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# Surgical management of the compromised recurrent laryngeal nerve in thyroid cancer

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Surgical management of thyroid cancer requires careful consideration of the recurrent laryngeal nerve and its impact on glottic function. Management of the compromised recurrent laryngeal nerve is a complex task, requiring synthesis of multiple elements. The surgeon must have an appreciation for preoperative recurrent laryngeal nerve function, intraoperative anatomic and electromyographic information, disease characteristics, and relevant patient factors. Preoperative clinical evaluation including preoperative laryngoscopy and assessment of recurrent laryngeal nerve risk is essential to formulating a surgical plan and providing appropriate patient counseling. Intraoperative neuromonitoring information has significant implications for surgical management of the injured or invaded recurrent laryngeal nerve and informs strategy with respect to staging of bilateral surgery. Disease characteristics and patient-related factors, including patient preference, must be considered with intraoperative decision-making. Multidisciplinary discussion and patient communication are

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essential for effective management and successful surgical outcome.



## Introduction

Surgical treatment of thyroid cancer mandates careful evaluation and management of the recurrent laryngeal nerves (RLNs), the main nerves controlling vocal cord mobility. The proximity of the RLNs to the thyroid places them at risk for direct invasion by tumor or injury during thyroid surgery, with compromise resulting in vocal cord paralysis (VCP). Consideration of the RLN and the impact of its dysfunction must occur throughout thyroid cancer management.

The RLN is one of the most frequent sites of invasion by locally aggressive thyroid cancer. Approximately 33–61% of patients with locally invasive differentiated thyroid cancer (DTC) present with RLN invasion [1–3]. Preoperative detection of RLN invasion can be problematic as RLN function may be preserved despite invasion. Additionally, patients with unilateral VCP may be asymptomatic with normal voice production. Patients may also harbor pre-existing VCP either ipsilateral or contralateral to the tumor side from an unrelated cause. It is therefore incumbent upon the clinician to assess for RLN compromise through comprehensive clinical evaluation.

Surgical manipulation of the RLN with loss of function and resulting VCP is a feared outcome of thyroid surgery. Unilateral VCP may be associated with considerable morbidity, including dysphonia, dysphagia, aspiration and difficulty breathing. Dysphonia is the most common manifestation of unilateral VCP and may significantly impact quality of life, interfering with an individual's ability to work or conduct normal daily activities [4,5]. Voice impairment after thyroid surgery may also engender severe emotional or psychological distress as the patient comes to terms with the surgical outcome [6]. Bilateral VCP is an especially morbid outcome of thyroid surgery. The resting position of the paralyzed vocal cords in a paramedian location results in glottic obstruction, necessitating tracheotomy or acute surgical airway intervention in approximately half of cases [7].

The VCP rates following thyroidectomy are difficult to elicit for multiple reasons, including variability in practice of postoperative laryngeal examination and the fact that RLN dysfunction may not be symptomatic. Unilateral VCP rates following thyroidectomy have been historically quoted at 3–5%, though this is likely an underestimate of the true incidence. Recent data from two large national databases (Scandinavian Quality Register and British Association of Endocrine and Thyroid Surgeons Audit) suggests that postoperative VCP detection is increased by two-fold when routine postoperative laryngeal examination is employed [8,9]. A systematic review of over 25,000 patients by Jeannon et al. found the average unilateral VCP rate after thyroid surgery to be 9.8% [10]. Francis et al. reviewed over 5600 DTC patients who underwent total thyroidectomy and identified an 8.2% unilateral VCP rate and a 1.3% bilateral VCP rate [11]. In a study of over 1000 nerves at risk, Steurer et al. reported a 14% rate of temporary VCP for patients undergoing thyroidectomy for DTC [12].

## Preoperative evaluation

### *Voice and laryngeal assessment*

Preoperative voice assessment should be performed to establish a baseline prior to thyroid surgery. There are many validated instruments which may be utilized to document vocal function, but at a minimum, the subjective assessment of vocal function by the patient, family and surgeon should be documented [13].

