Revisited anatomy of the recurrent laryngeal nerves

Guglielmo Ardito, M.D.\textsuperscript{a,*}, Luca Revelli, M.D.\textsuperscript{a}, Lucia D’Alatri, M.D.\textsuperscript{b}, Valentina Lerro, M.D.\textsuperscript{a}, Maria Lavinia Guidi, M.D.\textsuperscript{c}, Francesco Ardito, M.D.\textsuperscript{a}

\textsuperscript{a}Department of Surgery, Catholic University of Sacred Heart, Rome, Italy
\textsuperscript{b}Department of Otolaryngology, Catholic University of Sacred Heart, Rome, Italy
\textsuperscript{c}Department of Anesthesiology, Catholic University of Sacred Heart, Rome, Italy

Manuscript received February 27, 2003; revised manuscript July 4, 2003

Abstract

Background: The most frequent postthyroidectomy complication is recurrent laryngeal nerve (RLN) damage with subsequent vocal cord palsy.

Methods: We have undertaken an intraoperative study aimed to determine the course, distribution, and RLN’s anatomical relationships with adjacent structures. Only its identification and its careful exposure allow prevention of iatrogenic injuries.

Results: The RLN was always routinely exposed and identified in 1,543 thyroidectomies. All patients underwent laryngoscopic evaluation before surgery and at the time of discharge. A total of 2,626 RLN were observed. The number of nerves exposed to risk was 673 (25.6%). In the whole series, of 2626 nerves controlled, there were 11 (0.4%) permanent palsies.

Conclusions: Our study confirms that damage to the RLN or to one of its branches may be avoided only by identification and careful exposure of the nerve itself. An experienced surgeon with good knowledge of the anatomy of the RLN and its anatomical variations is required for uncomplicated treatment of thyroid disease. © 2004 Excerpta Medica, Inc. All rights reserved.

Keywords: Recurrent laryngeal nerve; Anatomy; Thyroid surgery; Thyroidectomy; Nerve palsy

A correct knowledge of the current concepts on thyroid surgery and the recognition of the variations in regional neurovascular anatomy is essential for uncomplicated treatment of thyroid disease. Since the most frequent postthyroidectomy complication is recurrent laryngeal nerve (RLN) injury, in our opinion, the routine exposure and preservation of this important structure should become a standard procedure during thyroidectomy; therefore, an accurate knowledge of the anatomy of the RLN and its anatomical abnormalities or variations, is fundamental for the thyroid surgeon.

In an attempt to improve our results of thyroidectomy we have undertaken a careful study to determine the course and distribution of RLN, making records and photos of its major anatomical variations. This report covers 10 consecutive years (1990 to 2000) of identification of the RLN and proposes it as an initial step in performing safe thyroid surgery.

Galeno of Pergamo [1] was the first anatomist to describe the RLN as a branch of a cranial nerve. Vesalio [2] and Willis [3] described the anatomy of the larynx and of the RLN as they are now found in standard anatomical text books [4]. In 1923 Lahey [5] emphasized, in the performance of thyroid surgery, the importance of RLN and developed a standard technique of its identification and exposure.

The RLN carries motor, sensory, and parasympathetic fibers. The nerve divides into an internal branch, which supplies sensation to the vocal cords and subglottic region, and an external branch, which provides motor function to four intrinsic laryngeal muscles except the cricothyroid muscle which is innervated by the external lateral branch of the superior laryngeal nerve. These four muscles are the thyroarytenoid, the lateral and posterior criocarytenoid, and the transverse and oblique arytenoid. Prior to entering the larynx the nerve sends branches to the inferior constrictor and cricopharyngeus muscles.

The usual course of the RLN differs in the two sides of
the neck. The two nerves arise from the vagus in the superior part of the thorax. The right nerve crosses the undersurface of the right subclavian artery and ascends in the neck aiming at the right tracheoesophageal groove. It may cross superficially or deep to the inferior thyroid artery or between its branches. The left recurrent nerve hooks around the arch of the aorta and ascends more vertically and deeper in the left tracheoesophageal groove. It may have a similar relationship to the left inferior thyroid artery, as does the right nerve. Both nerves enter the larynx at the cricothyroid articulation through the fibers of the inferior constrictor muscles of the pharynx.

