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Preservation of Laryngeal Nerves during Thyroidectomy

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Abstract: ***The recurrent laryngeal nerve (RLN) provides motor innervation to the abductor and adductor muscles of the vocal cord, whereas the external branch of the superior laryngeal nerve (EBSLN) provides motor innervation to the cricothyroid muscle, which is the tensor muscle of the vocal cord. Both the RLN and the EBSLN are anatomically close to the thyroid and are therefore at risk of injury during thyroidectomy. These 2 laryngeal nerves must be carefully preserved during surgery to ensure that the function of the vocal cord is not impaired. Currently, complete exposure of the RLN during thyroidectomy is accepted as the gold standard method for the preservation of RLN. Sufficient knowledge of surgical anatomy, clinical experience, and meticulous surgical techniques are key factors in the identification and safe dissection of the RLN. During a thyroidectomy, the RLN can be identified using four different approaches, depending on the type of thyroid growth and choice of the surgeon: There are lateral, inferior, superior, and medial approaches.***

Keywords: thyroidectomy, laryngeal nerves, vocal cord, surgery preservation, surgical techniques

1. Introduction

The vocal cords are structures that perform very important tasks, including mainly the formation of sound and keeping the airway open during respiration. The intrinsic laryngeal muscles are responsible for movements of the vocal cords. The recurrent laryngeal nerve (RLN) provides motor innervation to the abductor and adductor muscles of the vocal cord, whereas the external branch of the superior laryngeal nerve (EBSLN) provides motor innervation to the cricothyroid muscle, which is the tensor muscle of the vocal cord. (1) In this context, both the RLN and EBSLN are at risk of injury during thyroidectomy due to their close vicinity with thyroid gland. Therefore, both of these laryngeal nerves must be carefully preserved during surgery in order to prevent impairment of vocal cord functions. (2) In this article, the methods of preservation of the RLN during thyroidectomy are discussed.

2. Anatomy

Recurrent Laryngeal Nerve

Anatomical Course of the Recurrent Laryngeal Nerve

As one of the important branches of the vagus nerve, the RLN innervates the larynx via its motor, sensory, and parasympathetic fibers. (3) The anatomical course of the RLN is different on the right and left side. The right RLN, which arises from the vagus nerve at the point where the brachiocephalic artery is divided into 2 branches, rotates backward around the right subclavian artery and advances toward the tracheoesophageal groove after passing behind the carotid artery at an angle of 15° to 45° with the trachea. The left RLN arises from the vagus nerve at the level of the ligamentum arteriosum and turns backward from the front aspect of the aortic arch and reaches the tracheoesophageal groove from the medial to the left common carotid artery. Because the angle between the left RLN and the trachea varies between 0° and 30°, it is localized deeper than the right RLN and communicates with the tracheoesophageal groove more inferiorly. Furthermore, the left RLN is approximately 2 times longer than the right RLN due to different levels of origin from the vagus nerve.

One of the important structures associated with the RLN is the inferior thyroid artery (ITA), which may be located in front of or behind this artery or branches or may pass through its branches. The RLN, which usually follows the same anatomical route on both sides after passing the level of the ITA usually comes close to the Zuckerkandl tubercle (ZT) then to the Berry ligament; therefore, the risk of injury to RLN increases in this area. (4, 5)

Non - Recurrent Laryngeal Nerve: The nerve arising from the upper part of the vagus rarely reaches the larynx without turning around the main vessels. This anomaly is defined as non - recurrent laryngeal nerve (non - RLN) and was found on the right side in 0.7% of the cases in the clinical series and 1.4% in cadaver studies according to a recent meta - analysis. On the left side, non - RLN is very rare and is associated with situs inversus. (6)

Extralaryngeal Branches of the Recurrent Laryngeal Nerve: Extralaryngeal branching of RLN is not rare. The RLN may mostly divide into branches at the most distal 2 cm. In a recent meta - analysis involving 28.327 RLNs, (extralaryngeal) branching was determined in approximately 39.2% of cases intraoperatively and 73.3% in cadaver studies. (7) Extralaryngeal branching may be unilateral or bilateral. (8, 9)