Currently, preoperative laryngeal examination is not uniformly performed for patients undergoing thyroid surgery [8,14]. However, growing recognition of the importance of improving voice outcomes in thyroid surgery has led many national societies to develop best practice guidelines relating to evaluation and management of the voice and larynx for patients receiving thyroid surgery. The American Academy of Otolaryngology - Head and Neck Surgery (AAO-HNS), American Head and Neck Society (AHNS), and American Thyroid Association (ATA) have recently published guidelines recommending preoperative laryngeal evaluation for patients at risk of RLN compromise, including those with preoperative voice abnormalities, history of neck or upper chest surgery placing the RLN or vagus nerves at risk, malignancy with evidence of posterior or extrathyroidal spread, or extensive central neck adenopathy [13,15,16]. The British Thyroid Association recommends preoperative laryngeal assessment for all patients undergoing thyroid surgery for cancer [17]. The German Association of Endocrine Surgeons has recommended both preoperative and postoperative laryngoscopic examination for all patients undergoing thyroid surgery, and the International Neuromonitoring Study Group (INMSG) recommends preoperative and postoperative laryngoscopy for all patients undergoing thyroid surgery with intraoperative neuromonitoring (IONM) [18,19].

*Patient counseling and treatment planning*

Thyroid cancer surgery planning should be multidisciplinary and involves patient-centered decision-making. The likelihood of RLN injury or requirement for RLN resection and the subsequent impact on voice and swallowing should be discussed with the patient ahead of surgery. Patients should be counseled on the possibility of staging bilateral surgery in the event of unilateral loss of RLN function. Where preoperative VCP is present and surgical manipulation of an only-functioning nerve is planned, the surgeon should explicitly discuss the possibility of tracheotomy if bilateral VCP should occur. The intraoperative decision to resect a functional but grossly invaded RLN should be preoperatively discussed with the patient. For instance, a patient may prefer to preserve voice and swallowing function in favor of less aggressive resection, understanding the implications for adjuvant treatment, surveillance, recurrence and potential need for nerve resection in subsequent surgery. Careful assessment of risk to the RLN should prompt the surgeon to initiate this discussion before surgery.

## Surgical anatomy of the recurrent laryngeal nerve

*Anatomic considerations*

Visual identification of the RLN during surgery is critical, and as such, the thyroid surgeon must have intimate familiarity with its surgical anatomy. On the left side, the RLN arises from the vagus nerve and passes anterior to the aortic arch, looping behind the arch to course superiorly within the tracheoesophageal groove. On the right side, the RLN arises from the vagus nerve, looping behind the subclavian artery before ascending in the neck. Thus, the right RLN enters the neck in a more lateral and anterior location, coursing posteriorly and medially before assuming a paratracheal position in the last centimeter of its course. In its distal course, the RLN can be surgically manipulated until it enters into the larynx beneath the most inferior fibers of the inferior constrictor muscle [20] (Fig. 1).

It is imperative for the thyroid surgeon to understand branching patterns of the RLN in order to avoid inadvertent injury to critical neural fibers. After its entry point into the larynx, the RLN divides into anterior and posterior branches, with the anterior branch supplying motor innervation to the intrinsic laryngeal musculature, and the posterior branch providing sensory innervation to the glottis and subglottis. Extralaryngeal branching of the RLN commonly occurs with sensory and motor branches extending to the trachea, esophagus and inferior constrictor muscle. Importantly, the anterior branch supplying motor fibers to the larynx may originate prior to the laryngeal entry point and may be smaller in caliber than the posterior branch [21,22]. As such, the surgeon must not fail to recognize its presence, believing the posterior branch to be the main trunk. Failure to recognize the extralaryngeal anterior branch may result in its injury and subsequent VCP.

The surgeon must also recognize the nonrecurrent pattern of the RLN, which presents typically on the right side, approximately in 0.5% of cases [23]. Nonrecurrent laryngeal nerve (NRLN) occurs due to failure of the fourth right aortic arch to develop, creating an aberrant right subclavian artery that instead courses behind the esophagus. The NRLN traverses medially from the vagus at or near the