During its ascent from the thorax to the larynx numerous anatomic variations may be encountered. Many studies report that nerves usually divide into two or more branches when approaching the inferior constrictor muscle before entering the larynx. Rustad [6], in his autopsy studies, noted that 43% of RLN, divided into one or more branches on both sides and the anterior division may pass either anteriorly or posteriorly to the cricothyroid articulation and then, coursing along the cricoarytenoid muscle innervates all the intrinsic laryngeal muscles with the exception of the cricothyroid. The posterior branch usually innervates the posterior cricoarytenoid and arytenoides muscles.

In his surgical experience, Nemiroff [7] confirmed that approximately 40% of RLN divide into two branches and occasionally more, before entering in the larynx and this occurrence cannot be considered an anatomic rarity. The distance of bifurcation or trifurcation from the inferior border of the cricoid cartilage ranges from 0.6 to 4.0 cm. Extralaryngeal branches can take place at any point, peripheral to the origin of the main trunk of the nerve from the vagus, but branching is uncommon below the level of the inferior thyroid artery. In the cases in which the main trunk remains unbranched extralaryngeally, it can be found entering the larynx behind the cricothyroid articulation.

The course of the RLN frequently varies despite normal anatomy, or as consequence of congenital vascular anomalies or distortion of regional anatomy by extension of goitre by neoplasm or inflammation. An extremely important variation of the pathway of the RLN depends on congenital vascular alterations. Rarely (0.6%), in presence of aberrant right subclavian artery, arising from the aorta after the left subclavian artery has given off, the right recurrent laryngeal nerve passes directly from the vagus in the neck towards the larynx and does not recur around subclavian artery. This uncommon anatomic variation of the RLN that makes it highly susceptible to surgical injury is known as “nonrecurrent” inferior laryngeal nerve [8–11]. The possibility of nonrecurrence of the inferior laryngeal nerve on the left side is a very rare exception and it is reported in an autopsy case (Berlin, 1935) [12] and in two clinical cases (Henry, 1988) [10] associated with a right-sided aorta and a left retroesophageal subclavian artery.

When approaching the inferior pole of the gland, the RLN may be traversed by the ITA (inferior thyroid artery) or may pass between the arterial ramifications. Steinberg [13] reported that the RLN ascends in the neck between the branches of the inferior thyroid artery in about 6.5%, posterior to the inferior thyroid artery in 61.5%, and anterior to the inferior thyroid artery in 32.5%. Marginal or minimal differences are described but all the authors just quoted agree that the nerve, most commonly, lies deep to the artery.

Interesting is, also, the relationship of the RLN to the tracheoesophageal groove. It has been reported by Hunt et al [14] that on the right side the RLN ascending in the neck is located in the tracheoesophageal groove 65% of the time, whereas on the left it is there 77% of the time. It was found that the nerve is located lateral to trachea 33% of the time on the right and 22% on the left. Rarely it ascends anterolateral to the trachea and, consequently is widely exposed to surgical injury.

Regarding the relationship of the RLN to the thyroid gland it has been reported that no nerve or nerves were found to enter the substance of the gland. It occurs that the nerve may be attached to the back of the pretracheal fascia but never penetrates the fascia.

In many cases (Hunt, 50%) [14] the RLN is embedded in the posterior suspensor ligament of Berry [15] and during glandular traction the nerves may be pulled forward and are therefore vulnerable to injury.

### Patients and methods

A prospective study involving 1,543 consecutive thyroidectomies was performed between January 1990 and December 2000 at Catholic University, Department of Endocrine Surgery. The patients ranged in age from 8 to 82 years (mean age 47) and were 1,204 women (78%) and 339 men (21.9%).

There were 1,083 patients scheduled for total extracapsular thyroidectomy and 460 for lobectomy (259 right lobectomies and 201 left lobectomies). Total thyroidectomy was performed in 495 patients for multinodular goiter, in 70 for recidivous goiter, in 63 for Graves’ disease, in 198 for toxic nodular goiter, and in 257 for thyroid cancer. Hemithyroidectomy was performed in 449 patients for thyroid adenomas, and in 11 patients for thyroid cancer. All patients underwent laryngoscopic evaluation before surgery and at the time of discharge.

