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Management of the recurrent laryngeal nerve in thyroid surgery

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The importance of preservation of the recurrent laryngeal nerve in thyroid surgery has been well known since the early 19th century. All modern endocrine surgeons need to have a thorough knowledge of both anatomy and strategies for management of the recurrent laryngeal nerve which, importantly, includes neural monitoring. Important considerations for surgical approaches to the recurrent laryngeal nerve, nerve-monitoring techniques, and management of infiltrated or traumatized nerves are described.

Management of the recurrent laryngeal nerve (RLN) requires the surgeon's awareness of vocal cord function. Therefore, a preoperative laryngeal examination is an essential part of the preparation and counseling for all thyroid surgeries. The importance of this examination cannot be overly stressed. It is essential in all patients who are undergoing thyroidectomy. The absence of voice or swallowing symptoms is not indicative of vocal cord mobility. Two recent studies suggested that from 32% to 66% of patients with preoperative vocal cord paresis are asymptomatic.[1,2] In one series, vocal fold impairment also was seen contralateral to the thyroid lesion, lending further evidence to the importance of glottic examination. Vocal fold paresis is a strong indicator of malignant invasion, and knowledge of the invasive nature of the tumor will aid in operative planning.[2] Conversely, patients with hoarseness or other glottic complaints may experience these symptoms from other causes such as vocal cord pathology, dysphonia, or infection. Therefore, preoperative documentation of glottic function is necessary.

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Approaches to the RLN

Any approach that results in safe identification of the RLN during surgery is a good approach. However conceptually there are 3 main approaches to the RLN during thyroidectomy. The type of surgical approach must take into account previous surgery and is dependent on the nature of the thyroid gland. Each approach evolves through a different sequence of surgical steps relative to the thyroid gland. Visualization of the RLN is absolutely essential to good surgical outcomes because many authors report a decreased incidence of vocal cord paresis with visualization.[3,4] Visualization is enhanced by a bloodless field and loupe magnification.

The lateral approach is used most commonly for routine thyroidectomy (Figure 1). In this approach, the nerve is identified at the mid-polar level with medial retraction of the thyroid and lateral retraction of the strap muscles (similar to Kocher's "medial dislocation of the goiter" maneuver). The middle thyroid vein is divided for greater exposure of this region. The nerve is identified at a relatively high position in the neck, typically at the thyroid midpole level, allowing for limited nerve dissection and preservation of the blood supply to the inferior parathyroid gland. Although useful for routine cases, one must be aware of any extralaryngeal branches that may be present at this relatively distal portion

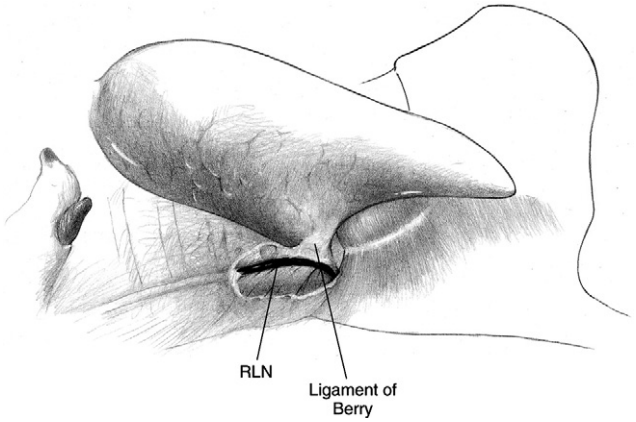

Figure 1 The lateral approach to the recurrent laryngeal nerve. (Reprinted with permission.[13])

of the nerve. This approach is less useful when previous surgery has caused extensive scarring in the thyroid bed.

The inferior approach, useful for revision cases and goiter surgery (without substernal extension), is used to identify the nerve at the thoracic inlet (Figure 2). Generally the nerve is more laterally based on the right and lies in the medial location of the tracheoesophageal groove on the left. The nerve is found in soft areolar tissue away from scarring of previous surgery and proximal to the inferior thyroid artery crossing point. The nerve dissection is longer in the inferior approach, and one must be aware of the potential for devascularization of the parathyroid glands. A benefit of this approach is the nerve is found quite proximally before any extralaryngeal branching.