Zuckerkandl Tubercle: The Zuckerkandl Tubercle (ZT) is considered to be the fusion point of the ultimabranchial body (lateral thyroid body) and the median thyroid, and may become prominent, usually growing posteriorly. (10) It is classified as grade 1 if it is observed as a consolidation of the lateral margin of the thyroid lobe, as grade 2 if it is smaller than 1 cm, and grade 3 if it is greater than 1 cm.63%–77% of thyroidectomies were reported to have an enlarged ZT, and it was found that the RLN mostly (93%) courses medially and rarely, (7%) laterally to the ZT. (11)

Berry Ligament: The RLN courses between 2 fascial structures after passing immediately cranially to the ITA. The

first of these structures is the superficial vascular fascia covering the upper aspect of the RLN, which is observed when the lobe is rotated anteromedially during thyroidectomy. It contains the delicate tertiary artery, branches of veins of the thyroid gland, including the ZT and the upper parathyroid gland. In other words, it covers the RLN from the lateral aspect. When this structure is opened, the RLN becomes visible in the tracheoesophageal groove. At approximately the last 2 cm of the RLN, the real Berry ligament, a deep fibrous facial layer medial to the RLN, appears. (12) The Berry ligament of the thyroid is a suspensory ligament formed by the consolidation and thickening of the pretracheal fascia, and it allows a limited area of the posteromedial and posterolateral regions of the thyroid to be attached to the cricoid cartilage and the first 2 tracheal rings. (3, 13) The median length of the true ligament between the thyroid and trachea is 8 to 11 mm, its thickness is 2 to 7 mm, the distance between the middle of the trachea and the ligament is 10 to 20 mm, and the distance between the site of attachment to the cricoid cartilage and the entry of the RLN is 1.9 mm in average. (13) The vertical length of the ligament was calculated considering the measurements reported by Kim et al. (14) Taking into account the length of the tracheal ring and the distance between rings, the vertical length was calculated as 11.4 mm for females and 14.1 mm for males. However, the topographical relationship between the RLN and the Berry ligament can be different, depending on the point of view.

It can be said that RLN is at the inferior or posterior aspect of the ligament when the lateral approach is applied and at the posterolateral aspect of the ligament when the medial approach is applied. However, the expression of RLN coursing along the lateral side of the ligament is generally accepted.

When the Berry ligament comes close to the thyroid, i. e., when it adheres to the posteromedial and posterolateral surfaces of that part of the thyroid, it appears as 2 layers, and this becomes more apparent when the thyroid grows between these layers and approaches the RLN. Generally, RLN is located lateral to the Berry ligament in the tracheoesophageal groove, and the thyroid tissue may occasionally extend posteriorly toward the RLN. (15) It should not be forgotten that the RLN is most commonly injured due to this anatomical structure. In this case, the anterior layer of the ligament is first cut, and then the posterior layer is cut after applying traction to the thyroid to the medial aspect in the lateral approach and to the lateral aspect in the medial approach, ensuring that the thyroid is not under excessive tension. If the thyroid extends posteriorly toward the RLN and does not contain cancerous tissue, no further dissection should be performed, and it should be left at the site under the RLN 15

Preservation Methods of the Recurrent Laryngeal Nerve

RLN injuries are one of the most serious complications of thyroidectomy. Bilateral RLN injuries can lead to life - threatening respiratory problems, (1) whereas unilateral RLN injuries can cause problems such as hoarseness and aspiration at different degrees of severity that can significantly impair quality of life. (1) In a recent meta - analysis on RLN injuries, 25.000 cases were evaluated; the rates of transient and permanent vocal cord paralysis (VCP) were found to be 9.8% (1.4%–38.4%) and 2.3% (0%–18.6%), respectively. (36) In another meta - analysis, the incidence rate of bilateral VCP was 2.43 and 5.18 per thosand for whom IONM was used or not used, respectively. (37)