Eight hundred seven patients operated on from January 1990 to September 1996 underwent indirect laryngoscopic evaluations, whereas 636 patients operated on from October 1996 to the end of December 2000 had a videolaryngostroboscopy with stiff optical fibers at 70 degrees for the appraisal not only of the laryngeal morphology and mobility but also of the widthness and symmetry of the vibratory mucous waves and a spectrographic analysis with a narrow side filter. The videolaryngostroboscopy was performed with Kay RLS 9100 Rhinolaryngeal Stroboscope (Kay Eleuretrics Corp, New York), while the recording and the
Analysis of voice signals were performed with a computer assisted Kay CSL 4300 B Spectrograph (Kay Eleuretrics Corp). All patients were operated on by the same surgeon, and the RLN nerves were routinely exposed and identified using the standard technique developed by Lahey [16].

All nerves have been measured from the inferior border of the cricoid cartilage, which is considered a standard anatomic landmark. We have tabulated records of all nerves and have described their anatomical variations documented by intraoperative photos.

Results

A total of 2,626 RLNs were observed: 1,342 on the right side and 1,284 on the left side. Before entering the larynx 722 nerves were unbranched (27.6%) along all its course from the point of identification to its penetration into the larynx. In 1,891 cases, the nerve divided in two or more branches at the third superior of its cervical course. The distance of bifurcation from the inferior border of the cricoid cartilage ranged from 0.3 cm to 4.5 cm. The relative number, size, and course of divisions were noted.

We observed 1,856 nerves (70.6%) bifurcated and, of these, 911 (49%) were on the left, while 945 (51%) were on the right side. Twenty-three instances of trifurcation occurred: 14 on the left side (Fig. 1), and 9 on the right side. The remaining 14 nerves divided in small branches.

In its course to the larynx, the nerve appeared as a single trunk at its third inferior except in 4 cases of 2,626 in which appeared from mediastinum as two trunks until entering the larynx (Fig. 2). Four nerves, on the left side, appeared from the third inferior of the larynx in a fanwise fashion (Fig. 3).

The relationships between the RLN and the tracheoesophageal groove were respectively: 581 right nerves (61.4%) were located in the tracheoesophageal groove, 358 right nerves (37.8%) were located lateral to the trachea, 6 right nerves (0.6%) were anterolateral to the trachea; 614 left nerves (67.3%) were located in the tracheoesophageal groove, 282 left nerves (31%) were located lateral to the trachea, 15 left nerves (1.6%) were anterolateral to the trachea.

The relationships between the RLN and the inferior thyroid artery on both sides were as follows: 113 nerves (12%) laid in front of the right inferior thyroid artery; 576 nerves (61%) deep to the right inferior thyroid artery and 256 nerves (27%) between the branches of the right thyroid artery; 18 nerves (1.9%) in front of the left inferior thyroid artery; 706 nerves (77.4%) deep to the left inferior thyroid artery; and 187 nerves (20.5%) between the branches of the left inferior thyroid artery. In 3 patients the branches of the inferior thyroid artery involved the recurrent laryngeal nerve in spiraloid direction, in 2 cases on the right side (Fig. 4) and in 1 case on the left side.

Five cases of a "nonrecurrent" laryngeal nerve were noted on the right side. In all cases the nerve passed directly from the vagus nerve to reach the larynx by passing deep to the lateral border of the thyroid lobe (Fig. 5).

We observed, at preoperative laryngoscopic evaluation, 12 patients of 1,543 with a unilateral palsy of the vocal cord (10 previous hemithyroidectomies, 2 immersed goiters) and 62 of 1,543 with benign neoformation of the vocal fold (36 chronic oedema of the vocal folds, 8 nodules, 18 polypuses). All these patients had a preoperative disphony.

During postoperative laryngoscopic evaluation (second day) 78 patients of 1,543 presented a unilateral cordal palsy (46 on the right side and 32 on the left one) that in 9
patients, who did not complain of disphony, presented only minimal modification of the spectrographic analysis. After 12 months from surgery, at last follow-up, was documented only in 11 patients the presence of palsy (in 4 of whom a total thyroidectomy for invasive carcinoma it has been executed). The authors agree that a palsy that remains after 12 months is to be considered permanent. Videolaryngoscopic findings never demonstrated any alteration of the vibratory mucous waves related to an isolated monolateral lesion of the external branch of the higher laryngeal nerve.

In our surgical experience we have never had complications such as bilateral palsy of the vocal folds.