The superior approach identifies the nerve at the laryngeal entry point and can be useful for large substernal goiters, when the lateral and inferior approaches are impractical, or when other approaches fail (Figure 3). The nerve can be difficult to identify because of the dense adherence of the ligament of berry; however, here the nerve is in the most

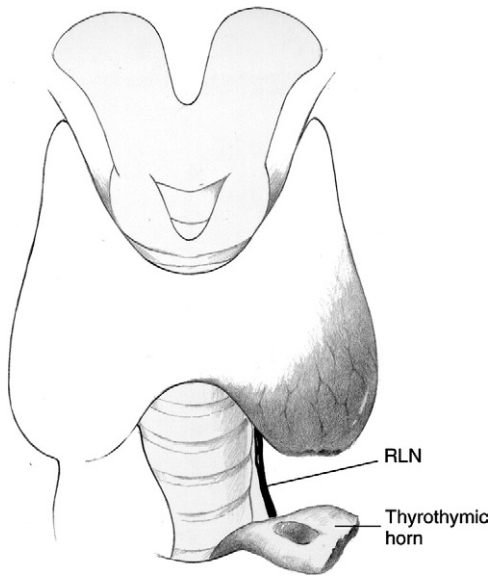

Figure 2 The inferior approach to the recurrent laryngeal nerve. (Reprinted with permission.[13])

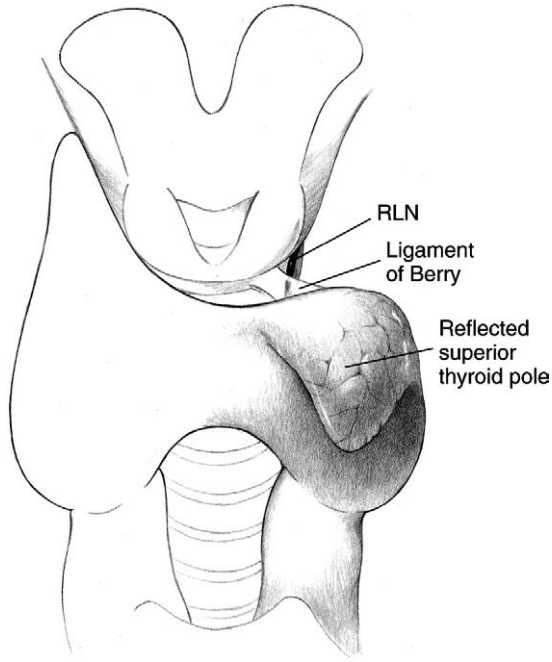

Figure 3 The superior approach to the recurrent laryngeal nerve. (Reprinted with permission.[13])

constant anatomical position that is at the lower edge of the lateral aspect of the cricoid cartilage. The nerve should be sought after dissection of the superior pole. A challenging superior pole dissection may be aided by sectioning the laryngeal head of the sternothyroid muscle. The nerve should be identified just caudal to the lowest fibers of the inferior constrictor, approximately one centimeter below the inferior border of the thyroid cartilage. One must be cautious to avoid the external branch of the superior laryngeal nerve as well as the superior parathyroid and again be aware of extralaryngeal branching.

Nerve monitoring

Neural monitoring has important uses as an adjunct to the visual identification of the nerve. It provides more information than is available with just nerve visual information. This added information is, in good surgical hands, always helpful. Endotracheal-based monitoring systems (eg, Medtronic NIM, Jacksonville, FL) are used to monitor the bilateral thyroarytenoid muscles for ongoing real-time EMG activity. Also, a sterile nerve stimulator, typically set at 1-2 mA, is used intermittently to stimulate the vagus and the recurrent laryngeal nerve for an evoked response. The purpose of recurrent laryngeal nerve monitoring in thyroid surgery is 3-fold. Nerve monitoring aids in identification of the nerve, aids in neural dissection, and gives prognostic information for postoperative function.