The risk factors that increase RLN injury during thyroidectomy are primary or recurrent malignant diseases, recurrent benign diseases, thyrotoxicosis (Graves' disease), the extent of the surgery, routine non - observance of RLN (no RLN dissection), low - volume hospital or surgeon, substernal goiter, nerve branching, aberrant course of the nerve, and presence of non - RLN. (38 - 44) Even after Lahey (45) indicated that the risk of RLN injury could be reduced from 1.6% to 0.3% within 3 years with routine visual identification and dissection, it has still been a topic of discussion for a long time. Jatzko et al. (46) evaluated the literature compared with their own series of RLN procedures and detected that the rate of transient and permanent VCP significantly decreased with routine visual identification of the RLN. Similarly, in a study conducted between 1979 and 1999 in which a single - center primary surgery was performed for benign thyroid diseases and 27.000 RLNs were examined, Hermann et al. (47) found that the number of injuries significantly decreased with visual identification of the RLN. They found that complete dissection is highly superior to a only localized, or partial exposure of the nerve Currently, the complete appearance of the RLN during thyroidectomy is accepted as the gold standard method for the preservation of the RLN. (48) The meaning of the above - mentioned term "RLN dissection" is important. We believe that this should imply visual identification of the nerve in an area, and its course must be fully revealed throughout the surgical field with one of the approaches (defined below) used to identify the RLN. For this purpose, particularly in patients who did not undergo central neck dissection, as much as possible, the nerve should not be separated from its bed and the thyroid should be dissected from the nerve by dissecting medially to the nerve.

Methods for Detecting the Recurrent Laryngeal Nerve

During a thyroidectomy, the RLN can be identified using 4 different approaches, depending on the type of thyroid growth and the choice of the surgeon: there are lateral, inferior, superior, and medial approaches. (3) Visual identification of the RLN requires adequate knowledge of surgical anatomy and clinical experience. In addition, some basic rules contribute to safe dissection of the nerve. The surgical field must be appropriately exposed during surgery, and if the retraction of the strep muscles and the thyroid are not sufficient to provide an adequate visual field, the strep muscles should be cut and adequate light should be provided. (49)

It is extremely important to work in a bloodless surgical field during identification and visualization of the RLN. Despite careful dissection, particularly in the Berry ligament area, bleeding may occur due to dissection or rupture of thin veins due to excessive tension on the thyroid. If the nerve is observed in this case and is within a safe distance, then these bleeding vessels can be clamped or controlled with bipolar cautery. Otherwise, bipolar cautery or clamping should not be used blindly, and minor bleedings should be checked using gently applied compression with a gauze tampon. (49) In this

context, it is very important not to cut any tubular structure without detecting the RLN. After the RLN is observed, a minimal dissection from the medial aspect of the RLN should be performed, if possible. Care must be taken to protect the nerve's vaso - nervosums, and energy devices should not be used near the nerve. Forceful aspiration and compression with gauze tampons should not be applied. The use of magnifying glasses with sufficient light also significantly contributes to dissection. (50)

Lateral Approach

This technique, which is often applied in primary thyroid surgery, should not be confused with lateral intervention, also called the "backdoor approach, " performed between the sternocleidomastoid and strep muscles as secondary surgery or parathyroid surgery. (51) In this method, the thyroid and strep muscles are first dissected away and the lateral thyroid veins are ligated with cauterization. If there is no suspicion regarding the presence of non - RLN on the right side, then releasing the upper pole initially may provide an additional advantage. Before performing dissection for the RLN during the surgery, the stimulation of the vagus nerve with IONM provides important clues in terms of nonRLN. Non - RLN can also be detected with preoperative radiological methods.

