr>
<tr>
<td>Hisham and Lukman,9 2002</td>
<td>502</td>
<td>34.0</td>
<td>Clinical</td>
</tr>
<tr>
<td>Page et al,10 2003</td>
<td>251</td>
<td>14.6-23.8</td>
<td>Clinical</td>
</tr>
<tr>
<td>Wang et al,11 2005</td>
<td>63</td>
<td>76.2</td>
<td>Clinical</td>
</tr>
<tr>
<td>Beneragama and Serpell,12 2006</td>
<td>213</td>
<td>36.2</td>
<td>Clinical</td>
</tr>
<tr>
<td>Yalcın et al,13 2006</td>
<td>96</td>
<td>85.4</td>
<td>Anatomical</td>
</tr>
<tr>
<td>Yalcın et al,14 2008</td>
<td>110</td>
<td>93.6</td>
<td>Anatomical</td>
</tr>
<tr>
<td>Present study</td>
<td>2154</td>
<td>64.5</td>
<td>Clinical</td>
</tr>
</tbody>
</table>

Figure 4. Adding magnification markedly improves the ability to detect extralaryngeal branching, especially around the area of the Berry ligament. A, Left recurrent laryngeal nerve with no visible branching. B, A small posterior branch is visualized (arrow) only with magnification.
Berry ligament, caution must be exercised when dissecting the RLN to avoid injuries to its branches, particularly to the anterior ones.

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Author Contributions: Dr Cernea had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Cernea, Hojaij, and Brandão.

Acquisition of data: Cernea, Hojaij, De Carlucci, Gotoda, Plopper, Vanderlei, and Brandão. Analysis and interpretation of data: Cernea, Hojaij, and Brandão. Drafting of the manuscript: Cernea, Hojaij, and Brandão. Critical revision of the manuscript for important intellectual content: Cernea, Hojaij, De Carlucci, Gotoda, Plopper, Vanderlei, and Brandão. Administrative, technical, and material support: Cernea, Hojaij, and Brandão. Study supervision: Cernea, Hojaij, and Brandão.

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