Efficient nerve identification can be performed when neural mapping is used to trace the projected course of the nerve. The stimulator probe on a setting of 2 mA will guide the surgeon to the course of the RLN. Once the nerve is

Algorithm for Monitoring Tube Placement

A. Intubation with a short-acting, nondepolarizing paralytic agent with or without stylet. Note depth of insertion and rotation of exposed electrodes relative to vocal cord.
B. Position the patient (head extended, thyroid bag/shoulder roll), with anesthesia staff carefully holding endotracheal tube stable in position.
C. Secure tube in place with tape and address support of tube as it exits the mouth. Tape surface ground electrodes in place on the skin.
D. After all patient positioning, check monitor function and endotracheal tube electrode position by assessing the following:
   1. Respiratory variation of the baseline
   2. Impedance values of less than 5 kOhm and impedance imbalance of less than 1 kOhm
   3. Monitor settings:
      a. Event threshold, 100 μV
      b. Stimulator probe, 1 mA
E. In the surgical field:
   1. Test stimulator probe on muscle first; identify local muscle twitch and confirm that current is being received back on the monitor.
   2. Before accepting tissue as being truly negative (in terms of recurrent laryngeal nerve [RLN]), visually identify the RLN and obtain a true, positive signal.

Figure 4 Steps to ensure appropriate monitor placement. (Reprinted with permission.[13])

neurally mapped, it is dissected and visualized. Neural mapping as a technique in nerve identification allows the surgeon to know where the nerve is exactly before attempts to dissect and visualize it are made. Once the RLN is uncovered, the stimulator probe on a setting of 1 mA can be used in difficult areas such as the ligament of Berry to aid in dissection. Fibrous bands or scar will provide no stimulation and this negative response will allow for directed dissection of the neural tissue with full removal of thyroid tissue. Stimulation of the vagus nerve at the end of the procedure is useful prognostic information when deciding to proceed with total thyroidectomy. With good electrical stimulation

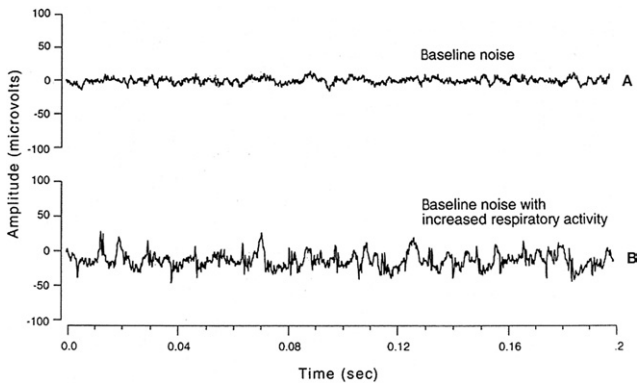

Figure 5 Tracings from NIM-2 monitor. (A) Baseline noise, typically between 10 and 20 μV. (B) Coarsening of the baseline with intermittent amplitudes occurring in the 30 to 70 μV range, consistent with respiratory activity. (Reprinted with permission.[13])

Figure 6 Patient and monitoring endotracheal tube (ETT) scheme. (Reprinted with permission.[13])

of the vagus nerve, the surgeon can proceed with confidence to the contralateral side. One should not be concerned with overstimulation as no data has come forth to suggest that repetitive stimulation during thyroid surgery at 1-2 mA puts the neural tissue at risk.

The endotracheal tube placement is key to accurate nerve monitoring (Figure 4). Either no muscle relaxant or intubation with succinylcholine should be used for quick return of neuromuscular function. The endotracheal tube should be carefully placed without lubrication so that the exposed segment of the electrodes is in contact with the vocal cords. When in position, the depth and rotation of the electrodes should be noted. The patient is then placed in final surgical position and respiratory variation should be visualized on the nerve monitor before the securing of the endotracheal tube (Figure 5). The surface ground electrodes should then be placed on the shoulder and the endotracheal tube and grounds connected to the monitor (Figure 6). Impedance