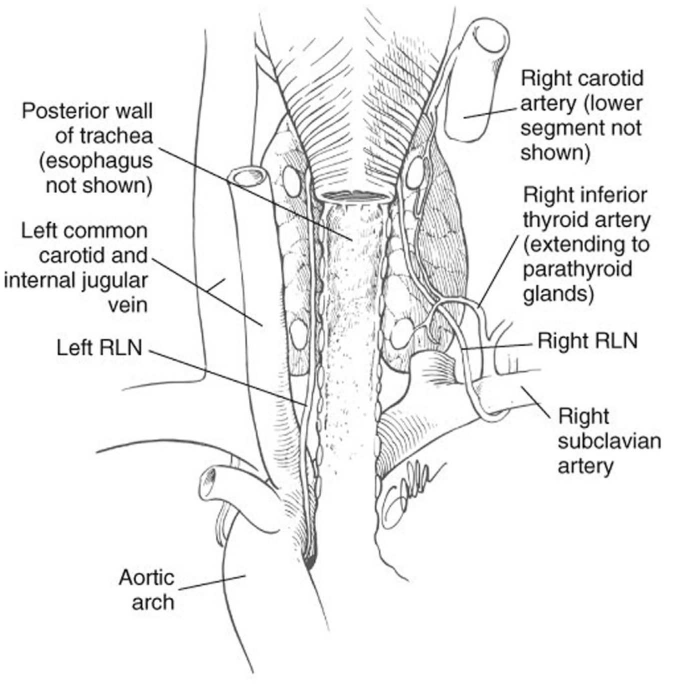


**Fig. 1.** Posterior view of the neck and upper chest showing divergent courses of right and left recurrent laryngeal nerve. (Reprinted from Ch 33: Surgical Anatomy and Monitoring of the Recurrent Laryngeal Nerve in Book: Surgery of the Thyroid and Parathyroid Glands, ed Randolph G W, 2013).

inferior thyroid artery and ascends within the tracheoesophageal groove to its laryngeal entry point. Non recurrent left RLN is very rare and is associated with situs invertus.

Finally, the surgeon must understand the complex relationship of the RLN to the Ligament of Berry, the fibrous ligament which anchors the thyroid to the laryngotracheal complex. Neural mapping studies have shown this to be the most common site of surgical injury to the RLN [24,25]. The Ligament of Berry consists of anterior and posterior dense fascial leaflets, through which thyroid tissue may be infused. The RLN may course posteriorly to the Ligament of Berry or traverse through these leaflets, even penetrating the thyroid tissue contained between them [20,26] (Fig. 2). As such, employing capsular dissection as a surgical strategy to avoid neural injury is unreliable.

*Intraoperative neuromonitoring (IONM)*

The importance of RLN identification in avoiding iatrogenic injury during thyroidectomy has been long recognized [27]. While visual identification of the RLN during thyroidectomy is the gold standard, it is critical to recognize that an anatomically intact nerve may not represent a functional nerve. Various forms of injury can preserve the structural appearance of the nerve while compromising its neural integrity. As such, IONM offers a functional dynamic to RLN assessment in thyroid surgery.

The impact of neuromonitoring on VCP rates is difficult to assess for several reasons, including variability in the performance of preoperative and postoperative laryngeal examination, and lack of standardization across studies with regards to disease severity, extent of surgery, and surgeon experience. Additionally, Dralle et al. have demonstrated that a study adequately powered to detect a statistically significant difference in VCP rates with use of IONM would require nearly 40,000 patients per arm for thyroid cancer surgery and over 9 million patients per arm for benign goiter surgery [28].

These challenges are reflected in the available literature. Zheng et al. performed a meta-analysis and found significantly decreased rates of overall and transient RLN palsy with use of IONM vs. visual identification. Permanent RLN palsy rates were not significantly decreased with IONM [29]. Conversely,