Comments

In 1970 Riddel [17] reported that “thyroidectomy is such a precise operation” and stressed that permanent laryngeal palsy is a surgical tragedy comparable to a surgically induced facial paralysis. Vocal cord paralysis represents the main damage of the thyroid surgery, and for this reason it requires an experienced surgeon with accurate knowledge of neurovascular neck anatomy. According to us, the only safeguard against recurrent laryngeal nerve damage, when performing a thyroidectomy, consists of identifying rather than avoiding the nerve. Although there is still some controversy, identification of the nerve is usually proposed as an initial step in thyroidectomy.

Many surgeons agree that the careful dissection of the recurrent laryngeal nerve by an experienced surgeon, as opposed to an inexperienced one, accounts for the variation in rate of occurrence of vocal cord paralysis.

The first routine pattern for identifying the nerve is to find the inferior thyroid artery used as an anatomic marker. However, because of the numerous variations of this neurovascular relationship altered also by pathologic conditions of the gland, identification of the artery does not assure consequent identification and preservation of the recurrent laryngeal nerve. Meticulous hemostasis and delicate technique are required and, once found, the nerve with all the identified branches must be followed superiorly through the entire course, until it enters the larynx.

It is necessary to stress that the identification of a recurrent nerve trunk does not represent the nerve in its entirety.

It is wrong and unnecessary to dissect or strip the nerve of its ensheathing fascia. Injury to the nerve usually results from suturing or crushing or by stretching if too much traction is exerted on the gland. If the nerve has not been found inferiorly it is justifiable to search for it in the upper part of the gland using as landmark the posterior suspensory ligament of Berry or the inferior corn of the thyroid cartilage, which can be located by palpation. It must be clear that the recurrent nerve should be identified through its entire course prior to completing the thyroidectomy. If RLN is not found in its normal position, an experienced surgeon must take into consideration the possibility of the rare anomaly defined as nonrecurrent laryngeal nerve (5 cases in our experience) and must investigate the vagus to exclude its presence.

The most common site of injury to the nerve, when performing thyroidectomy, is the area of the Berry ligament where the nerve enters the larynx. Damage may be caused for two reasons: first of all, during glandular traction, embedded nerve fibers may be pulled forward and are thus vulnerable to injury; second, the hemostatic stitches, used to suture the remnant gland, may enclose the nerve and therefore damage it.

Excessive traction must be avoided in order to safeguard the nerve. A total extracapsular thyroidectomy must be performed. This offers the advantage of a bloodless field and allows excellent visualization with identification and preservation of the nerve until entering the larynx, rendering unnecessary the apposition of stitches, otherwise the stitches are always very visible. Another area at increased risk is the lower pole of the gland; in this area, in fact, the nerve may be included in the ligature of the inferior thyroid veins. This can happen especially if a mass ligature is used for securing the veins and particularly when the nerve is anterolateral to the trachea. For this reason the nerve should first be found and then the veins tied.

Finally, an experienced surgeon must be careful about
hemorrhage, which is the most dangerous agent that predisposes to damage.

Patients with toxic goiter must be brought to an euthyroid state preoperatively, and meticulous hemostasis must be employed because the thyroid gland is a highly vascular and delicate organ.

In the current series all thyroidectomies were performed by the same surgeon and recurrent laryngeal nerves have been always identified. The permanent palsy rate has been 0.7% (11 patients of 1,543) or 0.4% (11 permanent injuries of 2,626 nerves exposed), but in our opinion if we had not carefully exposed the recurrent laryngeal nerves in all patients during thyroidectomy, especially in those at risk, we should have had, certainly, a higher palsy rate. In fact those nerves we have reported as being lateral to the trachea, and especially those anterolateral to the trachea, were at extreme risk and therefore quite vulnerable if we had failed to identify the nerve.

In particular great jeopardy are nerves with congenital anatomic variations in their position so called nonrecurrent nerves. Our series include 5 such observations in 1,342 visualized right recurrent laryngeal nerves during 1,543 thyroid operations: an incidence of 0.37% on the right side. When the right recurrent cannot be found, it is necessary to identify the vagus and to follow it upward so it may likely appear in the nonrecurrent location. Three nerves were found to roll up in spiral manner between the branches of the inferior thyroid artery. These last cases are another example of an anatomical variation that may put at risk the nerve if it is not visualized carefully.

In conclusion, we believe that a correct technique of thyroidectomy requires routine direct visualization and identification of the recurrent laryngeal nerves. Only careful exposure of the recurrent nerve allows its subsequent protection and results in less nerve damage.

References