Monitor Problem Solving

If EMG activity absent when stimulating the RLN:
1. Assess laryngeal twitch
   a. If present, neural function is ensured and monitoring dysfunction is present (likely electrode displacement)
2. If laryngeal twitch is not present, consider:
   a. Whether stimulation current is being delivered. Check monitor for current return
   b. Checking ground shoulder electrodes, which can be displaced
   c. Possibility of probe malfunction; consider obtaining new probe
   d. Checking connections at connector box
   e. Whether neuromuscular blockade has been administered
   f. Possibility of neural injury

Figure 7 Steps to take when monitor function is suboptimal. (Reprinted with permission.[13])

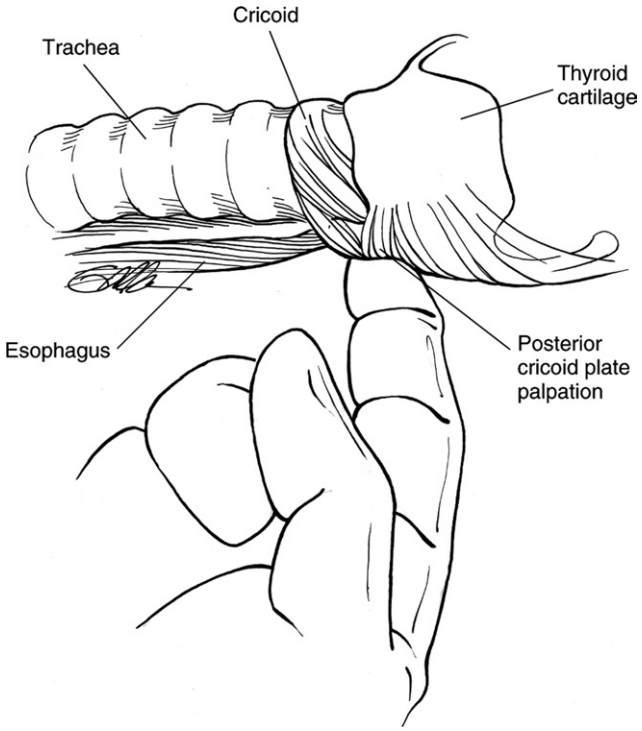

Figure 8 Side view of larynx, demonstrating position of finger to palpate laryngeal twitch. (Reprinted with permission.[13])

values of less than 5 kOhm and impedance imbalance of less than 1 kOhm are desirable. Impedance values in this range assure good endotracheal tube electrode contact with the body. This does not mean the electrodes are necessarily in contact with the vocal cords. It is the presence of respiratory variation that gives information regarding good vocal cord contact in the positioned patient.

An event threshold of 100 mV is used to define positive EMG activity. Audio feedback regarding nature and amplitude of the response is available to the surgeon as well as a waveform tracing on the monitor. Vagal stimulation is used to assess accuracy of tube placement before dissection near the recurrent laryngeal nerve. With positive vagal stimulation, one can search for the RLN in the paratracheal region with the knowledge that a negative stimulation is not a system problem but in fact that the nerve is not present at the site stimulated. The important of this initial vagal stimulation cannot be over stressed.

If appropriate EMG signal is not obtained during the case, a specific problem solving algorithm should be employed (Figure 7). First, the surgeon should palpate behind the posterior cricoarytenoid muscle to assess for laryngeal twitch with electric stimulation (Figure 8). If the laryngeal twitch is palpable, monitoring dysfunction such as minor endotracheal electrode displacement is likely present. The endotracheal tube should be adjusted, most commonly with slight retraction of the endotracheal tube or counter-clockwise rotation. The tube should be maneuvered until vagal stimulation greater than 250 mV is established. If the laryngeal twitch is not palpable, the connections should be checked for malfunction. First, check the monitor for current return to see whether stimulation current is being delivered and check ground shoulder electrodes, which may be displaced. Next, consider probe malfunction and obtain new a new stimulator probe as well as check connections at the connector box. Discuss with anesthesiologist if neuromuscular blockade has been administered and finally, neural injury must be considered.