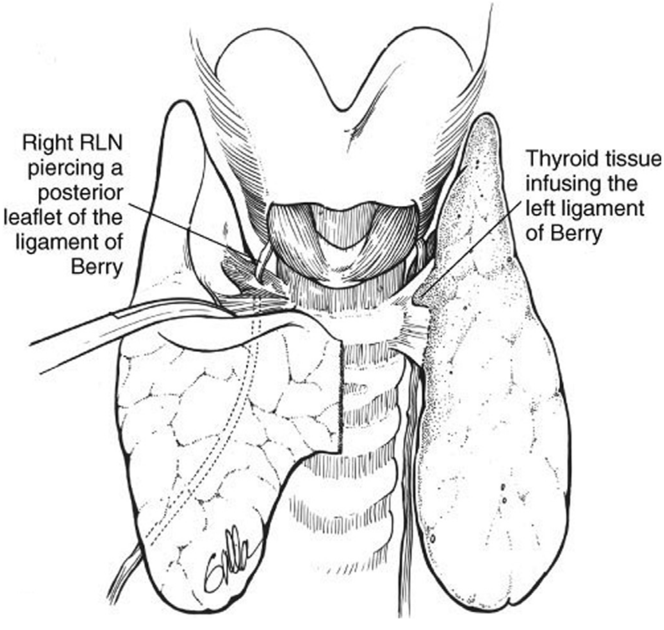


**Fig. 2.** Anterior and posterior leaflets of the Ligament of Berry, on the right side, the recurrent laryngeal nerve is piercing through the posterior leaflet and on the left side, thyroid tissue is infiltrating the Ligament of Berry. (Reprinted from Ch 33: Surgical Anatomy and Monitoring of the Recurrent Laryngeal Nerve in Book: Surgery of the Thyroid and Parathyroid Glands, ed Randolph G W, 2013).

Higgins et al. in their meta-analysis found no difference in VCP rates using IONM vs. visual identification [30]. Meta-analysis by Pisanu et al. reported no difference in VCP rates with IONM vs. visual identification but cautioned that their results were mainly derived from non-randomized observational studies [31]. In a cohort study derived from the Scandinavian Quality Register for Thyroid Parathyroid and Adrenal Surgery, Bergenfelz et al. found IONM reduced the risk of permanent VCP [32].

The benefit of IONM in high-risk surgical groups was studied by Wong et al. in a meta-analysis. They found IONM decreased rates of overall RLN palsy in re-operative cases and reduced rates of transient RLN palsy in thyroidectomy for malignancy [33]. Barczynksi et al. performed a randomized study and found that neuromonitoring significantly decreased the incidence of transient VCP, especially in high-risk-surgeries [34]. These researchers also performed a retrospective cohort study of 850 patients undergoing re-operative thyroid and parathyroid surgery and found a decreased rate of transient RLN paralysis with use of IONM [35].

Several medical and surgical organizations have recommended use of IONM in thyroid surgery. The German Association of Endocrine Surgery and the INMSG have published guidelines recommending neuromonitoring in all cases of thyroid and parathyroid surgery [7,18]. The AAO-HNS guidelines for voice optimization in thyroid surgery suggest IONM provides benefit in neural identification/mapping, understanding mechanism and site of injury, and in postoperative nerve prognostication [13]. AHNS guidelines for the management of invasive thyroid cancer suggest that IONM should be considered in all cases of thyroid cancer, especially where preoperative RLN dysfunction is present [36].

The benefits and applications of IONM have been recently characterized in guidelines published by the INMSG and include the following [7]:

1. Intraoperative neural identification and mapping of the RLN

Neural electrical mapping of the RLN facilitates dissection, as electrical neural identification often precedes visual identification [37]. IONM has also been shown to increase the speed of RLN identification compared with visual identification alone [38].

2. Facilitation of neural dissection

IONM allows for differentiation between neural and non-neural structures in nerve dissection. This facilitates nerve dissection and identification of anatomic variants that have increased potential for injury, such as extralaryngeal branching.

3. Intraoperative identification of impending neurologic injury

Evolving EMG responses during surgical manipulation of the RLN can predict impending neuropraxia, allowing opportunity for modification of surgical maneuvers [39,40]. Moreover, if loss of neuromonitoring signal occurs (LOS), retrograde testing of electrical response along the course of the nerve can identify the injured nerve segment. Elucidation of the site of injury has implications for treatment and presents a learning opportunity for the surgeon.

4. Neural prognostication at the completion of surgery

The ability to predict the functional status of the RLN is one of the most important applications of IONM. It allows the surgeon to determine the need for staging of contralateral surgery in order to avoid the risk of bilateral VCP.

Intraoperative RLN injury can occur due to stretch, compression, thermal injury or transection. In a series of 281 injured RLNs, Dionigi et al. found that the most common mechanism of injury was traction (71%), followed by thermal (17%), compression (4.2%), clamping (3.4%), ligature entrapment (1.6%), suction (1.4%) and transection (1.4%) [41]. Several workers have shown that the majority of traction injuries occur at the Ligament of Berry where the RLN is tethered by dense fibrous tissue [40,42,43]. Importantly, in the majority of cases, injury to the RLN is not detected visually, emphasizing the importance of EMG information to guide surgical decision making [8,41].