Usually, the strep muscles and carotid artery are retracted laterally and the thyroid anteromedially to expose the paratracheal region where the RLN is anatomically located. (49) While looking for the RLN, the parathyroid, ZT, ITA, and the lower border of the inferior horn of the thyroid cartilage can be used as a guide. The RLN is usually found by dissection around the inferior thyroid artery at the level of the middle pole of the thyroid. To preserve the inferior parathyroid artery, a branch of ITA, the RLN may be found when the inferior parathyroid is dissected from lower pole of the thyroid, just before the lobe is retracted medially. (52)

At this level where RLN is visualized, because the nerve stands at a more lateral position than the trachea and thyroid at the right side, it may not need to be exposed proximally, but it is useful to visualize it to the last point where the lower pole is released on the left side. It should be kept in mind that extralaryngeal branches may separate particularly in the last 2 cm of the nerve when cranial dissection is advanced from the area where the RLN is first observed. (51) This approach can be difficult in cases of large goiters or a large ZT. In secondary surgeries, searching for the nerve within this area may have risks, due to the formation of dense scar tissue. Also, in the presence of non - RLN, the lateral approach may be risky because the nerve courses perpendicularly to its normal course in secondary cases. (49, 51)

Inferior Approach

This approach generally describes the detection of the RLN from its entry in the neck region devoid of scar tissue during secondary surgical procedures. (3) This area is also known as the RLN triangle with the boundaries defined in 2 different ways. According to the definition of Lore et al., (53) the thoracic entry forms the top of the triangle, the common carotid artery forms the lateral margin, the trachea and esophagus form the medial margin, and the lower border of the inferior lobe of the thyroid forms the base. In recent publications, it has been stated that the lateral edge of the triangle which is delineated by the placement of retractors in the thyroid, is formed by the strep muscles and the medial edge is lined with trachea. In fact, both of these definitions are correct, according to the method of approach in the region. According to this, the second definition is valid in the conventional midline approach, whereas thefirst definition is valid for the lateral intervention (backdoor approach), in which the strep muscles are retracted medially and the common carotid artery laterally. As indicated in the anatomy section, because the entrance of the RLN to the thyroid area differ, the RLN is sought at an area more lateral to its thoracic inlet on the right side, whereas it issought closer to the paratracheal area on the left side. Extralaryngeal branching is rare in this region, and the RLN is present as a single trunk, and thus, its laryngeal course may be easily visualized. However, it is stated that the dissection in the long segment may increase the risk of nerve injury. (3, 49) In addition, because the inferior parathyroid vessel runs in a lateral to medial direction, the risk of parathyroid devascularization may increase. In order to avoid this, after identifying the RLN, the fatty tissue area through which the parathyroid vessel passes is bypassed and the dissection is continued toward the cranial region. (17) The inferior approach is not appropriate for patients with large substernal goiters and in the presence of non - RLN. (3, 49)

Superior Approach

This approach is also called the medial superior approach and may be recommended for patients with huge goiters or large substernal goiters because releasing the lobe using the inferior or lateral approach may make it difficult to find RLN. The superior approach is also a good option for non - RLN suspected cases or remote - approach endoscopic thyroidectomies such as transoral thyroidectomy, or when RLN is not found with the other approaches. (49)

The most important anatomical hallmark in this approach is the lower border of the cricopharyngeal muscle, and under this muscle, RLN enters to the larynx. In all these cases, the position of the RLN is fixed and does not change. After the upper pole of the thyroid is released, the pole is pulled forward and laterally. With a careful dissection, the cricothyroid and cricopharyngeal muscles are found, and the lower part of the cricopharyngeal muscle is reached to reveal the laryngeal entry of the RLN. Subsequently, the Berry ligament is cut step by step medially from the RLN, and the lobe is gently retracted toward the lateral aspect and is separated from the proximal section of the RLN and the trachea.