Many studies have reviewed the utility of nerve monitoring. It should be noted that many of these studies are insufficiently powered as a great number of nerves at risk would be required to demonstrate statistically significant benefit. Neural monitoring does not replace visual identification, but serves as an important adjunct in thyroid surgery. Surgeries with known increased risk to the RLN such as cancer operations, revision cases or surgery on the only functioning nerve certainly deserve the additional benefit of nerve monitoring. However, not all difficult cases are known before incision and with a short learning curve, the nerve monitor can be easily used for all thyroid surgery.

Malignant infiltration of the nerve

Management of an infiltrated nerve requires knowledge of both the histology involved and vocal cord function (Figure 9). If the nerve is known to be paralyzed preoperatively from invasive carcinoma, the nerve will not recover and should be included in oncologic resection. Before resection of a nerve that is seemingly adherent or infiltrated, however, the nature of the invasive or encasing pathology should be confirmed and fully evaluated. Benign disease has been shown to be associated with vocal cord paralysis and can sometimes appear to encase or be adherent to the RLN especially at the ligament of Berry region.[5] Despite preoperative paralysis patient should be counseled that following resection of an infiltrated nerve, glottic function may decrease. It is common with infiltrated RLNs that the infiltrated nerve still carries some neural tone to the glottis despite lack of gross motor function. Therefore, with resection, patients may lose this neural tone and experience vocal weakening and increased aspiration.[6]

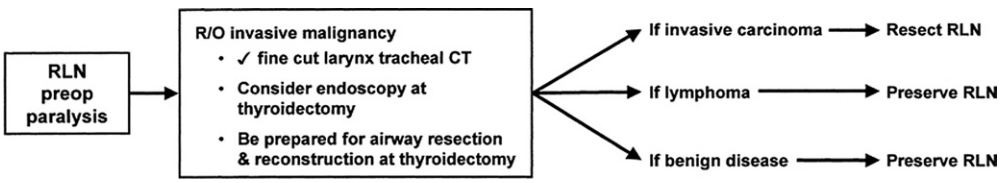

Figure 9 Management of the RLN in preoperative RLN paralysis. (Reprinted with permission.[13])

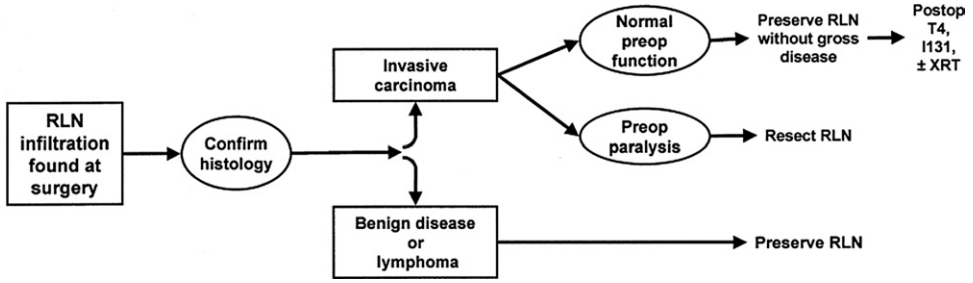

Figure 10 Management algorithm of the RLN infiltration found during surgery. (Reprinted with permission.[13])

A nerve found to be infiltrated at the time of surgery without vocal cord paralysis should be left intact if at all possible (Figure 10). Resection of all gross disease should be performed. Microscopic disease remaining may be treated postoperatively with T4 suppression, radioactive iodine or external beam radiotherapy. Resection of a functioning nerve has not been demonstrated to increase survival.[7,8] Similarly, a nerve infiltrated with benign disease or lymphoma should be preserved as postreatment such nerves may resume function.

Management of a severed nerve

All endocrine surgeons should be prepared to confront the untoward event of a severed nerve during thyroidectomy (Figure 11). For a severed nerve without segmental loss, the nerve should be reanastomosed with 2 to 3 9-0 epineural sutures without tension. This is not intended to provide full purposeful abduction and adductor function, but by providing nerve continuity we potentially provide the impaired glottis with muscle tone and some adductor activity which will improve postoperative voice and may lessen postoperative aspiration.[9] Such immediate repair doesn't preclude a static vocal cord repositioning procedure such as injection or open thyroplasty which may be considered 6 months postoperatively depending on voice and swallowing function at that time.