Iatrogenic RLN injury with LOS can be categorized into two types. Type 1 reflects a segmental injury where there is loss of signal proximal to a focal segment and preservation of signal distal to it. This pattern reflects a defined point of injury. Type 2 represents a global type injury where there is signal loss throughout the course of the ipsilateral vagus and RLN and a discrete injury point is not identified. In a recent multi-institutional study, Schneider et al. prospectively examined 115 cases with LOS and found VCP on initial postoperative laryngoscopy in 95% of type I injuries and 70% of type 2 injuries. Recovery rates were better in type 2 injuries, suggesting a less severe type of neural injury in Type 2 LOS [42].

*IONM and intraoperative management of the recurrent laryngeal nerve*

The preferred method of IONM utilizes an endotracheal tube (ETT) with embedded surface electrodes that record EMG activity within the vocalis muscle bilaterally. Intraoperative direct electrical stimulation of the vagus or RLN produces an EMG waveform with characterizable amplitude, latency and morphology. Notably, meaningful interpretation of intraoperative EMG data is dependent upon appropriate set-up and technique. This requires coordination with the Anesthesiologist to ensure proper positioning of endotracheal tube electrodes and avoidance of long-acting paralytic agents [44].

To promote uniformity in the application of IONM, the INMSG has recently published guidelines including standards for use [7,45]. Intraoperative interpretation of adverse EMG changes or LOS requires establishment of adequate baseline parameters. The INMSG recommends that an initial EMG waveform with an amplitude of >500 μV be obtained with a stimulation current of 1–2 mA, along with a detectable laryngeal twitch [7]. During surgical manipulation of the thyroid, changes in the amplitude or latency of the EMG signal are observed. An event which precipitates a concordant amplitude decrease of >50% and latency increase of >10% compared with baseline is regarded as a marker of impending neuropraxia and should direct the surgeon to terminate the surgical maneuver which triggered it [39]. Importantly, these EMG changes have been shown to be reversible in 70–80% of cases if the surgical maneuver is altered within 40–60 s of onset. However, as additional neural insults occur, EMG changes evolve to become less reversible and the risk of VCP increases [39,40]. A LOS is defined by the INMSG as an amplitude response of <100 μV and suggests a high risk of neuropraxia with only a ~15–25% likelihood for intraoperative recovery [7]. Intraoperative recovery, should it occur, is expected within 20 min [46]. The INMSG recommends that if LOS is present at the conclusion of surgery, a 20-minute period of recovery be allowed. Amplitude recovery to >50% of baseline and a minimum of 250 μV suggests a very low risk of VCP, whereas values below 250 μV represent a high risk of VCP and should direct the surgeon to stage contralateral surgery [7].

Understanding the prognostic significance of possible LOS requires that the surgeon recognizes testing errors associated with use of neuromonitoring equipment. As a prognostic indicator, LOS is considered a positive test for VCP. Signal preservation at the conclusion of surgery is considered a negative test for VCP. A false-positive test (LOS with intact RLN function) may occur due to ETT malposition, inadequate stimulating current or failure of stimulus conduction due to overlying fascia or blood, or use of neuromuscular blockade, among others. A false-negative test (preservation of signal with RLN paralysis) may result from simulation distal to the injured nerve segment, injury occurring after the last stimulus test, delayed onset of neuropraxia, and still-evolving EMG changes at the conclusion of surgery, among others [47].

When LOS has occurred on the first side, the surgeon must make a decision about whether to proceed to the second side. This requires consideration of a number of factors, including disease aggressiveness, whether a lobectomy alone would be appropriate, whether the timing of surgery is critical, and whether the patient is medically fit for a second anesthesia. Consideration of these factors should occur prior to surgery and should be discussed with the Endocrinologist and with the patient during the informed consent process. If the disease is high-risk, the patient's willingness to undergo total thyroidectomy in lieu of staging with subsequent risk of bilateral VCP and potential tracheotomy should be explicitly discussed prior to surgery.