The cervical thyroidal segment, which was previously dissected from the strep muscles or dissected just at this stage of the surgery, can be moved circularly to the left and to the right, and by that, the enlarged lower pole and the substernal fragment, if present, can be delivered without overstretching the nerve. (3) However, this approach also has disadvantages. Minor bleeding that may occur during dissection in the Berry ligament region can mask the field of view. The RLN can also enter the larynx in several branches, and distinguishing thin branches can be difficult. (17) However, it should not be forgotten that there is a high risk of tension - related neuropraxic trauma because the RLN is fairly fixed in this area. (49)

Medial Approach

This approach is preferred for patients with substernal or enlarged retropharyngeal goiters. (15, 49) In this method, the isthmus is first divided, and then the isthmus and medial part of the lobe are dissected away from the trachea to reveal the anterolateral part of the trachea. At this stage, visual identification of the cricothyroid muscle fascia and dissection between the medial part of the superior thyroid pole and cricothyroid muscle fascia may provide ease at the later stages. The fibers between the trachea and the thyroid, and the Berry ligament fibers are gradually divided to the cranial direction by starting from the inferior portion of the second tracheal ring which is already laterally revealed or from 3 mm medial to the lateral aspect of the third tracheal ring, (54) allowing the RLN to enter the field of view from the medial aspect of the thyroid and the lateral aspect of the trachea. (15, 49) The later stages are similar to those of the superior approach.

If the RLN is displaced posterior to the trachea, it may not be detected with this approach. In this case, the upper pole is dissected, and the upper pole and thyroid are pulled in the lateral direction; the RLN can be found under the cricopharyngeal muscle where it enters into the trachea as observed in in the superior approach. The remaining connections of the Berry ligament are cut after the nerve is located at this point. (15)

Intraoperative Neuromonitoring in Thyroidectomy

The preservation of the anatomical integrity of the RLN does not indicate that its function is also preserved. IONM is a tool for the functional assessment and identification of RLN, and so this method is an addition to visually identifying RLN, which is the gold standard. (48) The use of IONM in thyroidectomies has increased in recent years. Currently, IONM with the application of an endotracheal tube containing a surface electrode has become the standardized non - invasive method. This method is based on the electromyographic (EMG) determination of the contraction of the thyroarytenoid muscle, the main adductor of the vocal cord, via the stimulation of the RLN. (48) The standards of IONM were defined by the Intraoperative Neural Monitoring Study Group (IONMSG). (48, 55) The best outcome from IONM is achieved by applying it according to the defined standards (Table 3). The most sensitive test that predicts postoperative vocal cord function is the glottis response achieved by the vagus nerve stimulation at the end of the operation (V2). (48)

3. Conclusion

The lateral approach is the most commonly used technique in primary thyroid surgery. The RLN is usually found by dissection around the inferior thyroid artery at the level of the middle lobe of the thyroid. RLN is generally found at the site of its entry into the neck region devoid of scar formation when the inferior approach is used especially in cases with secondary surgery. The superior approach is recommended for patients with an huge goiter or large substernal goiter. In this approach, the upper pole of the thyroid is first released and then pulled forward and laterally, and the RLN is exposed on the nerve's entry point (NEP), into the larynx, under the cricopharyngeus muscle. The medial approach is preferred for patients with substernally or retropharyngeally enlarged goiters. In this approach, the isthmus is first dissected and divided, and then the isthmus and the medial part of the lobe are dissected away from the trachea to reveal the anterolateral part of the trachea. The fibers between the lateral aspect of the second or third tracheal rings and the thyroid, and the fibers of the Berry ligament are gradually dissected cranially, to allow RLN to enter into the field of view lateral to the trachea. The preservation of the anatomical integrity of the RLN does not indicate that its functional integrity is also preserved. IONM is a tool for the functional assessment of RLN, and so this method is an addition to visually identifying RLN, which is the gold standard. IONM significantly contributes to visual identification of the RLN, determination of its anatomical variations, intraoperative recognition of RLN injury, prevention of bilateral vocal cord paralysis, and detection and preservation of electrical activity in the nerve in patients with preoperative vocal cord paralysis.

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