A severed nerve with segmental loss, not an uncommon scenario in cancer resection, which cannot be reapproximated should be treated with ansa cervicalis to distal RLN anastomosis. The ansa cervicalis, neural input to the strap musculature, is a proper size match and has no donor site morbidity. The anastomosis is performed with epineural sutures of 9-0 nylon and does not provide full vocal cord mobility, but prohibits loss of laryngeal muscle tone. Several authors have reported excellent medialization and improved voice outcomes, making this the procedure of choice for segmental loss.[10,11] It is simple and easy to perform but requires the surgeon regarding and preserving the ansa on the jugular vein as the thyroid cancer surgery begins. A

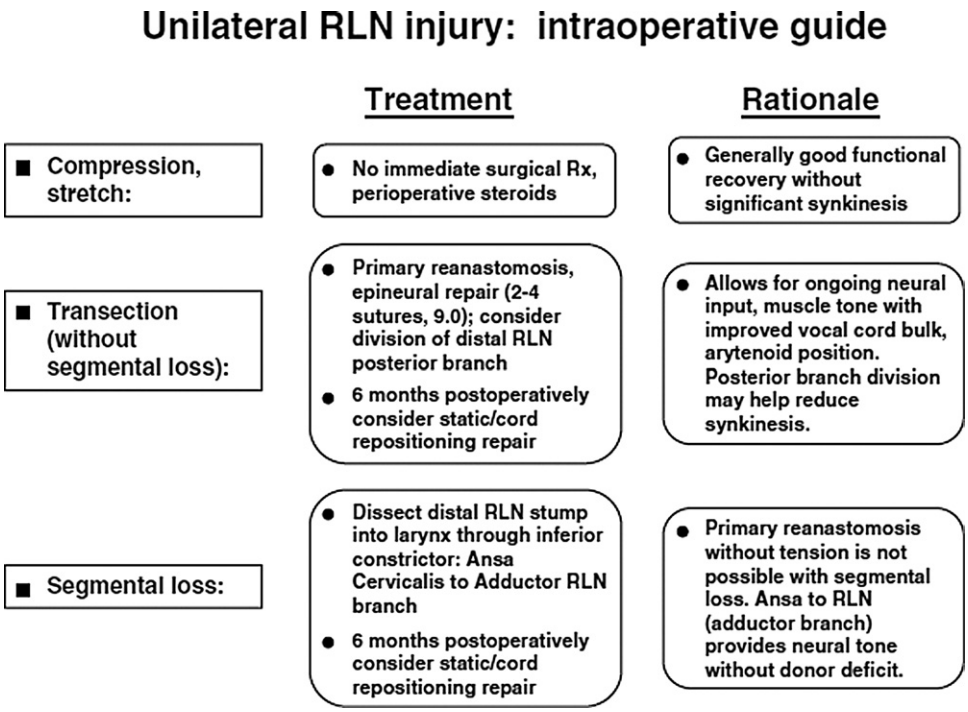

Figure 11 Intraoperative guide for unilateral recurrent laryngeal nerve injury for blunt, transection, and segmental loss. (Reprinted with permission.[13])

static cord repositioning procedure may again be considered adjunctively.

Blunt nerve injury

A nerve that sustains injury from blunt dissection, stretch, or electrocautery but remains intact requires no intraoperative treatment. Functional recovery should generally occur in the following weeks to months with no long term ill effects. Steroids can be considered in the immediate postoperative period.

Postoperative considerations

As symptomatic assessment is inaccurate, the postoperative laryngeal examination allows for accurate knowledge and recording of surgical outcomes. Additionally, patients with symptomatic voice and swallowing complaints may have sustained injury from intubation such as vocal cord hemorrhage, traumatic granuloma, or arytenoid dislocation.[12] Because of the divergence of symptoms and glottic function, laryngoscopy is essential postoperatively.[13]

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