For planned bilateral surgery, the INMSG recommends that neural monitoring information be incorporated into surgical strategy, informing the decision to stage contralateral surgery in the setting of LOS. Moreover, when LOS occurs, the surgeon should reflect on the morbidity associated with bilateral VCP and tracheotomy and prioritize its avoidance over concerns about deviating from a surgical plan or the perceived impact on one's reputation [7]. Algorithms for the management of intraoperative LOS and staging of contralateral surgery have been published by the INMSG to facilitate surgical decision-making [7].

Staged surgery is optimally offered to patients undergoing thyroid surgery for benign disease or low-risk DTC, though has been shown to be effective in surgery for advanced thyroid cancer [48]. The benefit of staged surgery facilitated by IONM has been readily demonstrated. Goretzki et al. retrospectively examined over 1300 cases of planned bilateral thyroid surgery and found a 0% rate of bilateral VCP when surgery was staged for LOS, vs. a 17% rate of bilateral VCP where surgeons proceeded to the second side with a known or unrecognized nerve injury on the first side [49]. Others have also demonstrated a zero rate of bilateral VCP when surgery is staged after initial LOS [42,47,50]. Willingness to stage surgery with LOS was evaluated in a survey distributed to over 1200 surgical departments in Germany, with 94% of respondents indicating they were willing to change their surgical strategy in this setting [51]. Melin at al. demonstrated that there was no difference in patient satisfaction for patients who underwent single-stage vs. two-stage surgery [52].

## Recurrent laryngeal nerve invasion

### *Risk factors for recurrent laryngeal nerve invasion*

Local invasion occurs in approximately 13%–15% of cases of DTC [1,53]. Among all DTC types, extrathyroidal spread occurs most commonly in papillary thyroid carcinoma [54]. Clinical and pathological factors associated with invasion include older age, larger tumor size, presence of lymph node metastases and aggressive histologic type, including tall cell and diffuse sclerosing variants [55]. BRAF V600E mutation has also been associated with invasive disease [56].

The RLN is one of the most frequent sites of invasion, which may occur through spread from the primary tumor or from lymph node metastases in the central neck [54]. When the RLN is invaded by lymph node metastases, it more commonly occurs on the right side and most patients do not experience preoperative VCP [57]. Because glottic function may be preserved in the setting of invasion, it is critical for the thyroid surgeon to assess the clinical, radiographic and pathologic features of disease to assess risk to the RLN. Even in the absence of VCP, features of aggressive histology, posterior location within the thyroid gland, evidence of extrathyroidal extension or bulky central neck metastases should alert the surgeon to the possibility of RLN invasion. In this setting, assessment of RLN function through preoperative laryngoscopy, is of critical importance in guiding surgical management and intraoperative decision-making [45].

### *Intraoperative management of recurrent laryngeal nerve invasion*

Surgical management of the invaded RLN may include preservation or resection of the nerve. It is important to recognize that RLN invasion does not independently influence survival [1]. Whether an invaded nerve is resected or preserved appears to have little impact on prognosis [3,54,58,59]. Multiple factors influence the decision to resect or preserve an invaded nerve and must be considered both preoperatively and intraoperatively as anatomic and electrical neural information becomes available. These elements include [1] preoperative ipsilateral and contralateral vocal cord function [2], intraoperative proximal EMG stimulability [3], location and extent of neural infiltration [4], overall disease characteristics, including histologic type and presence of unresectable locoregional or distant metastatic disease, and [4] patient-related factors.

Preoperative knowledge of vocal cord function is critical to determining intraoperative management of the invaded RLN. Kamani et al. demonstrated that 45% of invaded RLNs present with normal preoperative laryngeal function [60]. When an invaded RLN is associated with normal laryngeal function, attempts should be made to preserve the nerve with gross macroscopic tumor resection if possible. In a series of 18 RLNs subjected to shave/partial layer resection, Kihara et al. reported an 83% rate of recovery of neural function [61]. When contralateral VCP is present and the tumor invades an only-functioning nerve, careful shave resection should be attempted with consideration of adjuvant treatment in an effort to avoid bilateral VCP [36,45].

Intraoperative EMG data provides additional insight into the functional status of the RLN. Kamani et al. demonstrated that 60% of invaded nerves can be electrically stimulated intraoperatively, including 33% of nerves with preoperative glottic dysfunction [60]. Thus there may be maintenance of neural activity in the setting of invasion even when preoperative VCP is present. Resection of such a nerve would lead to worsening of glottic function. Indeed, Chi et al. have demonstrated that preservation of invaded nerves with preoperative VCP but intraoperative stimulability prevents development of vocal cord atrophy and decline of vocal function [62]. The INMSG recommends that proximal stimulability be used as a parameter to assess RLN function and direct intraoperative decision-making [45]. Algorithms for surgical management of nerve invasion incorporating EMG data have been discussed by the INMSG to guide intraoperative decision-making in this setting [45].

The location and extent of neural invasion has important bearing on the determination to resect or preserve an invaded nerve. The extent of RLN invasion varies by tumor and can range from adherence to the nerve to complete encasement by tumor. The ability to achieve macroscopic removal of tumor while preserving the nerve depends upon the extent of neural infiltration. When invasion extends only into the epineurium, a shave excision can allow for macroscopic resection of tumor and subsequent recovery of neural function [58,61]. However, when tumor extends into the perineurium and endoneurium with infiltration along neural fibers, a plane of dissection between the nerve and the tumor cannot be easily identified and macroscopic tumor resection cannot be readily achieved without resection of the nerve. In some instances, the surgeon may consider leaving a small amount of macroscopic disease to preserve the integrity of the RLN. This may be warranted if adjuvant treatment is planned and re-resection may be offered in the event of local recurrence or progression. Notably, however, when the nerve is invaded near its entry point into the larynx, residual disease may progress along its path into the larynx. Subsequent surgical treatment of disease within the laryngeal framework necessitates more aggressive and morbid resection. In this setting, resection of the nerve to achieve macroscopic tumor resection should be considered at the initial surgery.

Patient- and disease-related factors should also play an important role in intraoperative management of an invaded RLN. A tumor with an aggressive histopathologic type or genetic alteration may direct the surgeon towards nerve resection. Where disease is recurrent and known to be iodine refractory, or where a patient has previously received external beam radiation therapy, an aggressive surgical approach may also be warranted. By contrast, for patients with distant disease or disease that is judged to be unresectable, resection of an invaded nerve may offer little benefit and nerve preservation should be considered. For patients in whom glottic dysfunction would be detrimental (including voice professionals and older patients or others at risk for aspiration pneumonia), the surgeon may favor nerve preservation. For younger patients with DTC or patients for whom iodine avidity is anticipated, nerve preservation should also be considered [45]. Finally, patient preference is of importance in determining surgical strategy. As previously stated, discussion with the patient during the informed consent process should explicitly address these decision points and their associated outcomes. Involving the patient in determining surgical strategy serves to align expectations and to ensure that the goals of care are appropriately met.

## Summary

Compromise of the RLN and resultant VCP can be associated with significant morbidity. RLN dysfunction may occur due to tumor invasion or through surgical manipulation. Preoperative assessment of glottic function is essential and should inform surgical strategy. Various clinical, radiographic and pathologic features should raise suspicion for neural invasion even in the setting of normal glottic function. When RLN invasion is evident or suspected, the risk of unilateral or bilateral VCP should be explicitly discussed with the patient preoperatively. Intraoperatively, the application of neuromonitoring provides EMG information that facilitates neural mapping and dissection, allows the surgeon to recognize impending neural injury, offers a functional parameter for guiding management of the invaded nerve, and informs strategy with regard to staging of bilateral surgery. In developing and executing a surgical plan, the surgeon must also consider relevant disease characteristics and patient factors. Multidisciplinary assessment and communication is critical to this process.

## Conflicts of interest

The authors have no conflicts of interest to disclose.

### Practice points

- Vocal cord paralysis resulting from recurrent laryngeal nerve compromise is a morbid complication of thyroid surgery, and measures should be taken to avoid it.
- It is essential to perform thorough preoperative evaluation including voice assessment, laryngoscopy and imaging studies to assess for recurrent laryngeal nerve invasion when planning for thyroid cancer surgery.
- Information provided by intraoperative neuromonitoring should be used to guide surgical strategy as it relates to management of the recurrent laryngeal nerves.
- Intraoperative decision-making should be influenced by multiple disease and patient related considerations.

**Research agenda**

- Need of studies focusing on accurate preoperative determination of the risk of recurrent laryngeal nerve invasion in thyroid cancer patients.
- Studies centering on outcomes of nerve sparing vs sacrifice of invaded recurrent laryngeal nerve are needed.

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